The socio-technical history of manual sport wheelchair devices

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Abstract

Sport wheelchair technology was driven by the goals, ingenuity, and lived experiences of wheelchair athletes. Wheelchair sport emerged as a form of medical and social rehabilitation during the 1940s, growing quickly into significant international competitions which were administered by practitioners. Contemporary wheelchair devices were unsuited to the demands of sports activities, such as wheelchair basketball or wheelchair racing, as disabled people were not imagined to lead active lives. Resisting medical control over wheelchair technology and sport administration, wheelchair users took innovation into their own hands, tinkering their chairs for sport and creating new devices which revolutionised daily use. In this context, the act of modification and innovation is constructed as a site of social and political agency, as users asserted their own interpretations of wheelchair devices and sport.

This thesis draws on semi-structured oral history interviews, digital resources, and archival data to examine the role of wheelchair users within the development of sport wheelchair technologies. Language and models from the field of Science and Technology Studies such as the Social Construction of Technology are employed to trace the evolution of manual sport wheelchair devices, and establish a user-orientated approach to locate disabled people within this narrative. Recent historical research into objects made and used by disabled people and literature from sport and Paralympic studies are also incorporated to establish disabled athletes as significant actors in the development of disability objects (Hamraie and Fritsch, 2019). It is asserted that technological innovation, entrepreneurialism, and rule-breaking constituted acts of self-determination and agency-affirmation for disabled athletes. This thesis argues that the history of sport wheelchair technology is a significant site of autonomy for disabled people, which has previously lacked significant consideration within disability studies.

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With that said, any mistakes remaining in this thesis are all my own work.

Author's declaration

I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the result of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution.

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Signature:

List of abbreviations

ANT – Actor Network Theory

E&J – Everest and Jennings

FESPIC - Far East and South Pacific Island (Games)

IPC – International Paralympic Committee

ISMGF – International Stoke Mandeville Games Federation

ISOD - International Sports Organisation for the Disabled

NHS – National Health Service

NPHT – National Paralympic Heritage Trust

NWAA – National Wheelchair Athletics Association

NWBA – National Wheelchair Basketball Association

PVA – Paralysed Veterans of America

SCOT – Social Construction of Technology

SMG – Stoke Mandeville Games

STS – Science and Technology Studies

Chapter 1 – Introduction

Wheelchairs substantially evolved following the emergence of organised wheelchair sports in the 1950s. Wheeled-chair devices have been utilised throughout human history for a variety of purposes, including the transportation of sick, injured, or impaired people (Kamenetz, 1969). In the twentieth century, the use of wheelchairs globally increased due to the wider availability of purpose-built devices and amplified demand. Following the Second World War, improvements in medical technologies and procedures led to an increased number of ex-servicemen living with injuries resulting in impairments, such as spinal cord injuries (paraplegia, tetraplegia, and quadriplegia) or amputation. Wheelchairs were therefore increasingly used by newly disabled people to enable their mobility following medical treatment and rehabilitation (Roulstone, 2016). Moreover, new wheelchair technologies were utilised by those born with impairments, including people with spina bifida, as well as people who were impaired as a result of injury. Developments in wheelchair technology throughout the twentieth century enabled disabled people's mobility, employment, rehabilitation, and participation in mainstream society.

Wheelchair sport marked a significant development in rehabilitation programmes for patients with spinal cord injuries. Medical practitioners in the United Kingdom and United States identified the physical and psychological benefits of sports activities for physically impaired patients in the early twentieth century. Sport became a part of rehabilitation methods at medical institutions such as Stoke Mandeville Hospital in Buckinghamshire, United Kingdom, as a way to encourage patients to take an active role in their rehabilitation (Huberman, 1983). The popularity of sport at Stoke Mandeville led to the development of the annual Stoke Mandeville Games (SMG), which later became the Paralympic Games (Brittain, 2012; Bailey, 2008). The SMG initially comprised of wheelchair sports events - archery, fencing, and table tennis – alongside sports such as swimming that did not require a wheelchair (Brittain, 2012). Simultaneously, wheelchair users in the United States began to play basketball, establishing teams and a wheelchair basketball league by 1949 (Labanowich and Thiboutot, 2011). Sport was utilised within rehabilitation practices across the globe by the 1960s, and the SMG grew into international events. New wheelchair sports were introduced, including athletic track events (dash, race, relay, and slalom), alongside javelin, discus, shotput, bowls, and shooting events (Brittain, 2012). By the 1980s, wheelchair users had devised new sports such as wheelchair tennis and rugby.

Existing wheelchair technology, however, was largely unsuited for sporting activities, as medical practitioners and manufacturers designed wheelchair devices for an inactive end user. Wheelchair users' feedback was dismissed by wheelchair manufacturers, due to the assumed expertise of medical professionals over disabled people's lives (Woods and Watson, 2004; Williamson, 2019). Wheelchair athletes began to modify their existing wheelchairs for improved sports and everyday performance, and later created entirely new devices for athletic use (Stewart and Watson, 2019). Importantly, technological change emerged alongside resistance to medical control over sports administration and changes within the Paralympic movement (Bailey, 2008; Frost, 2020). Technological change emerged as athletes sought to improve their athletic abilities, move wheelchair sport away from the medical realm, and utilise equipment intended for wheelchair sport. Ultimately, disabled athletes wanted wheelchair and other disability sports to be recognised as legitimate competitive activities alongside non-disabled sports.

The technological evolution of sport wheelchair devices is closely linked to wider changes in the Paralympic movement and wider trends within disability politics. Athletes modified and adapted their existing wheelchairs to better suit the needs of athletic activity, rejecting wheelchair models largely made by non-disabled engineers and medical professionals. As the organisation and administration of disability sports shifted away from the medical realm, wheelchair athletes drew on their experiential expertise to create dedicated sporting equipment and assert their interpretation of wheelchair sport and technology. As a result, the evolution of sport wheelchair technology has distinct social and political significance for wheelchair athletes and other disabled people.

This research seeks to outline the technological evolution of sport wheelchairs and contextualise acts of modification and innovation within a wider social and political context. Focusing on wheelchair devices used in the 1950s to the early 2000s, this thesis draws upon frameworks and concepts from Science and Technology Studies (STS) to present this narrative and communicate wheelchair athletes' roles as innovators. Qualitative research methods have been utilised to present athlete testimony and consider the social, political, and economic impetus and consequences of technological innovation. This thesis makes the argument that the evolution of sport wheelchair devices was driven by the actions of wheelchair athletes, acting as an important site of autonomy against wheelchair designs which restricted their athletic abilities.

1.1 – Research context

The following sections briefly outline important concepts and context for this thesis.

1.1.1 – Sport wheelchair devices

This research explores manual sport wheelchair devices. A sport wheelchair can be defined as a wheelchair which has been primarily designed for use in recreational or professional athletic activities. Moreover, the term 'sport wheelchair' can be used as an umbrella term to categorise numerous wheelchairs designed for specific sporting contexts. For instance, the modern three-wheeled racing wheelchair is a device specialised for the purposes of track or road races. Racing wheelchairs can be categorised accordingly as a type of 'sport wheelchair', alongside other specialised devices, such as basketball, tennis, and rugby wheelchairs.

Modern sport wheelchairs are therefore designed to be used in this context. This thesis will show that in the historic evolution of wheelchair devices, modifications and designs which benefited sport also benefited other uses. Notably, Stewart and Watson (2019) highlight that the modern ultralightweight everyday wheelchair emerged from modifications to wheelchairs for the purpose of sport. Hospital-provided wheelchair devices were heavy and cumbersome, suggesting that wheelchair designers perceived the end user as someone who was inactive and would remain confined to their home or a hospital ward (Woods and Watson, 2004). Wheelchair users interested in sport accordingly modified their devices, or created new wheelchair designs, to better accommodate their athletic pursuits. Wheelchair users who were not athletes, but still sought to live active and independent lives, also benefited from these innovations. By the 1990s, wheelchair models intended specifically for racing, tennis, and rugby were introduced, as athletes sought to augment the performance advantages their equipment could provide.

This thesis explores four types of manual sport wheelchair devices. Innovations within basketball and racing wheelchairs are the primary focus of this research due to the significance of these innovations within wheelchair technology and the popularity of these sports throughout this time period. Tennis and rugby wheelchairs are also highlighted, as these devices were initially similar to basketball wheelchairs but later specialised for their specific athletic contexts.

It should be noted that due to scope and focus, this thesis does not explore other types of sport specific wheelchairs which emerged in the research. Sport-specific manual wheelchairs designed for Ballroom and Latin dancing (known as wheelchair dance sport or para dance sport) and wheelchair motocross (known as WCMX) appeared in the research data. These recent sport wheelchair varieties were ultimately not included as the scope of the thesis was limited between the 1950s and the 2000s. The development of this equipment may be significant for future research into this subject. Likewise, other sport equipment used by wheelchair users was not included in the thesis despite some presence in the interview data. Wheelchair fencing, for instance, uses specialised frames which hold the wheelchairs in place during competition. This equipment was not included because innovation primarily occurred to the frames as opposed to the wheelchairs themselves. Other excluded examples include sit-skis for skiing events and throwing frames for athlete events such as javelin and shotput, which retired wheelchair athlete and academic Abu Yilla (2004, p.34), refers to as ‘wheelchairs without wheels’. The technological and use-case differences between a sit ski and a basketball wheelchair exceeded the scope of the thesis. Similarly, research data does include instances of powered wheelchairs used in sports such as powerchair football. Nevertheless, technological disparities and the historiographic differences between manual and powered disability sports, also proved challenging to include in the same thesis.

1.1.2 – Users as innovators

Central to this research is the focus on users as key innovators within the history of technology. Recent historic and social science literature has emphasised disabled people's expertise and agency within technological innovation. Hamraie and Fritsch's Crip Technoscience Manifesto (2019) outlines political meaning in disabled people's critiques, modifications, and reinterpretations of existing technologies. The authors assert disabled people's status as 'knowers and makers' of technologies, privileging their expertise and knowledge (Hamraie and Fritsch, 2019; p.7). Likewise, scholars have identified historic and modern legacies of disabled people as innovators, such as Williamson (2012; 2019), Dokumaci (2023), Virdi (2020a; 2020b) and Serlin (2004). Accordingly, this research asserts the agency of disabled people as actors who are able to challenge structures and institutions in their roles as technological innovators (Watson, 2019).

This literature alone is insufficient for conceptualising the development of technological devices. Frameworks and debates from the larger field of STS have been employed to formulate the relationship between human actor (disabled athlete) and technological actant (wheelchair). In particular, literature that examined the role of the end user in the evolution of technological objects was of key interest. Oudshoorn and Pinch (2003, p.3) write that technological objects and their users co-construct each other. This refers to the role of users in defining the purpose, function, and meaning of the technological artefact and the object's role in shaping what the user may do. In the case of wheelchair technologies, heavy and cumbersome wheelchairs defined users as inactive and restricted their athletic capabilities. In turn, users modified their wheelchairs to enable improved performance, redefining these devices into pieces of sports equipment. Specialised sports equipment consequently afforded the creation of new techniques and extended athletes' range of movement. Thus, an important material and semiotic negotiation exists between object and user.

The use of STS frameworks in this thesis draws upon previous research into wheelchair technology, published by Woods and Watson (2004) and Stewart and Watson (2019). These papers consider the development of everyday wheelchair technology utilising the concepts of the Social Construction of Technology (SCOT) and boundary objects respectively. Both papers aim to showcase the extent to which wheelchair users were involved in the development of wheelchair technology. Woods and Watson (2004), for instance, highlight that the wheelchairs provided by the British National Health Service (NHS) between the 1940s and 1960s restricted the end user, as they presupposed disabled people to be inactive. Despite the feedback and objections of end users, the re-design of subsequent wheelchair models was directed by the perspectives of medical professionals, government officials, and wheelchair manufacturers (Woods and Watson, 2004). Outside institutional structures, Stewart and Watson (2019) show that in the 1970s and 1980s, wheelchair users modified and created new devices themselves, for the purposes of sport. These technological advancements were subsequently adapted for the everyday wheelchair market, as wheelchair users found that sporting modifications benefited daily use. Whilst Roulstone (2016) and Williamson (2019) briefly note the contributions of wheelchair athletes in larger publications about disability, design, and technology, there is limited academic literature on athlete involvement in the development of sport wheelchair technology.

1.1.3 – Language and definition of disability

This thesis builds on sociological and historic research about disability, impairment, and disabled people. The language used to define disability is based on the social model of disability. The social model separates impairment and disability, the former referring to a biological point of difference and the latter as a social construct (Shakespeare, 2014; Rembis, 2019). The social model reorientates the individual and medicalised 'fault' of impairment to focus on structural barriers which disable those who are impaired. Therefore, when the term 'disabled people' is used in this thesis, it is used to refer to a politically and socially marginalised group of people (Shakespeare, 2014, p.19). However, the terms ‘wheelchair user’ and ‘wheelchair athlete’ are used due to the focus on sport wheelchair technology. This thesis is primarily concerned with people who use wheelchair devices either in daily life or specifically in a sporting context, as not all wheelchair athletes utilise wheelchairs in their daily life. ‘Wheelchair user’ and ‘wheelchair athlete’ are preferred in this thesis to specify the group being studied. Moreover, references to ‘athletes’ are used to indicate wheelchair athletes unless stated otherwise.

Athletes and disabled people may be described as ‘active’ in this thesis. The term ‘active’ may simply be used to refer to someone who engages with sport or other forms of physical activity (Niedbalski, 2020). Despite focussing on sport technology, however, this research utilises a broad understanding of the term ‘active’ in order to capture a range of physical activities, lifestyles, and affordances for movement. Significantly, the dichotomy between passivity and activity has important implications for negative attitudes towards disabled people. Negative stigmas surrounding disability and impairment may presume that disabled people cannot, or are not interested in, participating in activities or lifestyles which involve physical exertion (Woods and Watson, 2004). This ranges from independent actions, such as the user propelling their own wheelchair in day-to-day life, to exercise or competitive sports and games. The term active may also be associated with independence, employment, and engagement with wider society, and the idea of passivity is accordingly associated with economic, medical, or social dependence (Brisenden, 1986). Activity, therefore, carries political weight for shaping or reshaping negative attitudes towards disability. Levitt (2017), for instance, proposes an active model of disability to highlight how disabled people’s actions shape their own disabilities, such as via self-help, support groups, or by the use of assistive technology. Active disabled people may therefore refer to both disabled people who are physically active, such as athletes, and those who engage in actions which shape social attitudes towards disability, either explicitly as activists, or implicitly via their daily life. In this research, many of the wheelchair athletes described fit both interpretations of the term.

When discussing influential athletes in the development of sport wheelchair technology, the terminology ‘lead users’ is employed. ‘Lead users’ was coined by Shah (2000) in her exploration of innovations in skateboarding, snowboarding, and windsurfing technologies. The term is defined as "users who exhibit both of two characteristics: they have a high need for an innovation and they experience that need ahead of the bulk of the target market" (Shah, 2000, p.12). This term is thus used later in the thesis when discussing wheelchair athletes who made significant innovations or contributions to the development of sport wheelchair technology and its associated manufacturing industry.

1.2 – Research aims and questions

Athlete contribution to wheelchair design is largely unrepresented within academic research and archival collections, but is known to those within athlete communities. Using snowball sampling techniques, thirty-nine semi-structured interviews were conducted with athletes, wheelchair designers, and other relevant individuals, for this research. Following the conclusion of this project, these interviews will be donated to the National Paralympic Heritage Trust (NPHT) for public and research use, dependent on participant consent. These interviews were conducted in order to:

- Identify how attitudes towards disabled people and wheelchair sport both informed and were a result of wheelchair design.
- Explore the evolution of manual wheelchair technology, focusing on the creation of wheelchair modifications and devices made for the purpose of sport.
- Consider the role of wider social and political factors that exist between users and designer, and the consequences of innovation on wheelchair sport and wheelchair athletes.

Three research questions were designed to address the above research aims:

1. In what ways did different interpretations of wheelchair sport held by medical professionals and athletes influence the development of wheelchair technology?

2. How did manual wheelchair design evolve and stabilise to create different varieties of sport wheelchair technologies?
3. What was the socio-political and economic context and impact of technological change, and what consequence did this have on the autonomy and self-determination of wheelchair users?

This thesis has utilised qualitive research to address these questions, including interview data and sources gathered from physical archives and social media platforms. Collected data was then analysed via reflexive thematic analysis framework.

1.3 – Thesis structure

This thesis is comprised of an introductory chapter, two literature reviews, a methodology and methods chapter, three data chapters, and one concluding chapter. Descriptions of each chapter can be found below.

Chapter 2 – Literature review: Sport wheelchair historiography

This chapter explores academic literature in the fields of Paralympic studies, sport history, and disability history to frame the analysis of technologies used in sport or by disabled people. Previous scholarship about the history of everyday and sport wheelchair devices are also outlined, establishing the socio-historical approach utilised in this research.

Chapter 3 – Literature review: Science and Technology Studies

The second literature review outlines different approaches within the sociological field of Science and Technologies Studies (STS) drawn upon in this thesis. This chapter begins by outlining attitudes towards users within STS, linking feminist approaches by scholars including Cowan (1987) and Wajcman (1991), and Pinch and Bijker's (1984) SCOT to the study of disabled people. The succeeding section outlines concepts such as affordances, boundary objects, and technological frames. The final section considers the relationship between users and designers, ending with the concept of user expertise over technologies.

Chapter 4 – Methodology

This chapter expands on the theoretical approach and methodological practice employed for this research. This chapter includes discussions of oral history methodology and practice, alongside research design, and the use of reflexive thematic analysis.

Chapter 5 – Interpretations of wheelchair sport

Chapters 5-7 outline the findings of this research. Chapter 5 outlines the historical context of wheelchair sport and the Paralympic movement, highlighting two interpretations of wheelchair sport held by medical professionals and wheelchair athletes. These interpretations shape the conceptualisation of wheelchair technology, framing later technological and regulatory changes.

Chapter 6 – Technological evolution of sport wheelchair devices

Chapter 6 lays out technological changes to wheelchair devices made by athletes between the 1950s and 2000s. This is presented in a broadly chronological order, starting with small adjustments to existing devices and progressing onto the creation of new wheelchair frames. This chapter initially focuses on developments made for wheelchair basketball and highlights their benefit to everyday wheelchair use. As wheelchair devices evolve, the division between sport and everyday wheelchairs emerges, leading to an exploration of sport-specific wheelchairs used in racing, tennis, and rugby.

Chapter 7 – Athlete self-determination in sport administration and industry

Chapter 7 focuses on the autonomy and expertise of users as innovators of wheelchair technology, investigating athlete resistance to wheelchair sport regulations and their entrepreneurial creation of sport wheelchair manufacturers. This considers concepts of disabled people's self-determination within sport administration, and autonomy within the wheelchair manufacturing industry.

Chapter 8 – Thesis Conclusion

The final section provides an overview of the thesis, summarising the key arguments and perspectives of the research. It also offers further discussion points for this topic, including themes present in the research that could not be included in great detail in this thesis. This chapter demonstrates the original contribution of this project and areas for future research.

Chapter 2 – Literature review: Sport wheelchair historiography

Despite the prevalence of wheelchair sport worldwide, historical and sociological research has featured limited analysis of sport wheelchair technology. Scholarship has begun to critically engage with the technologies created for and used by disabled people in more detail, mapping to wider growth in the fields of disability studies and disability history. Fields of sport scholarship have similarly taken an increased interest in the technologies that enable sport. Simultaneously, the study of disability sport has expanded as researchers turn to the Paralympic movement as a site of historic and sociological interest. Studies of sport history and disability history can be drawn together via the investigation of technology, particularly as researchers in both fields have identified similar trends of user-directed (athlete, disabled person) design. Instances of these ideas in scholarship highlight concepts of economic development, user autonomy, and resistance in technological innovation. These themes are key to the history of sport wheelchair technology, in which disabled athletes modified and created wheelchairs for specific athletic purposes. This thesis connects and builds upon existing research from both sport and disability scholarship to contextualise the wheelchair objects used and created by disabled athletes.

This chapter is split into two sections. The first focuses on sport history and disability history to highlight the analysis of technological objects within this scholarship. The sections of this subchapter explore a range of literature to highlight similarities between sport and disability histories, and consider the relative lack of historic investigation into sport wheelchair technologies in existing Paralympic literature. The following subchapter outlines existing historic literature about everyday and sport wheelchair technologies. Recent socio-historic approaches establish the focus on wheelchair users and the wider theoretical perspective utilised in this research.

2.1 – Disability, sport, and technology

This subchapter establishes the historiographical context in which this research exists and outlines the significance of dedicated research into the history of sport wheelchair technology. This is achieved by exploring three fields of interest: Paralympic/disability sport studies, technology in wider sport history, and technology in wider disability history. The first section details historic research into disability sport and the Paralympic movement and highlights the limited historical exploration of disability sport technologies in this literature. The next section outlines how historians of other sports have analysed equipment and artefacts used by athletes, highlighting how scholarship has drawn out commercial and economic interests in this field. Following this, the final section considers recent trends of object-focused research in disability history. This features a distinct focus on histories of design, in which disability has become a recent focus. Across these literatures, a thread concerning the users of sport wheelchair technologies can be identified, establishing the user-focused methodology of this research.

2.1.1 – Disability sport and Paralympic history

Historic research into disability sport initially emerged from rehabilitative and medical scholarship, as authors briefly explored the development of athletic activities as means of rehabilitation and its role in physical therapy for disabled people (Guttmann, 1973; Adams et al, 1972; Herron, 1969, found in Aubert, 1973; Huberman, 1971; Sommer, 1971). Similarly, sports science scholarship concerned with the Paralympic Games or disability sport occasionally featured limited historical detail of the Paralympic movement (McCann, 1996; Cooper, 1990; Webborn, 1999). In the United Kingdom, a few notable non-academic texts were produced about Stoke Mandeville and the 'father' of the Paralympic movement, Dr Sir Ludwig Guttmann (Anderson, 2011). Examples include Goodman's (1986) biography of Dr Sir Ludwig Guttmann, or Scruton's (1998) overview of the administrative history of the Paralympic movement between 1948 and the early 1990s. These accounts of disability sport and the Paralympic movement explored this history from a medical or administrative perspective, presenting uncritical biographic descriptions of Guttmann's medical and administrative work, and limited acknowledgement of athletes' contributions to sport. Historical literature concerning the Paralympic Games began to emerge in the 2000s. Subjects of study included Guttmann's work establishing the Games (Anderson, 2003; Brittain, 2008; Brittain, 2012), the development of the Paralympic movement (Bailey, 2008), and the growth of non-Paralympic disability sport events (Brittain, 2014; Frost, 2020). Similarly, historic explorations of disability sport and Paralympic events in regions such as sub-Saharan Africa (Noutcha, 2008; Novak, 2014) or individual countries[1] have been produced. Scholarship in the early twenty-first century connects the history of Paralympic events and disability sports to wider social and economic developments, emphasising the potency of sport as a topic of analysis for disability history and studies.

A noticeable trend within historic research has been an increased focus on athletes' experiences and political agency. Authors such as Peers (2009) and Schantz and Gilbert (2012) have critiqued how athletes were represented in prior histories of the Paralympics. Peers (2009) questions the assumptions which underpinned the histories presented by Bailey (2008) and Steadward and Peterson (1997), as these narratives are perceived as disempowering athletes. This is the result of different tropes across the two works, as disabled people were depicted as tragic figures, whilst the work of non-disabled medical professionals and sports administrators has been commended. Peers (2009) argues that disabled athletes are rendered invisible in this depiction and their roles as political actors are undermined. This critique of Paralympic histories has been addressed by recent scholarship which placed more focus on the experiences and actions of athletes. For example, some scholars have examined the role of athletes as activists during the controversial participation of South Africa (Greig, 2005; Brittain, 2011; Mallet and Sikes, 2021) and Rhodesia (Little, 2008; Novak, 2014) in the 1976 Toronto Games. Similarly,

[1] Examples of this literature include; the United Kingdom (Brittain, 2012), Australia (Lockwood and Lockwood, 2007; Jobling et al, 2012), New Zealand (Bradbury, 2008), Malaysia (Omar and Maid, 2008), France (Ruffié et al, 2014), Slovenia (Topic, 2008), and Japan (Frost, 2020).

scholars such as Brittain (2012) and Frost (2020) have specifically identified the names, experiences, and achievements of athletes in their scholarship, rectifying Peers' (2009) critique of disabled people as invisible and anonymous.

Consideration of technology is most present in non-historic Paralympic literature via discussion of the 'cyborg' (where disabled people who use mobility devices or sports equipment are described as hybrids of organic and machine material) and the way disabled athletes' bodies are represented in mainstream media.[2] Some scholars have argued that depictions of Paralympians reinforce stereotypes about impairment and ability (Schell and Duncan, 1999; Goggin and Newell, 2000; Thomas and Smith, 2008a; Kolotouchkina et al., 2021). One such representation is the concept of the 'supercrip', in which disabled athletes overcome limitations via their athletic prowess, and become 'superhuman' (Thomas and Smith, 2008a; Crow, 2014; McGillivray et al., 2021). Sports equipment has increased visibility within the 'supercrip' narrative, as elite athletes' use of high-performance technologies, such as racing wheelchairs or running prosthetics, is used to identify achievement (Howe and Silva, 2017; Pullen and Silk, 2020) or rehabilitative success (Seymour, 1998). Howe (2011) relates this trend to the 'cyborgification' of disabled athletes' bodies, as athletes who are able to adapt to and use technology are most celebrated by the International Paralympic Committee (IPC) and other sport organisations (Howe, 2008). Similarly, disgraced South African athlete Oscar Pistorius became representative of the 'celebrity supercrip' (Pullen and Silk, 2019; Tamari, 2017) through his athletic success and use of dual carbon-fibre running-blade prosthetics. Pistorius sparked debate around 'cyborg' bodies and athlete classification when he applied to compete in the 400m at the 2008 Beijing Olympics and other events (Thomas

[2] Broadly, popular themes within this literature beyond media representation include topics of classification (Howe and Jones, 2006; Thomas and Smith, 2008b; Buckley, 2008; Tweedy et al, 2014; Connick et al, 2018), the economic and urban impact of Paralympic Games (Darcy, 2001; Misener et al., 2018; Frost, 2020), and the impact of sport on disability politics (Schantz and Gilbert, 2012; Brittain and Beacom, 2016; Braye and Gibbons, 2021; Haslett and Smith, 2021) and identity (Peers, 2012; Sparkes and Smith, 2003; Huang and Brittain, 2006).

and Smith, 2008b). The International Association of Athletics Federations ruled against his entry, citing his use of running blades as presenting an advantage over non-disabled runners, which was successfully challenged (Norman and Moola, 2011). Scholars used Pistorius' case to not only consider representations of the athlete as a 'supercrip' or 'cyborg' (Swartz and Watermeyer, 2008), but also to examine the identification of technology as performance enhancement akin to drugs – referred to as 'techno-doping' (Wolbring, 2018) – and the transgressions of boundaries between non-disabled and disability sport (Norman and Moola, 2011, Richard et al., 2021). Whilst the wheelchair sport events discussed in this research are primarily comprised of competitions between disabled people, such publicity influences how wheelchair technology, sports, and athletes are perceived in mainstream society. Technology is therefore an important site of inquiry in Paralympic studies, as it relates to the past and future development of disability sport, the representations of athletes, and the relationship of disability sport to wider disability politics and non-disabled sport.

Explorations of sporting equipment, however, are limited within literature concerning the history of the Paralympics or wider disability sport. These instances are relegated to passing references to the development of technology in wider histories of Paralympic sport (Bailey, 2008). Peers (2009) briefly refers to disciplinary technology such as administrative systems or training programmes which act to assert control over athletes' bodies, specifically exploring power exercised within classification practices and techniques. However, Peers' (2009) article is primarily a sociological discussion of Paralympic narratives rather than a historical analysis, despite the brief use of historic examples in the argument. Similarly, Brandmeyer and McBee (1986) invoke the history of racing wheelchair technology in relation to athletes' use of sport as a means of social acceptance, but this aspect of their analysis is shallow. In the same collection, Steadward and Walsh (1986) consider the rapid improvement of disabled athletes across the history of the Paralympics but make no mention of advances in technology in this discussion.

Yet technologies utilised within disability sport have distinct social and historical importance. The functionality and availability of these artefacts have shaped the evolution of disability sports events, and facilitated changes in athletic ability and classification. Similarly, sport technologies have considerable influence on the use and development of accessibility, mobility, and assistive technologies, as will be seen by the development of sport wheelchair models into lightweight, everyday wheelchair models (see Chapter 6). Sport technologies can be interpreted, accordingly, as political instruments. As historic explorations of the Paralympics and disability sport evolve, disability sport equipment must be analysed through a critical sociological and historical lens.

2.1.2 – Technology in sport history

Research investigating the development of sport wheelchair technology must also consider the ways in which sport historians have approached, theorised, and evaluated other examples of sport technologies. In comparison to disability sport histories, socio-historical analyses of technology are more prominent within wider sport history scholarship. Material culture is analysed within sport history to identify changing and enduring meanings of sport across time (Hardy et al, 2009). These studies have included the exploration of a variety of technological objects and equipment.[3] Histories of sporting technology outline the evolution of artefacts and explore the impact of these creations on sport or wider society. Booth (1999) demonstrates this within the history of surfboards, as new designs and materials were introduced throughout the twentieth century to improve manoeuvrability and weight. New surfboard technology facilitated new techniques and enhanced athletic performance. Booth (1999) also perceived technical

[3] Scholars have investigated a broad range of technical artefacts, such as bicycles (Ritchie, 1999), surfboards (Booth, 1999); skateboarding, snowboarding, and windsurfing technology (Shah, 2000); and motorsport cars (Dick, 2013; Hassan, 2012), amongst others. Moreover, scholarship has extended the idea of technology to artefacts such as protective gear (Moenig et al, 2012), hiking backpacks (Gross, 2022), and clothing (Stride et al, 2015; Goodrum, 2015; Munkwitz, 2018). Physical spaces have also been approached within this framework, exploring sporting venues such as courts (Luitzen, 2015), beaches (Booth, 2019), and pools (Murtha and Ozyurctu, 2021).

innovation as an extension of surfboard culture, as the function of boards or the materials used reflected the unique cultures at Australian and American beaches. Recently, this concept has been expanded by Gross (2022), who argues that technological change reflects wider social and cultural environments surrounding a sport and that athletes form specific identities around the use or disuse of new equipment (Gross, 2022). Accordingly, concepts from historical explorations of sports equipment provide effective frameworks which can be applied to the history of sport wheelchairs.

In the field of sport history, theoretical approaches into sporting technologies as socio-political artefacts have been largely limited – barring recent reference to theories or insights employed in STS or sports science (Gross and Roeder, 2022). However, sport historians have previously approached the topic of sport technologies via a lens of economic and business analysis. This allows scholars to consider the commercial forces which govern the creation, production, and dissemination of sports equipment (Nothen and Kidd, 2022). Hardy (1986) advocated for sport historians to analyse sports as industries in which economic forces shape the creation of sports equipment. The commercialisation of sporting technologies has been well noted in literature. Turner's (2019) history of the sneaker outlines transformations in shoe design and manufacturing but frames these changes within the development of new commercial interests. Similarly, Turpin (2018) explores how advertisers reinvented the imagined user and the cultural idea of the bicycle in American culture throughout its technological evolution in order to target new consumer groups and promote bicycle use during periods of economic uncertainty and the rise of the automobile. Exploration of sporting technologies as commercial products can reveal how innovation was proliferated to lay and elite athletes, and how this shaped the cultural perception of the artefact. Conversely, sporting equipment may influence social and cultural ideas about their user. Wallace (2022) demonstrates that the cultural perception of sneakers was shaped by commercial efforts of brands to associate their products with African American athletes and culture. In doing so, racialised marketing of sneaker technology perpetuated harmful or stereotypical ideas about African American culture. Consequently, Wallace (2022) argues that studies of commercial sporting equipment must consider how these objects act as sociocultural, political, or economic actors in society.

Hardy (1986) also framed entrepreneurism as a significant topic in the creation of sports equipment. Initially, historians perceived entrepreneurism entirely as a monetary venture, such as the growth of profit-seeking practices within sport in nineteenth-century America (Hardy, 1986). Vamplew (2018), expanding on Hardy's 1986 article, deploys a broad re-definition of the term. In the context of sports equipment, entrepreneurs are those who facilitate significant product change, for examples individuals who develop new equipment, establish new markets, or those who increase the supply or quality of a product (Vamplew, 2018). Entrepreneurism constitutes more than just economic gain but in many cases, sporting improvement (Munkwitz, 2018). Explorations of sporting technologies frequently highlight that athletes are the initial instigators of equipment innovation, as they seek to enhance their performance and capabilities in their sport. Shah (2000) found that in the development of skateboarding, snowboarding, and windsurfing equipment, athletes were responsible for all recorded instances of 'first of type' innovations which significantly transformed the function and form of equipment for that sport. Many of these athletes later established their own manufacturing companies, as they turned personal and athletic satisfaction into sources of monetary gain. Shah (2000) suggests that athletes, not manufacturing firms, were in the position to innovate in skateboarding, snowboarding, and windsurfing devices, due to the small size of the market, low cost of experimentation, and personal interest in the sport. As a result, these athletes helped to establish the market for these sporting devices first by creating new technologies and then by establishing firms through which these new creations could be sold to other athletes.

Collaboration between athletes and manufacturers similarly led to innovation in sporting technology. Munkwitz (2018), for instance, shows that in the late 1890s, female equestrians created their own equipment as there was a lack of commercially available devices due to gender norms that constructed horse riding as a male activity. Women began to patent new saddle and stirrup designs which improved safety and independent mounting of horses. Drawing on their expertise in horse-riding experience, women also made innovations in horse-riding clothing, such as safety skirts, which enabled women to be more effective and secure when riding. In both instances, female equestrians collaborated with manufacturers to create their designs, and established commercial and second-hand markets for these artefacts (Munkwitz, 2018). Likewise, Gross' (2022) research into the development of ultralightweight backpacks used in hiking highlights a similar narrative about athlete-created designs becoming commercialised via athlete collaboration with manufacturers. However, Gross (2022) suggests that athletes' acceptance and proliferation of the ultralight backpack was more due to its cultural and ideological potency among athletes than its commercial availability. Regardless, these narratives reinforce the role of athletes, not manufacturing firms, as the innovators of sports equipment. In Shah's (2000) study, the majority of significant innovations which hailed from manufacturers were actually created as a result of collaboration between athletes and manufacturers. These studies imply that innovation occurred primarily as a result of the practical expertise and enthusiasm of athletes, situated by these athletes' direct involvement in their sports. This literature therefore reinforces the expert status of athletes in the conceptualisation and creation of sports equipment and technology, in addition to underscoring the potent links between innovation and commercial interests.

Literature concerning the history of sport technology presents potent concepts and approaches in the study of sports wheelchair devices. The impact of technological change on human actors, sport, and society, for instance, is of pertinence to the impact of sport wheelchair technologies on everyday wheelchair devices (discussed in Chapter 6), wheelchair sport rules, and the manual wheelchair market (explored in Chapter 7). Moreover, the role of athletes as entrepreneurs, who directed the evolution of sport wheelchair equipment, carries distinct socio-political importance, as these developments not only represented the advancement of wheelchair sport, but the agency of athletes as disabled people. Accordingly, this research also draws on literature from scholarship concerning disability history and technology.

2.1.3 – Technology and disability history

Vamplew's (2018) concept of sport entrepreneurs has significant overlap with explorations of technology in wider disability history. Akin to athletes, disabled people have been involved in the design and creation of the artefacts they personally use and have been responsible for instances of significant technological evolution. Unlike athletes, this legacy is inextricably connected to disabled people's lack of representation in traditional environments of design and need to advocate for accessibility and independence. As such, disability historians have perceived technology as a significant way to examine the lived experience of disabled people throughout history. Scholarship in this area has grown in the last decade, led initially by Katherine Ott's insights into the relationship between disability and material culture (Blackie and Moncrieff, 2022). Ott (2018) argues that the category of disability is innately interconnected with technology, due to the role that objects play in the construction of disability as a social, cultural, and medical category across history. Furthermore, disabled people are impacted by social and economic forces that determine the availability, distribution, and cost of devices and equipment. Historians must analyse the historical contexts surrounding these objects, and consider their impact on the conceptualisation, manufacturing, use and abandonment of technological artefacts (Ott, 2014; Ott, 2018). In this way, the analysis of devices used by disabled people reveals aspects of lived experience which denote how disabled people have lived their lives (Blackie and Moncrieff, 2022). Ott (2014) gives examples of factors that may be considered, including the weight of a device, the range of movement it affords, and its design, which may indicate the impairment or bodily difference of the user.

Historians conducting material analyses of disability have investigated a range of technologies now classed as adaptive or assistive equipment (Guffey and Williamson, 2020; Williamson, 2012), such as hearing devices (Virdi, 2020a; Mills, 2012), canes (Fallon, 2020), and prosthetics (Ott et al., 2002; Serlin, 2004; Lieffers, 2020). This scholarship explores not only the creation and design of these devices, but the social, cultural, economic, and medical contexts in which they existed and were used. Virdi (2020a) explores hearing aids as 'cures' for hearing impairment in British and American history, analysing technological artefacts as medical, commercial, and socio-cultural artefacts. Virdi (2020a) also considers the action and perspectives of deaf users of these technologies, highlighting experiences of wearing and using hearing devices. Indeed, she refers to her own practice of using, maintaining, and tinkering with analogue hearing aids instead of relying on hearing aid specialists for technical support. Similar approaches have been employed in the study of wheelchairs (Woods and Watson, 2004; Stewart and Watson, 2019; Trembley, 1996), which will be further examined in Chapter 2.2.

The design and social context of technological devices has important consequences on the ways disabled people are perceived by the world around them. Utilising the sociological concept of stigma, technological artefacts can be understood as both the source of stigmatising attitudes, and a form of stigma management for disabled people. The concept of stigma was originally introduced by Goffman (1990) in 1963 to describe the association of attributes or behaviours to adverse social judgements about a person or group (Scambler, 2009; Chatzitheochari and Butler-Rees, 2023). Stigmas form as individuals deviate from certain norms or expectations, although the categorisation of deviation only occurs as behaviours or attributes are perceived as negatively different (Susman, 1994; White et al, 2023). Subsequent literature developed Goffman's concept to link stigmatising attitudes to power relations in society (Scambler, 2009; Gaffney, 2010). Link and Phelan (2001, 377), for instance, argue that stigma is enabled by socio-political and economic power relations, and exists alongside forces of 'labelling, stereotyping, separation, status loss, and discrimination' faced by marginalised groups (Saia et al. 2024; Chatzitheochari and Butler-Rees, 2023).

The attributes of assistive technologies lead to the formation of stigmatising attitudes which construct disabled people as less desirable. Saia et al (2024) found that the physical affordances of a wheelchair led to assumptions of an individuals' competence, intelligence, and ability. Similarly, Sapey et al (2005) argue that wheelchair use constructs users as immobile and incapable. Such attitudes manifest from the concept of the 'sick role', which presume that disabled people are dependent on practitioners due assumed medical expertise, and ability or self-sufficiency with walking (Gaffney, 2010; Sapey et al, 2005). Papadimitriou (2008) likewise argues that negative stigmatisation occurs due to the use of the wheelchair device alone, as opposed to the observation of deviant behaviours by others. As the iconography of the wheelchair is heavily associated with disability as a broad category, assistive technologies function as a source of stigmatisation (Parette and Scherer, 2004; Sapey et al, 2005). The ways in which disabled people therefore choose to adopt, reject, or change these technologies may therefore have significance as a form of stigma management. Drawing on ideas found in literature concerning both non-disabled and disability sports, stigma management is a key part of reducing the social power of others. In the case of disabled athletes, for instance, sport can challenge internalised and external ideas of incompetence and ability (Afroozeh et al, 2024; Niedbalski, 2020; Taub et al, 1999). Technology may exist as a similar site of stigma management, particularly in contexts where technology enables activity, such as sports participation.

Historic scholarship has explored other tools and objects used by disabled people. Some of these may be specialised tools or modified commercial products that enable independent living, such as faucet turners, mouth sticks, and ramps (Williamson, 2019; Hamraie, 2017). These objects highlight some of the physical barriers that disabled people face in domestic or public settings, how individuals navigate these environments, and instances of agency demonstrated by the creation of customised tools for their individual use. Such devices may also outline the social status of the user. Belolan (2020) details a range of objects employed by those with gout in seventeenth-century America, including custom-made carriages, specialised clothing and furniture, and hoists. Differences in gout clothing and furniture used by the wealthy and the poor were observable, and Belolan (2020) speculates how technologies were used to destabilise stigmas of impairment for wealthy individuals with gout. These objects reveal potent details about the lived experience of impairment and how artefacts interacted with stigmas of disability and productions of socio-economic status. Scholarship into the objects used by disabled people is also temporally varied. Whilst the majority of object-focused histories focus on the nineteenth to twenty-first centuries, scholars have also explored artefacts used by disabled people in ancient history, studying descriptions of artefacts or the limited material remnants of these objects (Draycott, 2018; 2021).

Scholars exploring these topics have drawn on a range of theoretical approaches and interdisciplinary research fields. Bess Williamson, for instance, draws both on elements of anthropological research (Williamson, 2019) and design history (Williamson and Guffey, 2020; Gooding, 2021) in order to establish her analysis. Extrapolating on the theoretical concepts of design history, Guffey and Williamson (2020) advocate for a design model of disability in which the physiological and social experiences of disability may be examined separately from the pervasive concepts of the social or medical models of disability. This is because the design of objects and environments enable and disable in ways distinct from medical or social categorisation (Guffey and Williamson, 2020). A design-centred approach allows historians to critically engage with artefacts and their impact on the definitions, experiences, and meanings of disability. One example of this may be the use of technology to construct and maintain gender norms. In investigating devices used by polio survivors, Williamson (2019) and Myjak-Pycia (2021) detail examples of adaptions to assist independent movement around the home, from objects such as rails and ramps, to altered cabinet and surface heights and belt braces to assist standing. These authors note that such artefacts intersected with attitudes towards women's domestic work, aiming to match disabled women to the model of traditional domestic work as non-disabled white, middle-class women (Myjak-Pycia, 2021; Puaca, 2020). Mujak-Pycia (2021) suggests this was a deliberate attempt to appeal to traditional gender roles, aimed to challenge negative perceptions which constructed disabled women as unproductive and unfit for marriage in mid-twentieth-century America. Serlin (2002; 2004) has, likewise, analysed the role of prosthetics in constructing or maintaining ideas of masculinity for disabled veterans in post-Second World War America. Physical impairments were associated with heterosexual male anxieties of the time, such as a lack of social status or sexual prowess, or the ability to work and maintain a family (Serlin, 2002; 2004). To challenge the perceived emasculation of disability, prosthetic limbs were made with modern materials and styled to highlight their function, whilst advertisement aimed to showcase prosthetic users engaging with 'normal male' activities. Serlin (2002, pp.61-62) illustrates this with photographs of prosthetic users lighting a cigarette or reading a newspaper. Prosthetics were thus deployed by the government to allow the body to conform to cultural and social ideas of masculinity.

A major trend within design studies literature about objects used by disabled people is the tinkering, modification, or creation of tools, objects, and devices by their end users. The term tinkering is used in this research to conceptualise the relationship between disabled people and technology. This terminology is used in care-focused literature, for example, to denote relationships between recipients of care and care practitioners, or as collaborative practices of support for recipients of care (Heerings et al, 2022). Winance (2010) used the term ‘empirical tinkering’ to explore the socio-technical arrangements between mobility aids and rehabilitation practices negotiated by users and other human actors. However, this research utilises the term tinkering to specifically highlight the material practice of technological change in which the disabled user or technologist enacts specific practical, functional, or aesthetic alterations to an existing device. This approach draws from material explorations of disability history or studies, which refer to the term tinkering as part of disabled people’s practice of re-working and re-making technological artefacts, although the term is not specifically defined (Hamarie, 2017; Williamson, 2012; 2019; Hamarie and Fritsch, 2019). The term hacking may also be used to define a politicised process of remaking, in which ableist or disablist attitudes towards disability are exorcised from the artefact during the process of material transformation (Ungurean and Vatavu, 2021; Barry et al, 2023). However, the terminology of tinkering can also be used for this purpose (Hamarie and Fritsch, 2019; van Grunsven, 2024). This research favours tinkering over hacking for the former’s association to material or mechanical devices, and to denote the small acts of adjustment users of devices such as wheelchairs engage in.

As tinkerers, disabled people formulated the concept, function, and design of an artefact to be employed in their own use. Examples of this include clothing (Linthicum, 2006; Belolan, 2020) and independent living tools or modifications, such as the installation of lifts and ramps, to the creation of specialised tools for operating household appliances and environments (Galán, 2022; Williamson, 2019). In some circumstances, disabled people also acted as engineer and manufacturer, whilst in others, disabled people collaborated with friends, family members, or professional engineers and designers. Scholars have highlighted the act of user-led modification and design, as this practice demonstrates the agency of the disabled person as both user and technologist, and the lived experience of social and political inequalities (Hamraie, 2017). In many cases, instances of user-led design transpired due to lack of adequate equipment available, necessitating the eventual user to adapt existing commercial products or pioneer new designs themselves (Williamson, 2019; Stewart and Watson, 2019). The lack of adequate devices, or presence of inaccessible environments, has been associated with the lack of disabled people within environments of design and creation (Gissen, 2018; Burgstahler, 1994; Matyas and Malcom, 1991) or lack of attention given to feedback from disabled groups or individuals (Woods and Watson, 2004). In some circumstances, these trends intersected with wider social and cultural forces. For instance, economic disparities faced by disabled individuals necessitated the creation of cheaper alternatives to expensive or medically distributed devices (Hamraie, 2017). Similarly, innovation led by disabled people in mid-to-late-twentieth-century America has been linked to wider trends of consumer 'do-it-yourself' culture, influenced by the high cost and shortage of skilled labourers and the ethos' of independence and domesticity (Myjak-Pycia, 2021, p. 9; Williamson, 2019).

Scholarship has also analysed instances of collaboration between disabled people and manufacturers or other professionals. These collaborations expand on discussions of agency, expertise, and authority. Some collaborations came about as disabled people hired technologists to make custom products for them. Belolan (2020) gives the example of a specialised carriage made for Pennsylvania Surveyor General John Luken in seventeenth-century America. Luken had gout, and commissioned a carriage maker to produce a specialised carriage which was lower to the ground and more spacious for his specific use. As far as Belolan (2020) demonstrates, this was a unique creation for Luken and did not form the beginning of a new type of carriage model that could be used by others with gout. This was only possible due to Luken's socio-economic status, indicating that collaboration with manufacturers was only available to wealthy disabled people at this time. Scholars have also identified instances of non-disabled experts collaborating directly with disabled people to help co-produce appropriate and effective tools, programmes, and methodologies. In comparison to Belolan's (2020) example, this suggests attempts from professionals to make significant alterations to the environments of design. Galán (2022) gives the example of the non-disabled architect, Raymond Lifchez, who taught at the University of California, Berkeley in the early 1970s. Berkely was home to growing culture of disability advocacy since the early 1960s (Williamson, 2019), and Lifchez challenged the assumed expertise of the architect in his classes, working to capture disabled people's experiences of independent living (Galán, 2022). Disabled students, such as undergraduate Mary Ann Hiserman, participated in the design studio, providing feedback on student projects based on their expertise. Linking this practice to disabled people's protests in the late 1970s, Galán (2022) argues that Lifchez's collaborative approach to design gave weight to the idea of disabled people as experts of their lived experiences. This concept can likewise be seen in scholarship about wheelchair manufacturer Everest and Jennings (E&J), co-founded by wheelchair user Herbert Everest due to his frustration with existing wheelchair devices (Trembley, 1996; Williamson, 2019, pp.81-82) (see Chapter 2.2.1).

Either as independent creators or in collaboration with non-disabled professionals, the knowledge and expertise of disabled people is privileged within this scholarship. Innovations occurred as medically designed devices were unsuited to the realities of use or desire for independent living (Stewart and Watson, 2019; Woods and Watson, 2004). Medical professionals and administrators asserted their expertise over disabled people, dismissing or ignoring patient input on the basis of their medical training (Williamson, 2019). As a result, innovation led by disabled people has been constructed as a form of activism or resistance against medical and ableist ideologies (Galan, 2022). These actions were also communal, as inventions and designs were shared to other members of their community, such as the proliferation of home-made creations in community published magazines in the mid-twentieth century (Williamson, 2019). Accordingly, this topic in recent scholarship has placed increased recognition on disabled people as technologists within the history of design and technology. These individuals straddled a divide between user and designer, as they tinkered with devices drawing on their lived experience and needs. This is most present in scholarship which explores disabled people's connection to technological artefacts and these objects' social, cultural, and political significance. A similar thread is present in the history of wheelchair technology (Sapey et al., 2005). Stewart and Watson (2019) identify how wheelchair athletes directed the development of sport wheelchair technology, due to the lack of suitable options from existing wheelchair manufacturers and to advance their own sporting interests – a concept which is explored in the following subchapter and later chapters.

2.1.4 – Conclusion

Across Paralympic, non-disabled sport, and disability history literature, scholars have emphasised the importance of user- and athlete-orientated research. In the context of disability sport and wheelchair devices, new research must consider the role and impact of disabled athletes on technology and sport. This exemplifies the value of user-focused STS frameworks explored in Chapter 3. Before this, the historiography of sport and other wheelchair technologies is explored. Further justification for the focus on the user emerges from this literature, as this research builds on existing scholarship which emphasises the role of athletes in the development of sport wheelchair technology.

2.2 – Historiography of sport wheelchair technology

This subchapter turns to focus on the historic literature concerning the development of everyday and sport wheelchair technologies. Some of the key ideas raised in the previous chapter may be considered in context of wheelchair technology, such as the role users played in technological innovation, and the creation of a commercial market for wheelchair technology. The first section of this subchapter outlines scholarship concerned with medical or everyday wheelchairs, considering how scholars have critically engaged with these artefacts and linked them to wider aspects of disability history. In particular, this section outlines how literature about wheelchair technology shifted from a linear description of technological advancement to one which explored the social, political, and material context in which wheelchair users and other actors existed. The second section explores the limited academic and non-academic literature concerning the history of sport wheelchair technology. Previous academic literature has grouped the development of sport wheelchair with that of everyday wheelchair devices. Non-academic sources, often written and published by wheelchair users, have however focused entirely on sport wheelchairs equipment, making this literature a significant resource for this thesis.

2.2.1 – Historic research into wheelchair technology

Initially, literature concerning wheelchair technology and its evolution was primarily concerned with its role within medicine and rehabilitation. However, scholars reframed the wheelchair as an artefact of distinct social and political importance within the wider history of disability politics. Notably, focus on those technologists granted or not granted access to the design of these objects represented wider themes within the development of technologies used by disabled people. This scholarship establishes the significance of wheelchairs as mobility devices, but also the facilitation of users' independence, disabled people's involvement in technological design, and the recognition of wheelchair users as economic consumers of these devices.

Histories of wheelchair technology often begin with Kamenetz (1969), who documented a range of devices used to transport the sick or impaired. He outlined a range of devices from ancient civilisations to the late nineteenth century which served similar functions to the folding four-wheeled wheelchairs of the 1930s. This lineage began with technologies including litters, carts, or wheelbarrows and continued on to devices more similar to the shape and form of the modern wheelchair, such as invalid or bath chairs of the eighteenth century. Kamenetz (1969) presents this evolution linearly and reinforces the recuperative purposes of these devices (Roulstone, 2016). Kamenetz's work has been influential on later scholarship and non-academic work about wheelchair history, although the linear presentation of technological advancement features little social, economic, or political analysis (Cooper, 1998; Nias, 2019; Sawatsky, 2002). Indeed, Goggins and Newell (2003) argue that this linear depiction of technological development ignores the socio-political context in which wheelchairs or similar devices were used, altered, made, or abandoned. Innovations in such technologies were presented as inherently good, without determining who made these changes or for what purpose (Roulstone, 2016).

Subsequently, sociologists and medical historians emphasised the social context which defined and created modern wheelchair devices. Research into polio survivors in 1950s America, for instance, highlighted a stigma around wheelchair use. A distinct cultural pressure around polio rehabilitation emphasised the return of patients to 'normal' and 'independent' lives (Williamson, 2019). In this context, walking was upheld as a key ideal by medical professionals, families, and society at large (Trembley, 1996; Williamson, 2019; Wilson, 2005; Wilson, 2009). In contrast, devices used in the rehabilitation of polio patients, such as wheelchairs, iron lungs and leg braces, were associated with confinement, dependency, and incapacity (Wilson, 2005; Wilson, 2009). Due to these cultural associations, many polio patients were initially apprehensive to use wheelchairs. Wilson (2005) provides examples of patients who felt shame or embarrassment around the use of wheelchair technology, detailing that wheelchair use represented some form of physical or spiritual 'surrender' (Wilson, 2009). Yet, Wilson (2005) and Trembley (1996) also highlight that these attitudes towards wheelchairs quickly dissipated as patients became used to the mobility and independence the devices offered in comparison to tiring or painful attempts at walking. This research shows that wheelchair adoption was heavily influenced by contemporary attitudes towards disability and technology.[4]

Moreover, scholars have investigated the development of wheelchair technologies following the Second World War, as technical change highlighted wider social and political discourse surrounding disability in western societies. Trembley (1996), for

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[4] This is also true of modern adoption of wheelchair devices, and the focus of rehabilitative programmes on walking (Sapey et al., 2005; Roulstone, 2016, pp.187-188).

instance, explored the Canadian government's distribution of E&J wheelchairs to spinally-injured veterans in 1945. These wheelchairs were offered to veterans as part of rehabilitation programmes to re-introduce injured veterans into civilian life. E&J were a wheelchair manufacturer founded by wheelchair user, Henry Jennings, and mechanical engineer, Herbert Everest (Trembley, 1996; Kamenetz, 1969). Frustrated with cumbersome wooden wheelchairs, they built lightweight wheelchairs made of aircraft tubing and established a small manufacturing company in California (Trembley, 1996). The company found success with their lightweight folding wheelchair models and subsequently, developed into a major international wheelchair manufacturer until the 1980s (Stewart and Watson, 2019).[5] Their chairs were light and manoeuvrable in comparison to other contemporary options made of wood or heavier metals, and the folding functionality allowed the wheelchair to be easily stored in a car during transit. These chairs emphasised new possibilities for active lifestyles, at home or in public (Williamson, 2019). Trembley (1996) highlighted that the technical benefits of the E&J wheelchair radically altered veteran's morale, opportunities for employment and independence, and integration into civilian communities. Eventually, E&J models were provided to veterans with other injuries and impairments, and for general hospital use. Trembley (1996, p.164) further suggests the proven benefits of the E&J model helped to redefine the wheelchair from an "invalid chair to transport patients to a method of independent transport." This history of wheelchair technology emphasises the material impact of functionality and design on end users.

2.2.2 – Socio-technical approaches to wheelchair history

Similarly, Woods and Watson (2004) investigate the site of wheelchair design in post-war Britain, employing sociological approaches to technological development. Their study utilised SCOT (defined in Chapter 3.1.2) to outline the range of actors involved in the

[5] E&J were not the first company to produce a device with folding functionality (Woods and Watson, 2004) but the most commercially successful and culturally influential.

development of Ministry-provided wheelchair models – namely the Model 8F wheelchair. By the 1950s, the British state had mobilised medical professionals as experts to address matters related to disabled people. This included the creation of government-provided wheelchairs, which transferred from the domain of the Ministry of Pensions to the Ministry of Health in 1953. Subsequently, wheelchair users were defined as patients and wheelchairs tools of medicine, the latter of which medical professionals had the power to define and shape (Woods and Watson, 2004, p.556). This scholarship emphasised how socio-medical assumptions about wheelchair users could manifest in wheelchair design. For instance, the Model 8F was criticised by users for being too heavy, which restricted self-propulsion and unaided storage inside an automobile. Moreover, the 8F featured solid rubber tyres, which were heavier than pneumatic tyres, but employed to eliminate the issue of keeping pneumatic tyres inflated. This issue, however, only affected less-active users, implying that the imagined wheelchair user would be home or institution bound (Woods and Watson, 2004). As the Ministry of Health sought to standardise their wheelchair models, wheelchair technology worked to define the user as immobile and dependent. Accordingly, the development of wheelchair technologies emerged as a site of political conflict and disability advocacy (Woods and Watson, 2004). Wheelchair users gave feedback on the Ministry designed models, citing specific grievances related to practical use, weight, and safety. Moreover, wheelchair users argued against the multitude of Ministry models (each of which had specific advantages and benefits in different circumstances) in favour of a lightweight, general-purpose, folding wheelchair, akin to the E&J model. Wheelchair users also mobilised into political groups, such as the Invalid Tricycle Association, which pressured the Ministry of Health to reconsider their choices around wheelchair design. Yet, the feedback of users was often dismissed in favour of the rationale of medical professionals. The development of the Model 8F thus represented wider struggles over the ideologies that defined disabled people and their place in society. Woods and Watson's (2004) article is significant in demonstrating a link between the history of technologies, including wheelchairs, and disability in social and political histories.

The market that made and distributed wheelchairs has also been investigated in scholarship. Brubaker (1986) disparages the contemporary trends for 'generic' wheelchair designs prescribed to patients, as these wheelchair designs remained static between the 1930s and 1980s. New developments were accepted slowly, and fearing product rejection, designers favoured simplicity and economical production, leading to standardised designs (Brubaker, 1986; Stewart and Watson, 2019). Brubaker (1986) argues that alternative designs, such as adjustable seats, would not only improve user experience and mental health, but limit the abandonment of prescribed devices. Similarly, Whitcombe-Shingler (2006) outlined the history of the wheelchair industry in twentieth century New Zealand, referencing the impact of policies concerning wheelchair prescription on local wheelchair businesses and welfare services. Vitally, scholarship has also connected trends in the wheelchair industry to the disability rights movement. Shapiro (1993) frames the development of ultralightweight wheelchair models with the success of Marilyn Hamilton's wheelchairs. Hamilton began to use a wheelchair following a hang-gliding accident in 1978. Seeking a better wheelchair for tennis, Hamilton and fellow hang-gliding pilots Don Helman and Jim Okamoto, created the *Quickie* (Hamilton, 2021). The *Quickie* was almost half the weight of the standardised chrome E&J wheelchair, featured a sleek, sporty design, and came in a range of colours. The three creators established a business, Motion Designs, which quickly grew into a $40-million-a-year company (Shapiro, 1993; Cooper et al, 2002). Shapiro (1993) attests the success of the *Quickie* to how it redefined the wheelchair into a colourful, fashionable, and sporty device, moving the device from the medical to the everyday, and making it a source of pride for users. Unlike E&J, Motion Designs was able to capture the growing generation of independent wheelchair users by marketing to them directly as consumers, as opposed to operating through medical and rehabilitative professionals (Shapiro, 1993). Subsequent scholarship has thus considered the development of medical and everyday wheelchair technology via the lens of the industry – who made, marketed, and sold wheelchairs – and re-approached wheelchair users not simply as operators of wheelchair devices, but as creators, consumers, and political actors.

2.2.3 – Academic histories of sport wheelchair technology

The most significant scholarship concerning the history of sport wheelchairs emerged from research into the development of ultralightweight, everyday wheelchair technology. This is referenced briefly in scholarship published by Brubaker (1986) and Roulstone (2016). Enthusiasm for wheelchair sport, particularly basketball and racing, developed amongst athletes in the United States and United Kingdom. By the 1960s, wheelchair athletes desired new wheelchair technologies which could enhance their athletic abilities (Stewart and Watson, 2019). Wheelchair manufacturers resisted users' feedback concerning sport functionality during wider market stagnation (Brubaker, 1986), which led users to take innovation into their own hands.

This topic is explored in detail in Stewart and Watson's (2019) article on the development of ultralightweight wheelchair technology. The authors highlight that modifications such as the removal of armrests or brakes were employed in wheelchair basketball to increase responsiveness and manoeuvrability. Most wheelchair athletes used the same wheelchair for sport and everyday life, and they found that sport alterations also benefited everyday use. Wheelchair users began to create more radical designs, which further benefitted sporting performance, and established manufacturing companies to make these new designs more accessible to other wheelchair users. In doing so, this article outlines the centrality of wheelchair users to the development of sport wheelchair technology, and sport wheelchair technology to modern, everyday wheelchair devices. Significantly, Stewart and Watson (2019) construct wheelchairs as 'boundary objects'. The boundary object expands on the interpretative flexibility of a technological object, invoked in Woods and Watson's (2004) employment of SCOT. This approach situates wheelchair devices as 'plastic enough' to adapt to the needs of groups, but 'robust enough' to maintain a common, shared identity across communities (Star and Griesemer, 1989). Wheelchair devices may encapsulate multiple interpretations of disability within a range of social and political contexts. To Stewart and Watson (2019), the development of sport wheelchair technology of the 1970s reflected resistance to medicalised attitudes towards disabled people and the hierarchies of power involved in technological work. In adapting wheelchair technology for sports and establishing their own companies to rival existing manufacturers, wheelchair athletes challenged historic patterns of exclusion.

Beyond Stewart and Watson's 2019 article, however, little sociological or historical academic research has been published on sport wheelchair technology. Largely, scholarship has acknowledged the impact of the sport wheelchair within the context of the ultralightweight wheelchair, as opposed to focusing on sport wheelchairs as technologies in and of themselves (Roulstone, 2016; Stewart and Watson, 2019). As discussed in Chapter 2.1.1, a small amount of technologically focused research exists within literature related to the Paralympic movement. In Bailey's (2008, p.28) history of the Paralympic movement, passing reference is made to the technological development of wheelchair technology, facilitated by athlete interaction and international sportsmanship. These technical factors are contextualised within the growth of the Paralympic movement between the 1960s and 1990s, where technological inequalities between nations eventually led to the involvement of the IPC in the production of sporting equipment in low-income countries and the creation of an International Wheelchair Exchange Fund (Bailey, 2008, p.28, p.78). In additional, Howe (2011; Howe and Silva, 2017), explores the cyborgification of Paralympians' bodies, and briefly mentions the advancement of racing wheelchair technology and replacement of wheelchairs in throwing events for throwing frames. The advancements of modern sport technologies afford devices to act as an extension of athletes' bodies, facilitating improved performance, and in the case of turning compensators in racing wheelchairs, allowing athletes to 'forget' about turning their chairs during corners (Howe, 2011). Howe and Silva (2017) also reference the collaboration of elite wheelchair athlete and manufacturers to create high-performance devices, which improve athletic performance and advance the Paralympic movement as a whole. Nevertheless, such references to the development of wheelchair technology are relatively minor across this scholarship.

2.2.4 – Non-academic histories of sport wheelchair technology

Outside of academic research, historical accounts concerning the development of sport wheelchair technology can be found in publications created by members of the wheelchair sport community. There are a small number of books and magazine articles written by wheelchair users or related individuals which document the history of wheelchair sports. The specialist wheelchair sport magazine *SPORTS 'n' SPOKES* was highlighted within interviews conducted in this research as a way for wheelchair athletes to share interest in their sport across the United States and the world. Published by the Paralysed Veterans of America (PVA), many articles were written by wheelchair users, and from the publication's origin in 1975 to 2007, editorial for the magazine was controlled by wheelchair user Cliff Crase (Crase, 2015). Articles from this publication are significant sources of factual information, and athletes' experiences and perspectives. A notable example is a three-part magazine article about the development of basketball and racing wheelchairs in the US between 1949 and 1983, published in *SPORTS 'n' SPOKES* between March and August 1984 (LaMere and Labanowich, 1984). The authors of the article drew on their direct experiences of the development of wheelchair sport. Labanowich was deeply involved with the development of wheelchair basketball in the United States in the mid-twentieth century and among other duties, served on several International Wheelchair Basketball Technical Committees between the 1970s and 1980s. Throughout these articles, technical changes are framed as the work of athletes, with reference to specific modifications made by individuals or teams. Other articles within *SPORTS 'n' SPOKES* have contributed to this history. For instance, these articles have outlined the history of specific sport wheelchair technologies (Best, 2021), provided information on significant wheelchair manufacturers and their history (Cooper et al, 2002; Hamilton, 2008), or showcased the perspective of lead users who were themselves involved in the technical evolution of sport wheelchairs equipment (Ball, 2000; Ball, 2005; Cooper, 2007; Hamilton, 2008).

Equally, non-academic books have detailed aspects of wheelchair design history. Labanowich, for instance, published a revised version of his basketball wheelchair history articles previously published in *SPORTS 'n' SPOKES* as a chapter of a book about the development of wheelchair basketball in the United States (Labanowich and Thiboutot, 2011). In this context, the history of basketball wheelchairs adds to the wider historical narrative of wheelchair basketball. Analogous to wheelchair technology, athletes shaped the organisation and administration of the sport and introduced their own classification rules (Labanowich and Thiboutot, 2011; Stewart and Watson, 2019; Yilla, 2004). Similarly, the Lawn Tennis Association commissioned a book about the history of wheelchair tennis in 2001 (Bunting, 2001). This included, amongst other things, minor details about the development of tennis wheelchairs, initially led by notable athletes Brad Parks, Randy Snow, and Jeff Minnebraker. Therefore, literature concerning the history of sport wheelchair technology has been published by and for this community of athletes and sports professionals.

It should be noted there is a large body of academic literature concerning sport wheelchair technology within the fields of sports science and medicine, and biomechanics. These publications are significant in their focus on sport wheelchairs as distinct sporting technologies.[6] Yet, this scientific literature has not been explored in detail for this project, as this literature is large published by non-disabled academics and generally lacks the social and historical context this research is concerned with. An exception to this is the early work of Dr Rory Cooper, a bioengineer and mechanical

[6] Fuss and Subic (2013), for instance, detail the impetus behind certain design elements, such as the shape and material of the wheelchair frame, the positioning and height of the seat and backrest, and the types of wheels and tyres that can be used in much detail. After, they detail the scientific forces that impact the use of racing and ball-sport wheelchairs, calculating the rates of acceleration and locating sources of energy loss. Similarly, Vanlandewijck has published or contributed to a range of scholarship, which explore topics such as the biomechanical factors which affect hand-rim propulsion (Vanlandewijck et al, 2012) and how seat positioning affects acceleration (Vanlandewijck et al, 2011). This type of research is critical, as it documents the technical and mechanic operations of sports wheelchairs, alongside the scientific forces at play and ergonomic positioning of users.

engineer who works with a variety of wheelchair technologies. His 1990 review of wheelchair racing sports science, for instance, briefly contextualises the principles of racing technology and science with the development of wheelchair racing and the design of racing wheelchairs. The narrative outlined by Cooper draws on his own experiences as an athlete and wheelchair engineer, which is referred to in more detail across chapters 5, 6 and 7. This type of narrative is seemingly unique within scientific literature on wheelchair technology. Nevertheless, it is possible this literature could be examined within a historic framework, as the origins of such research by the mid-1980s highlight a change in attitudes towards sport wheelchair technology. By this time, sport wheelchairs, particularly racing wheelchairs, were perceived as sports devices distinct from medical or everyday wheelchairs.

2.2.5 – Conclusion

In recent years, historical research concerning wheelchair technology has emphasised the wider economic, social, and cultural factors which influenced technical change. Study of sport wheelchairs, in turn, has emerged as a new site of research in academic literature. Non-academic sources help to foreground the historical context in which sports equipment emerged and changed, whilst preserving athletes' perspectives on this narrative. This research aims to expand on recent academic research by focusing specifically on the sport wheelchair, whilst drawing on athletes' testimony and publications directly.

2.3 – Chapter conclusion

This chapter outlined the historiographic context in which this research is based. The exploration of technologies used by disabled people and athletes highlights several important topics, themes, and perspectives that hold significance in the narrative of sport wheelchair technology. Sport historians, for instance, highlight the impact of equipment on the development of sport and the role that athletes play in creating new technologies and their associated industries. Likewise, disability historians showcase the political agency expressed by disabled people in the modification and creation of artefacts as a result of the exclusion of disabled people from sites of design and innovation. These actors seek to advocate for the interests of themselves and their community through the acts of design, tinkering and creation. In the context of wheelchair devices, existing scholarship has begun to explore the role of users in technological design, but further exploration of the work of wheelchair athletes is necessary due to the importance of user autonomy, expertise, and self-determination over sport.

In the next chapter, I will engage more closely with sociological debates to consider user-agency, societal and political contexts, and the relationships between humans and non-human artefacts. This will be achieved through a closer reading of theories and approaches from STS. This will include theories highlighted in this chapter, such as SCOT and boundary objects, which consider how human actors and technological actants interact. STS theories have been used by scholars researching disability artefacts (Woods and Watson, 2004; Mills, 2012; Stewart and Watson, 2019) to contextualise technical development within a socio-political context. I will build on these approaches to demonstrate the user-orientated theoretical frameworks used in this thesis.

Chapter 3 – Literature review: Science and Technology Studies

Existing literature about the history of wheelchair technology, alongside other examples of sport and disability-related equipment, has emphasised the importance of the end user. In the history of sport and everyday wheelchair technologies, the user has played a pivotal role in re-defining and re-designing wheelchair devices for new purposes. In line with the aims of this study, this research turns to the analytic frameworks introduced in the field of STS. This chapter explores how STS approaches may conceptualise and analyse the role of users, explore the context in which these changes took place, and outline the evolution of technological artefacts. The use of STS theories draws on prior research into wheelchair technology, which employed these frameworks to explore the plasticity of wheelchair devices (Stewart and Watson, 2019) and the differing interpretations of wheelchair devices by disabled and non-disabled groups (Woods and Watson, 2004). This chapter draws from these examples in a wider investigation of sport wheelchair technology.

This chapter is split into three sections. The first subchapter focuses on the end user, exploring the 'turn to the user' in STS. This section explores SCOT and contextualising its' emergence before drawing on feminist STS to better consider disabled people. The next subchapter considers the concepts of flexibility and stabilisation introduced by SCOT, which detail the process of evolution that artefacts undergo. Within these sections, related STS concepts and approaches are detailed, such as the boundary object or the psychological concept of affordances. The final subchapter examines the socio-political context of design, exploring the relationship between user and designer, and how designers imbue artefacts with meaning. In line with Chapter 2, the final section of this chapter explores the user as an expert of a socio-technical artefact, which has wide social and political consequences on marginalised groups in the history of technology.

3.1 – 'Turn to the User'

Historical and sociological research into the development of technological artefacts initially privileged the perspectives of individual inventors, divorced from wider cultural, social, or political context. In the last decades of the twentieth and the first decade of the twenty-first century, STS scholarship shifted focus to the environments in which artefacts were used. As detailed by feminist STS scholars and later proponents of SCOT, users hold significant influence over an artefact's technical development and social meaning. This 'turn to the user' (Oudshoorn and Pinch, 2003) marks the user as a key subject of investigation. Significantly, focus on the user provides opportunities to locate marginalised groups who would otherwise be excluded from traditional environments of design, engineering, and manufacturing. In context of disabled people's involvement in tinkering and modification (Williamson, 2019; Hamraie, 2017), focus on the user is vital when considering disability-related artefacts.

This subchapter begins by considering origins of STS and the emergence of social-shaping approaches such as SCOT. However, critiques of SCOT necessitate an exploration of users within feminist STS scholarship and how this approach may be used for the study of disabled people in the history of technology. The final section re-considers SCOT as a user-focused STS theory that can be utilised within this research.

3.1.1 – STS and the Social Construction of Technology

Key to STS is the relationship between technology and society. Technological determinism is the generalisation that technologies evolve based on a pre-determined trajectory (MacKenise and Wajcman, 1999). This view suggested that a technological artefact or system had direct and observable impact on societal change, and was taught by scientists and engineers in the 1950s and 1960s to demonstrate the impact of their achievements (Bijker, 2001; Cutcliffe, 2002). Consequently, the nature of societal change is reduced to that of technological evolution, whilst also dismissing the impact of social, cultural, political, or economic factors on the development of technological artefacts and systems

(MacKenise and Wajcman, 1999; Bijker, 2001). In the 1970s and 1980s, scholars began to reject technological determinism, exploring how political ideology, structures, and economics shaped the design and implementation of technological artefacts and systems (Hughes, 1983; Winner; 1980). This new generation of scholarship explored the role of society and human actors played in shaping the use and meaning of technologies (MacKenise and Wajcman, 1985; Hamraie, 2017). Cutliffe (2002, p.286) writes that this scholarship was more critical and anti-establishment in tone, triggered by wider acknowledgements of the possible negative impact of technology and science on the environment and workplace. Interest grew in reflexive analysis which considered how and why science and technologies emerged.

New theories contended that the creation and design of technological artefacts was socially determined and influenced by a range of human factors (Rohracher, 2015). This was the driving concept behind Pinch and Bijker's (1984) social constructivist approach to technological development. Within SCOT, technological change occurs as artefacts possess interpretative flexibility. Human actors may have different understandings of an artefact and its technological characteristics, and may be organised into social groups based on these interpretations (MacKenise and Wajcman, 1999). SCOT may be used to understand the symbolic meaning of an object and whether the object 'works' for a relevant group of actors. If actors within a relevant social group identify problems with an artefact, such as not meeting a certain desired function or meaning, the artefact may undergo technological change until said problems have been addressed.

Pinch and Bijker drew on sociological approaches to scientific knowledge, influenced by the 'strong programme'. Bloor (1973) proposed that the study of scientific developments required consideration of social, psychological, and material processes, as opposed to the sole consideration of human rationality (MacKenise and Wajcman, 1999). This also included a symmetry of explanation, which considered successful and unsuccessful knowledge claims. Pinch and Bijker used this principle in SCOT to consider successful and unsuccessful artefacts equally, determined by how much they 'work' – if they were accepted by a relevant social group. As well, Pinch and Bijker were influenced by Kuhn's concept of scientific paradigms (1962; 1970), which suggested that shifts in scientific theorems were based on the culture, values, and methodological practices set by groups of scientists (Bird, 2000). Within SCOT, artefacts are shaped by the wider context in which a device is conceptualised and made, and consolidated by human interpretation and adoption.

To exemplify their theory, Pinch and Bijker (1984) drew on the evolution of bicycle technology in the late nineteenth century. High-wheel bicycles such as the penny-farthing, were seen as ‘high-speed thrill machines’ by young male users and were primarily used as sporting or racing machines. Women and the elderly saw the bicycle as dangerous, or found value in its application as a mode of transport or leisure. Throughout the paper, a range of bicycle designs are showcased, some which succeeded – for example, the evolution of the boneshaker into the penny-farthing and the safety bicycle - and some which ultimately failed (Pinch and Bijker, 1984; p.413). This approach allows scholars to consider technological evolution non-linearly, exploring why new technologies are or are not adopted, or why they change, by analysing the wider context that informed the object’s use or meaning.

SCOT brought the social into the study of the technological. However, its critics argued that the original theory did not accurately account for power structures that may impact the visibility of certain actors or groups. According to Bijker (1995, p.46), social groups that are relevant to a technology may be identified by considering those who are “mentioned in relation to that artefact in historical documents.” This definition and rational necessarily excludes those groups where there is little evidence of interaction with an artefact, and privileges those with the resources and status to have influence over a technology. Following this critique, Winner (1993) questions whether social groups who are deliberately excluded and suppressed, but are affected by an artefact’s implementation, are consistently considered a ‘relevant’ social group by researchers utilising SCOT. This point is joined by others which question the researcher’s subjectivity in identifying which groups of actors are ‘relevant’ to a technology (Rosen, 1993; Clayton, 2002). In the case of disability studies, Winner’s objection speaks to the invisibility of certain groups of actors as a result of wider social, cultural, or historical discriminatory forces. Indeed, Bartis (2007) later argues that relevant social groups with more organisational power dominate how historical narratives are interpreted by later scholarship and researchers (Bartis and Mitev, 2007). Consequently, scholars who employ SCOT may need to make consideration of the social, political, and historical circumstances of the artefacts they investigate to capture the perspectives of marginalised groups who are impacted by artefacts but may otherwise be invisible within the history of technology. In order to utilise SCOT to consider disabled groups within the history of technology, this research looks to feminist STS to consider issues of power and marginalisation within the history of technology.

3.1.2 – Feminist STS

Intending to locate women within the history of technology, feminist scholars had to look beyond traditional spaces of design and manufacturing, as these became male-dominated environments (Mackay et al., 2000, p.744; Wajcman, 1991) or were represented in scholarship as genderless (Oudshoorn and Pinch, 2003). Accordingly, analysis of the user of technological artefacts was found to be a potent way to render women visible within the history of technology. Feminist scholars expanded analysis of artefacts into the environment of their operation, as opposed to focusing on the spaces in which they were designed and manufactured (Wajcman, 1991). Significant literature in this area was produced by Cowan (1985), who explored domestic technologies and framed the adoption of such artefacts via the lens of the consumer. Cowan later defined this as the 'consumption junction', where the consumer makes a choice between technical artefacts (Cowan, 1987; Oudshoorn and Pinch, 2003, p.4). By placing the user at the centre of analysis, Cowan argues researchers could use consumer habits to understand the adoption/success or rejection/failure of artefacts in new ways (Oudshoorn and Pinch, 2003, p.5; Cowan, 1987). Consequently, the user is situated within a specific economic and socio-political context, which can be explored alongside the functionality and design of the artefact.

This ‘turn to the user’ broadened how technological artefacts were analysed and promoted users as a significant group to researchers. Significantly, the work of feminist historians shifted perceptions of women within the history of technology from passive to active participants (Oudshoorn and Pinch, 2003). This is noteworthy for women and other marginalised groups who have often been excluded from traditional spaces of design and innovation, due to masculine, racial, classist, or ableist associations of knowledge and expertise (Wajcman, 2010). Much of this thought is rooted in the Marxist critiques of technological determinism and feminist analysis of the division of labour, which constructed technology as a source of male power (Wajcman, 1991; Cockburn, 1985, in Wajcman, 2010). Feminist scholarship further connected technology to gendered analysis of capitalism and militarism, to examine the role of technology in creating and reinforcing gendered perceptions societal constructs (Wajcman, 2010; Baron and Gomez, 2016; Haraway, 2016; Hamraie and Fritsch, 2019). Disability-focused approaches to the history of technology have subsequently drawn inspiration from the feminist tradition. Hamraie and Fritsch (2019), for instance, point out that disability studies and feminist STS share their turn to situated epistemologies and critiques of biomedicine and militarism. Haraway (2016), similarly, reinforces the non-innocence of technology in her concept of the cyborg.

The cyborg is introduced into posthuman feminist theory to deconstruct rigid boundaries between the categories of human, animal, and technology. In the deconstruction of these binaries and the impact of hybridity on identity, Haraway (2016) rejects a naïve view of technology that separates an artefact from its socio-political relations or origins. As the concept of the cyborg became popularised in academic literature and popular culture, it has been used to represent the relationship between disabled bodies and technological artefacts. Disabled bodies can represent a hybrid organism, which is a fusion of live organism and man-made technology, building on cyborg theory’s deconstruction of binaries between human and technology (Haraway, 1991; Silva and Howe, 2017). Indeed, Haraway (2016) suggests that disabled people experience the most complex form of hybridisation, due to the relationship between disabled people and mobility, assistive or medical technologies. The metaphor of the cyborg has become a common way to perceive the connection between disabled people and technology, particular elite athletes (see Chapter 2.1). The concept of the cyborg can be employed to deconstruct essentialist perceptions of the body – breaking down the divide between human and machine, or indeed, ability and disability (Kafer, 2013). However, the use of language surrounding disability and cyborg theory may be problematic. For instance, Kafer (2013) argues that Haraway relies on a medicalised perception of the disabled body and does not acknowledge the embodied experiences of impairment, or differences in how individuals use technology, when conceptualising disabled people. Accordingly, the 'turn to the user' must consider the lived experiences of disabled people and the ways in which they materially and semiotically interact with technological artefacts.

3.1.3 – SCOT, the user, and disability

Following critiques that SCOT could not account for inequalities in structural power, scholars began to 'turn to the user'. This trend drew on feminist STS scholarship, refocusing on the environment of the artefact's operation. This application of SCOT highlights the unintended meanings and uses of artefacts, which can emerge when divorced from the perception of the original creator. Telephones, for instance, were initially created for formal communication and use in business (Hutchby, 2001; Hsu, 2008). However, female users of the telephone used the device for informal conversation, whilst rural users could 'eavesdrop' on ongoing conversations, creating a culture of communal gossiping. Whilst producers were, at first, resistant to these applications, particularly as eavesdropping wore out batteries and occupied telephone lines, they later produced new technologies to fit these social patterns (Fischer, 1992; Martin, 1991; Kline, 2003). Similarly, Kline and Pinch's (1996) study of rural automobile use highlighted the importance of users in shaping technologies. Rural automobile owners began to use these artefacts to power agricultural and domestic devices, imbuing the artefact with new purpose – a source of power – alongside its original purpose as a means of transportation. Subsequently, this shaped future automobile designs, which limited users' abilities to use them as sources of stationary power, whilst also leading to the creation of new agricultural technologies, stand-alone gasoline engines, and automobile accessories for this new consumer. Kline and Pinch (1996) thus marked users as 'agents of sociotechnical change' within SCOT, as the unexpected reinterpretation and actions of users had significant ramifications on the evolution of technological artefacts.

A user-focus renders disabled people more visible within the history of technology, akin to the visibility of women in technology studies pioneered by Cowan (1987) and other feminist STS scholars. As disabled people have been excluded from traditional roles of design and manufacturing (Hamraie, 2017), studies of material objects provide one way for research to capture these narratives. Historical and sociological explorations of technologies used by disabled people have emphasised the important role played by the user of an artefact or socio-technical system. Woods and Watson (2004) employed SCOT to explore the connections of different relevant social groups, such as medical professionals, governmental institutions, and wheelchair users, to wheelchair devices. In doing so, the authors were able to highlight the different perceptions of wheelchair technology and wheelchair users which impacted the artefact's design. Medical professionals held more authority and power, allowing their wheelchair designs to supersede disabled people's feedback, regardless of the impact on wheelchair function and actual use. By focusing upon wheelchair users as key agents within this history, scholarship is able to reveal significant narratives of inequality, whilst simultaneously placing a spotlight on disabled people rendered invisible by the historical record. Indeed, disabled people tinker and modify devices (Stewart and Watson, 2019) or create their own equipment (Williamson, 2019) to better suit their lived experience (Hamraie and Fritsch, 2019). This suggests that disabled people's perspectives, as users, provides significant insight into the social and political context and meaning of technological artefacts.

A focus on disabled actors within SCOT may also call for tweaks to the way SCOT is formulated. As will be shown in Chapters 6 and 7, the majority of significant advancements in sport and lightweight wheelchair technology originated with wheelchair users who faced a range of cultural, economic, and administrative barriers in asserting their interpretation of wheelchair sport (Stewart and Watson, 2019). Wheelchair users are therefore more than a 'relevant' social group, and may be identified by Orlikowski and Gash's (1993) concept of a 'critical social group', which identifies key social groups in the process of social and technical change. This may help researchers specify the influence and role of different social groups and provide the researcher space in which to explore the structural inequalities between social groups.

3.1.4 – Conclusion

The 'turn to the user' presented the opportunity for STS scholars to identify marginalised actors within the history of technology and identify the social and political contexts in which technologies were adopted, rejected, or reinterpreted. This research draws on SCOT to highlight the non-linear development of artefacts' meaning, function, and purpose. Reacting to structural critiques of SCOT, feminist STS scholarship and later user-focused SCOT literatures is used to privilege the user within the history of wheelchair technology. Based on the interpretations held by users and other relevant social groups, the flexibility and stabilisation of a technological artefact can be considered. The next chapter explores these aspects of technological change within STS.

3.2 – Perception, interaction, and transformation

Disabled people's re-contextualisation of tools and objects reinforce the mutability of technical artefacts. Re-interpretation, modification and tinkering highlight ways in which users of technologies reclaim and deconstruct artefacts for new purposes. Acts of tinkering can be read as political action, as disabled people enable access, assert their own world view, and reject hegemonic ideas of disability and impairment. Simultaneously, some artefacts used by disabled people retain certain material or social qualities over time, despite a change in use, design, or function. STS scholars have considered processes of flexibility and stabilisation to capture the ways in which technological artefacts change and retain form and meaning. This concept is a key part of SCOT and the conceptualisation of users as 'agents of sociotechnical change' (Kline and Pinch, 1996). Scholarship in this area explores how users and other actors perceive and interact with devices and how these perceptions are influenced by material, psychological, and social factors.

This subchapter explores processes of change by considering how actors perceive and interact with artefacts. Different STS approaches to these processes are explored, centring around the flexibility and stabilisation of artefacts highlighted within SCOT. The first section explores technological frames, that describe how individuals and groups psychologically conceptualise objects. Affordances are outlined in the second section, expanding on the concept of interpretative flexibility introduced in SCOT. The third section details processes of closure and stabilisation in SCOT, marking when the form and meaning of an artefact becomes rigid. The final section considers the concept of the boundary object as a way to conceptualise the simultaneous meaning an artefact may have for different groups.

3.2.1 – Technological frames

Interpretative flexibility is a key concept within SCOT. Different groups of actors (relevant social groups) are able to shape the functionality of artefacts and their future iterations, as different groups of actors will interpret and use devices in distinct ways. Since the original invocation of interpretive flexibility in Pinch and Bijker's original 1984 article theorising SCOT, the concept has been refined to highlight the social and psychological processes at play. In 1993, Bijker introduced the concept of the technological frame. This refers to the worldview held by an actor, or group of actors, which dictates how they will interpret and interact with an artefact. The technological frame is a collective term for the corpus of elements which shape human-artefact interaction. Bijker (1993) references several constituent elements which form these frames, such as the goals or purpose of the technology, key problems with the technology, and existing tacit or theoretical knowledge. The concept of frames draws on Kuhn's (1970, quoted from Bijker, 1995) concept of a disciplinary matrix – a type of scientific paradigm which provides the methodological and theoretical framework from which scientists conduct research.

Similarly, the technological frame is the reference from which interactions between relevant social groups and artefacts are structured.

The technological frame held by wheelchair users will, accordingly, be formed of several elements, such as their existing perception of wheelchair devices, their own physical abilities, or how others around them interact with the technology. Yet, technological frames are not static, allowing for new interpretations of technological artefacts to develop. Lin and Silva (2005) demonstrated that within organisations, differing groups of actors with distinct technological frames can co-operate or be convinced to change their perception of an artefact. SCOT scholarship has recognised this possibility by the power of advertising and marketing in changing the perceptions of consumers (Rosen, 1993). In these cases, the artefact has been reframed in some way by another group, which either solves or changes the nature of a social group's problems with the artefact. Simultaneously, individuals can exist within a multitude of technological frames. An individual may be part of multiple social groups – for instance, a female bicycle rider may be considered part of the social group of bicycle users/riders and the social group of women. These two social groups will also have their own technological frames associated with that artefact, due to their material reality. As such, the female bicycle rider may draw on either technological frame, or draw on both simultaneously, when interacting with an artefact (Bijker, 2010).

The concept of the technological frame draws on similar developments within social cognitive research. The technological frame is an extension of shared cognitive structures, which can be referred to as frames, mental models, cognitive maps, scripts, or paradigms (Orlikowski and Gash, 1993, pp.1-2). These are employed to conceptualise how individuals understand and interpret their environment, organisations, or relationships, which then guides their actions (Berger and Luckmann, 1967, found in Davidson, 2006). Moreover, this cognitive frame will define how users perceive the ease of operation and usefulness of an artefact (Lin and Silva, 2005). Orlikowski and Gash (1993) extend this concept to technical artefacts, focusing on information technologies within hierarchical organisations. They suggest that organisations contain a range of technological frames which are often incongruent. This is because the social frame of the worker will be different to that of the stakeholder, which will necessarily impact how they view and operate the technology used within the organisation (Lin and Silva, 2005). This principle of incongruence may be extrapolated to consider other forms of hierarchy. The social, political, economic, and experiential differences between disabled people and medical practitioners or technologists, for instance, will invariably lead to the creation of different technological frames. The differences between these frames may be based on various factors, such as political power, social hierarchy, and bodily experience of impairment. Technological frames held by disabled people will thus differ from non-disabled people and afford alternative interpretations of technological artefacts.

3.2.2 – Affordances

The concept of affordances can be similarly employed to understand the process of interpretative flexibility by considering the material qualities of the artefact. Affordances originated in psychology, used to highlight the interaction between animal or insect and environment. Gibson (1979) suggested that the environment affords for certain interactions in relation to the physical qualities of animals. Water, for example, affords for lightweight insects to run upon its surface. However, it does not afford the same for heavier insects or animals (Gibson, 1979, in Schulz-Schaeffer, 2021). The material qualities of an object afford a constrained number of possible actions to an actor (Hsu, 2008). Using Pinch and Bijker's (1984) example of the bicycle, the material qualities of the penny-farthing afforded its initial use as a sports device. These qualities also afforded uses outside of sport, such as leisure and transportation. Those with different physical or social relations to a technology may perceive the objective qualities of an artefact in different ways, leading to unintended uses. However, function or intended use of an artefact may not be intrinsically self-evident. Affordances and interpretations are shaped by historic, legal, economic, political, and socio-cultural forces. David and Pinch (2006, p.25) use the example of book reviews, stating that social conventions can limit possible actions: "The physical limitation on the affordance of a book review does not constrain its length (physically we could write book reviews that were the length of novels) but the social limitation does constrain length." How an actor perceives the affordances of an artefact can thus be understood as a combination of the material and social – the design and functionality of an artefact and how that design or functionality interacts with the identity and social status of its user.

Dokumaci (2023) engages with the concept of affordances within ecological psychology to explore how disabled people interact with their environment. She proposes the idea of activist affordances, arguing that disabled people engage in processes of 'world making' to enable access. Dokumaci presents this as a type of performance, as disabled people 'make up' and 'make up for' affordances which do not materialise in the existing environment (2023, p.104). Here, Dokumaci engages with Hamraie and Fritsch's (2019) concept of Crip Technoscience, which similarly centres disabled people in the process of world-making, due to their labour as 'knowers and makers' of technologies (Hamraie and Fritsch, 2019; Dokumaci, 2023). Dokumaci, however, asserts that her concept of activist affordances pushes beyond the artefact-focused nature of technoscience (2023, p.105), as embodied performance itself affords disabled people to inhabit inaccessible environments. Nevertheless, the concept of activist affordances remains useful in the consideration of artefacts adapted, made, or redefined by disabled people. The psychological process underpinning this concept reinforces that disabled people identify new ways in which to interact with, or conceptualise, their environment or contexts for their own access and purposes. For wheelchair users, the design and function of wheelchair devices are part of these affordances.

3.2.3 – Closure and stabilisation

The interpretative flexibility of an object in SCOT was originally conceptualised as a temporary state, opened when relevant social groups were able to identify problems with existing artefacts and their intended purposes. The identification of different problems may arise in multiple avenues for technological development, creating a multi-directional approach for scholars to map out. Identification of these different strands emphasises how technological development is not linear but the result of a range of social and technological factors (Pinch and Bijker, 1984). As relevant social groups' problems are solved (or are perceived to be solved), interpretative flexibility undergoes a process of closure. At the point of closure, the artefact can be said to be stabilised. A stable artefact is no longer subject to further innovation, and this form of the technology subsequently becomes prototypical to that object's conceptualisation.

Later revisions to SCOT established that closure and stabilisation are not fixed processes, as new problems may be identified with stable technologies (Kline and Pinch, 1996). Rosen (1993), for instance, demonstrated that the closure of the mountain bike did not lead to stabilisation, but rather provided opportunity for further reinterpretation, as the design of mountain bikes was under constant revision as the needs of athletes and other users changed. Moreover, variations of the device became increasingly specialised, with a range of different mountain bike varieties developed for a range of use cases. This is a key concept in the development of sport wheelchair technology, as later chapters will show that as modifications and designs for sporting activities were introduced, athletes continued to iterate and create specialised devices for specific wheelchair sports. In both cases, users reinterpreted otherwise stable devices to better serve their performance needs. Nevertheless, the processes of closure and stabilisation necessarily require the artefact to maintain some form of material or ideological coherence to maintain the broad categorisation of the artefact.

Pinch and Bijker (1984) suggest some form of consensus is needed within and between relevant social groups to trigger stabilisation. Stabilisation does not begin at a set point but is a gradual process, in which technological stability may be more 'strong' or 'weak'. Humphreys (2005) expands on Pinch and Bijker's (1984) original language of 'degrees of stabilisation', proposing a structural analysis of the concept, which allows researchers to specify which aspect of a technology is under scrutiny, by relevant social groups. Humphreys (2005) outlines three distinct phases of flexibility which can be investigated in more detail to understand processes of closure and stabilisation. The first level, flexibility of language, refers to interpretative flexibility. This occurs when different social groups conceptualise technologies and their meanings in different ways. The second level is flexibility of use. Citing MacKay and Gillespie (1992), this refers to the different purposes users can have for artefacts. This is based on how ‘open’ or ‘closed’ an artefact is to reinterpretation and is heavily related to the flexibility of language.

Flexibility of structure, the third level of flexibility, refers to the classifications in which objects can be cognitively ordered. Drawing on Rosch (1976, cited in Humphreys, 2005), these can be conceptualised as hierarchical categories. Each level implies some categorisation of purpose, use, or functionality, and becomes increasingly specific downwards through the hierarchy.

- Objects can first be organised on the superordinate level, which is a broad and abstract category, such as ‘vehicle’ or ‘building’.
- The basic level of organisation follows, which is more commonly used to refer to types of objects, such as ‘car’ or ‘house’.
- Under this is the subordinate level, which is the most specific, such as a ‘sports car’ or ‘semi-detached house’.

Structural flexibility can only occur at the basic or subordinate levels, as innovation cannot be so extreme as to change the abstract categorisation of a range of technologies. Using the example of a car, changes at the basic level can create new subordinate categories, including family cars, off-road cars, or race cars. Changes can occur at the basic level whilst the structure of the subordinate level are still in flux. Importantly, changes at the subordinate level cannot change the basic level, as Humphreys (2005) suggests that the creation of the convertible car did not change how people conceptualised the wider idea of a car. This extension can help to conceptualise the cyclical process of innovation by specifying where in the structural hierarchy, technologies are reinterpreted in the cognition of actors.

In this structural categorisation, however, the type of reinterpretation undertaken by disabled people in the process of tinkering may be difficult to identify. Many instances of modification alter the object’s use case significantly. In the example of wheelchair technology, the reinterpretation of wheelchairs by athletes transferred these objects from the basic level of 'rehabilitation device' or 'mobility aid' to 'sports equipment'. This change was gradual, occurring over time, as modified or lightweight wheelchairs existed in both categories of sport and everyday mobility. Moreover, this classification is highly contextual to the individual, in the case of disability objects. Wheelchair users who were more athletic or active would be more likely to conceptualise their wheelchair as a piece of sports equipment, alongside its classification as an everyday mobility device. Other users may have classed it as both, particularly early into the history of modifications for sport. Alternatively, this may be a temporal issue, as modern wheelchair devices are more distinct in their design and intended use and could be strictly categorised in the basic and subordinate levels. Ambiguity may therefore still exist in this process of categorisation and stabilisation, as the use of objects by disabled people (and other actors) are not necessarily this rigid. Nevertheless, this type of stabilisation can be recognised on the subordinate level once sport wheelchair devices became increasingly specialised for different sports and performance criteria (see Chapter 6.3).

3.2.4 – Boundary objects

An alternative approach to both interpretative flexibility and stabilisation can be found in Star and Griesemer's (1989) suggestion of the boundary object. Boundary objects refer to artefacts which are simultaneously flexible enough to afford multiple interpretations across different communities but stable enough to display immutable content which constructs a common identity or structure across different social contexts (Star, 1989; Carlile, 2002). The concept of the boundary object emerged from social world theory and symbolic interactionism – unlike STS approaches such as SCOT, which emerged from social constructivism. Symbolic interactionism posits that on the micro scale, meaning arises from the social interactions between people (Blumer, 1969). The meaning of objects arises from how different people act towards one another in regard to the non-person entity (Blumer, 1969). However, these meanings must also be interpretated via social context and interaction, giving rise to social worlds – collective interpretations based on shared understanding, interests, or institutional settings (Demerath, 2005).

Star and Griesmer (1989) originally introduced the boundary object to outline practices of standardisation within scientific institutions, focusing on the transition of knowledge between different social groups within the Museum of Vertebrate Zoology at the University of California, Berkeley. How scientists and technologists cooperate without agreeing on universal categorisations or standardisations led to an ecological epistemology (Bowker and Star, 1999). Scientific and technological knowledge is collective, constructed across a range of groups who possess their own objectives, approaches, and expertise (Stewart and Watson, 2019). Boundary objects arise at the point of communication and translation, when the differing interpretations of artefacts are communicated across groups (Bowker and Star, 1999). Divergent interpretations result in frictions which may either lead to conflict or cooperation between communities. Taking this principle to the development of socio-technical artefacts, the concept of boundary objects suggests that flexibility and stabilisation are not rigid stages but interconnected, continuous processes which occur at differing points in line with the needs of social groups.

The boundary object may be useful in framing acts of tinkering and reinterpretation enacted by disabled people. Boundary objects are created based on the conflicting interpretations created by 'communities of practice', groups who form not on organisational or institutional grounds, but on how they 'do things' (Bowker and Star, 1999, p.294). Actors become familiar, or naturalised, with these practices over time and became closed to other practices, necessitating the boundary object to translate concepts between groups. In their history of ultralightweight wheelchair technology, Stewart and Watson (2019) argue that the wheelchair was a boundary object, as wheelchair users and medical practitioners asserted their own interpretations of these artefacts. For medical practitioners, existing conceptualisations of disability and impairment became naturalised into their 'community of practice', and manifested within their interpretation of wheelchair technology. Users, however, engaged with the field of sport to challenge these naturalised classifications, modifying wheelchair devices for athletic purposes, and implementing useful modifications in everyday use (Stewart and Watson, 2019). In analysing 'communities of practice', scholars are able to use the boundary object to situate clashes of interpretation within wider social, political, and cultural contexts. Gal et al. (2008) similarly suggest that the boundary object can be used as a resource to form and express social identity. This aligns with other scholarship which interprets the reinterpretation of technologies by disabled people as part of wider socio-political activism (Hamarie, 2017; Hamraie and Fritsch, 2019; Dokumaci, 2023).

3.2.5 – Conclusion

This subchapter has highlighted different ways in which STS scholarship has defined technological reinterpretation and transformation. Technological frames and the psychological concept of affordance outline how actors may perceive and interact with artefacts and how this shapes the reinterpretation of these artefacts' function and design. Concepts of closure and stabilisation introduced in SCOT advance this process, conceptualising when an interpretation of an object materialises and new designs become static. Boundary objects, on the other hand, show that artefacts may be technologically stable and still open to different interpretations by multiple groups. In the exploration of wheelchair technology, these processes frame how wheelchair users reinterpreted and re-designed wheelchair devices for new purposes.

3.3 – User-designer relations

By tinkering with technologies, disabled people reinforce the interpretative flexibility of artefacts. By 'turning to the user', STS scholars are able to explore how disabled people's interpretations of artefacts impacted the development of technologies such as wheelchairs. Social constructivist approaches are, however, broadly unequipped to account for realities of structural inequalities which impact marginalised groups including disabled people. Disabled people face a range of attitudinal, educational, physical, and economic barriers in society, which limits opportunities for disabled people to work in environments of design and product creation (Hamraie, 2017; Williamson, 2012). Users clashed with medical practitioners and technologists to assert their expertise and interpretation of disability objects – demonstrated in the development of wheelchair technologies (Woods and Watson, 2004; Stewart and Watson, 2019). As such, STS perspectives on the relationship between user and designer highlight ways in which structural inequalities which impact marginal groups can be explored.

This section explores STS scholarship concerning the relationship between user and designer. A primary focus of this subchapter is the way in which designers imbue artefacts with certain interpretations of users or social reality in order to shape their actions. In the first section, concepts such as configuration and script are considered to address these topics and explore the relationship between users, designers, and artefacts. The second section expands on the use of script theory regarding marginalised groups, outlining the concept of the gender script from feminist STS scholarship, and invoking the idea of a disability script. The last section concerns the importance of expert status in the relationship between user and designer and the political importance of this to disability politics.

3.3.1 – Configuration and script

Two theoretical approaches which begin to explore the relationship between users and designers are Woolgar's concept of configuration (1990) and Akrich's concept of script (1992). Woolgar (1990) invokes the idea of technology as text, framing users as 'readers' of artefacts. When designing an artefact, designers define their imagined user and enable said user to be able to 'read' (i.e., conceptualise and operate) the artefact with the intended meaning, via the artefact's properties and functions. Artefacts are created with this conceptualised user in mind, which is 'encoded' into the design of the technology (Woolgar, 1990). Simultaneously, the technologist acts to constrain other interpretations or uses of the artefact (Oudshoorn and Pinch, 2003). Users are thus configured to operate and perceive the artefact within set parameters. Drawing on the development of information technologies such as DNS and microcomputers, Woolgar (1990) highlights a struggle for technologists to configure an imagined user consistently across departments within large organisations. This emphasises the role of usability trials and testing within product development, as designers co-construct both the user and the artefact. Similarly, Akrich (1992) suggests that artefacts contain a ‘script’ of possible actions, which are inscribed into the artefact by designers. Drawing on role theory, an artefact’s script communicates constrained possibilities of interaction for the prospective user (Schulz-Schaeffer, 2021). Relating her concept to a film script, Akrich (1992, p.208) suggests that technological artefacts contain a “framework of action together with the actors and the space in which they are supposed to act”. As users conceptualise and interact with artefacts, the scripts imbued within become social realities, affecting human action.

Both configuration and script emphasise the actions of designers in shaping technologies; implying that designers hold political and social power over users (and other actors) in their interactions with artefacts. Configuration implies that only designers hold any form of expertise concerning the development of technological objects. Woolgar (1990) does not leave space for other types of actors who influence the meaning associated with an artefact, such as users, non-users, advertisers, journalists, policymakers (Oudshoorn and Pinch, 2003), or bystanders (Humphreys, 2005). In the case of disability technologies, this interpretation of designer authority has potent implications for the lived experience of the user. Drawing on the example of wheelchair technology highlighted by Woods and Watson (2004), wheelchairs designed by medical professionals carried an implicit script about the imagined wheelchair user. The authors write that in the Model 8F wheelchair, solid rubber tyres were used as these rolled more smoothly on indoor surfaces. However, they were heavy and unsuited for outdoor use, restricting the use of the device beyond the home or the hospital. The wheelchair was therefore inscribed with a particular role for the disabled person to embody. Those users who wished to be independent and active were not included in the script set out by the artefact’s designers. Moreover, wheelchairs were provided to patients by medical or government institutions, with few alternative options. Users of the Model 8F wheelchair were forcibly configured to act within set boundaries, constricted by the economic and political reality of the medical institution and the medical organisation of the wheelchair market.

Nevertheless, examples of disabled people resisting the scripts of artefacts or engaging in acts of tinkering and modification highlights that configuration or inscription are flexible and evolving processes. Script theory emerged from actor network theory, another STS approach which emphasises that human actors and technological actants exist within a mutual web of connection and influence (Matthewman, 2011). As artefacts may shape the actions of the user, the user can also alter how they interact with the artefact. Akrich and Latour (1992) outline a list of terminology regarding scripts, which expands upon how human actors interact with the script of an artefact. Among these concepts are the processes of 'anti-programme' and 'de-inscription', when users resist, reject, or renegotiate an artefact's inscription. This accounts for the reinterpretation of an artefact's function or meaning, whilst still asserting that designers inscribe objects with an imagined user. Mackay et al. (2000) proposes a similar process in the configuration of artefacts. As designers encode artefacts with an imagined user, users 'decode' artefacts to afford new interpretations of devices and their uses. This lends users more power in the user-designer relationship but also implies that users and other actors can configure designers. In hierarchical and consumer-focused organisations, for instance, a range of actors can impact the designer's choices, from pressure groups and advocates to audience insights and customer feedback (Mackay et al., 2000). This symmetrical approach to the user-designer relationship lends users more authority and power in technological innovation. Nevertheless, the ways in which designers imbue meaning into the initial design of socio-technical artefacts has significant impact on the lives of marginalised groups.

3.3.2 – Disability script

For marginalised groups, the ability to assert alternative interpretations of socio-technical artefacts has important political repercussions, due to the ways political and cultural attitudes towards these groups may manifest in the design of artefacts. In Bowker and Star's (1999) description of the boundary object, they observe how 'communities of practice' become naturalised to certain ideologies or concepts, which impact how they perceive objects. In their use of the boundary object in the history of wheelchair design, Stewart and Watson (2019) comment how medical knowledge naturalised practitioners' attitudes towards disability and impairment. They argue that these naturalisations later manifested in the design of wheelchairs, as medical practitioners lent their expertise to technologists and institutions (Woods and Watson, 2004). This idea put forth in the scholarship of wheelchair technology may be expanded upon by examination of script theory.

Specific use of script theory highlights how the perspectives and identity of the designer may inscribe cultural values into the material design of technological artefacts. Feminist STS scholars, for instance, have explored artefacts that contain embedded ideas about gender, or a gender script (Oudshoorn, 1996 in van Oost, 2003; Rommes et al., 1999; van Oost, 1995 in Rommes et al., 1999; van Oost, 2003). A gender script may be explicit, such as the case of 'pink-coded' toys or razors denoting a desired female end user (Sparke, 1995; Kearney, 2010; van Oost, 2003; Levy and Fivush, 1993). However, it can also be implicit, particularly as artefacts intended to be neutral (i.e., for all people) are more likely to reflect the values and outlook of their designers – who are often male, non-disabled, white, heterosexual, cis-gendered, and middle class (Rommes et al., 1999; van Oost, 2003). This 'I-methodology' inscribes a gender bias towards male symbols and competencies (van Oost, 2003). Biases may manifest in a variety of the artefacts' characteristics. For instance, the assumed level of prior knowledge in computer technologies assume a level of competency which was disproportionately more common among men in the later decades of the twentieth century due to inequalities in education and access to computer devices (Rommes et al., 1999).

Ravneberg and Söderström (2017), drawing on Olaussen's (2010) phraseology, denote a disability script, which argues that technologists inscribe particular attitudes towards disability and impairment into artefacts. This may be inferred in the assumed abilities of users – that the user would be non-disabled – or in the specific ways assistive technologies are inscribed with certain perceptions of disability, impairment, and disabled people (Brodersen and Lindegaard, 2014).

The ways in which disability scripts are embedded into socio-technical artefacts reveals the need for disabled people to advocate for alternative technologies. In this process, political and experiential divisions between the user and designer becomes apparent. Brodersen and Lindegaard (2014) give the example of Sophie, who had multiple sclerosis, and wanted to redesign her home so she did not need to continue to use the stairs. Sophie was assigned a municipality architect by the Danish domiciliary care system, who proposed a redesign of her home to incorporate assistive technologies. As such, the artefact of the home can be considered a socio-technical system, inscribed with a perception of disability by the architect. The redesign offered to her was inscribed with a sense of dependency, with track hoists built into the ceilings, a bedroom prepared for a hospital bed, and a new bathroom of vastly increased size, to allow for carers to assist her bathe. The 'Sophie' constructed by the architect (designer) was someone dependent on care. However, the actual Sophie did not need, or receive care of this nature. Sophie campaigned for technologies which would afford her self-sufficiency - for example, remote-controlled windows - but the designer insisted on features such as a larger bathroom, which could accommodate caregivers to help Sophie bathe in a possible future. The deployment of certain artefacts, or socio-technical systems by the municipal services implies these systems imagine the disabled recipient as dependent. Whilst Sophie campaigned against this narrative, the architect argued for the proposed technologies on the grounds of future care needs – rejecting the present Sophie for an imagined future Sophie (Oudshoorn et al., 2005). Sophie and the architect reached a compromise, but the exchange between designer and user highlights the institutional power of the designer, acting as a representative of the municipal care system, over the disabled recipient.

3.3.3 – User expertise

Within STS, technologists and users are traditionally assigned different types of expertise and authority. Technologists, such as designers, engineers, or manufacturers, are granted social status and power over the design of technological artefacts, due to knowledge gained in previous projects or in education. As shown, users are placed in a hierarchy under technologists, in which their expertise is devalued. Similarly, medical practitioners and rehabilitation professionals have been afforded expertise over disabled people and their bodies within medicalised approaches to disability. These two trends have resulted in a lack of acknowledgement of the expertise of disabled people in the fields of technology and design. Hamraie and Fritsch (2019) indicate that traditional approaches to technological design feature non-disabled actors who create artefacts for disabled people, rather than with or by disabled people. In these environments, disabled people are treated as clients or end users, with little acknowledgement for the ways in which disabled people tinker, hack, and alter objects and environments (Hamraie and Fritsch, 2019; Dokumaci, 2023). Acknowledgement of disabled people's work and expertise is thus entangled in political structures of power and authority which govern disabled people's status in society. Scholars in STS and related fields have explored the concept of users as expert and the impact this has on user-designer relations.

Within STS, expertise was understood as a relational quality attributed to actors in certain contexts or based on their social position (Collins and Evans, 2007; Collins et al., 2016). This perception of expertise is dependent on the attribution of expert status from other actors. Collins and Evans (2002; 2007) expand on the ways in which actors gain the status of expert, independent of external identification. The authors refer to real or substantive expertise, which defines expertise as the acquisition of knowledge and the socialisation of a set of practices. Expertise is therefore a social process which forms over time and with situated experience. Actors who possess substantive expertise are connoisseurs who are able to make judgements about artefacts based on their own knowledge and personal experience. Alternatively, interactional expertise posits that actors may be fluent in the linguistic aspect of a process without possessing the actual or experiential knowledge that could typically afford the status of expert (Collins and Evans, 2007; Collins et al., 2016). For instance, managers in hierarchical organisations may understand the language of their subordinate's work (the ways in which a machine or application functions) but may not possess the practical knowledge of using said system. Accordingly, the concept of expertise may take on many forms. Actors can be defined as experts, due to their lived experience of a process or concept, whilst others may be afforded this due to their social position or appearance of actualised experience.

This division in types of expertise is significant in the attribution of expert status to disabled actors. Substantive expertise, for example, has been claimed by disabled people as they assert the potency of their lived experiences. Hamraie (2017) and Williamson (2019), for instance, outline that disability activism in the United States in the 1960s and 1970s partly emerged as a rejection of non-disabled experts who lacked knowledge of the fundamental experience of impairment and social disablement. As Hamraie (2017) notes, however, the goal was not to dismiss developments in the fields of architecture or rehabilitation, but to promote the idea of the disabled person as the expert and for their inclusion in design. This need was recognised by some non-disabled experts in the mid-to-late twentieth century. For instance, architect Raymond Lifchez sought to incorporate the views and feedback of disabled students into his architecture classes at the University of California, Berkeley (Galán, 2022). Lifchez aimed to emphasise the expertise that accompanied the lived experience of disabled students and used to challenge the status afforded to non-disabled architects (Galán, 2022). When engaged in acts of tinkering and modification, disabled people drew expertise from their lived experiences (Hamraie, 2017).

This substantive expertise is also utilised by inventors in business. In the latter half of the nineteenth century, prosthetic leg user and inventor, James Foster, argued his products were superior to that of his non-disabled competitors, due to his experience of using his competitor's products and his ability to experiment (Hamraie, 2017). Likewise, Shapiro (1993) attributes the commercial success of the Quickie lightweight wheelchair to its co-creator, Marylin Hamilton. The general lack of lived experience in wheelchair design, prior to Hamilton's entry to the market, resulted in restrictive wheelchair models which were unsuited for active daily use (Stewart and Watson, 2019). As a wheelchair user, Hamilton understood the feeling of using existing wheelchair technologies, knew what wheelchair users wanted in the function and aesthetic of the chair, and sought to sell wheelchairs as consumer products as opposed to medical devices (Shapiro, 1993). Disabled actors relied on the potency of their substantive expertise within a range of political, social, and economic contexts, and served a distinct role within disability activism and justice (Hamraie and Fritsch, 2019).

On the other hand, interactional expertise may be employed to consider the extent to which medical professionals understand the lived experience of autism, chronic illness, or disability (Collins et al., 2016). Mazur (2003) argues that a new form of interaction may occur once practitioners deepen their understanding of the patient perspective. STS scholars have explored this in light of medical treatment or research concerning patients. Callon and Rabeharision (2003), for example, explore the potency of patient expertise and the way in which this may contribute to researcher knowledge. They give the example of a French muscular dystrophy group who acted as a partner organisation to medical researchers. Due to lack of interest from medical and scientific practitioners, patients conducted their own research into muscular dystrophy, collecting visual information to allow for comparisons between patients and sharing questionnaires to gather insights on different aspects of the condition, such as development, symptoms, and effects of treatment (Callon and Rabeharision, 2003). This knowledge complemented medical research, and patients advocated for structures to connect the knowledge of researchers, clinicians, and patients. Callon and Rabeharision (2003) suggest that the two sources of expertise are not intrinsically different as the same equipment and approaches were practised by patients. In the case of technological development, interactions between technologists and disabled users of technologies may allow for forms of interactional expertise to arise, as collaboration between different forms of expertise allows for trading of language, skills, and knowledge.[7] Indeed, this form of expertise within design addresses critiques in which artefacts for disabled people's use are made for, rather than by and with, disabled actors (Hamraie and Fritsch, 2019).

For marginalised groups, attribution of expertise is also relational. Wynne (1989) examined the interaction between scientists working on the behalf of the British Government and Cumbrian sheep farmers following the contamination of the farmers' pastures by radioactive fallout (Collins and Evans, 2007). Wynne (1989) established the

[7] See the concept of interactional expertise and trading zones in Collins et al (2010).

terminology of ‘lay expert’ to acknowledge the specialist knowledge of the sheep farmers, which the scientists lacked. Unlike the scientists, the farmers lacked formal qualifications that would be recognised as markers of intellectual expertise (Collins and Evans, 2007). The delineation of the farmers as ‘lay’ thus implies that expertise is not just the development of knowledge and experience, but the recognition of this knowledge by other actors and the affordance of cultural and social authority. Feminist interpretations of expert status in sociological research similarly identify the influence of wider social and political forces on the ontology and epistemology of expertise (Azocar and Ferree, 2016). Feminist analysis with the sociology of occupations and professions, for instance, has considered how attitudes toward gender influence how expertise is claimed and attributed (Azocar and Ferree, 2016). Likewise, some feminist STS scholars have employed the term ‘lay’ to recognise that some actors are excluded from the status of ‘expertise’ and the socio-political impact of this status on power relations (Saetnan et al., 2000, p.16, in Oudshoorn and Pinch, 2003).

For disabled actors, and actors of other marginalised identities, the attribution and recognition of expertise has significant social and political consequences. Epstein (1995) shows that AIDS activists, who were primarily patients, could gain credibility within the construction of scientific knowledge. AIDS activists established this credibility by learning the language of medical experts, constructing themselves as representatives of the community, and basing arguments in moral and scientific credibility (Epstein, 1995). The establishment of credibility led to the inclusion of AIDS activists on governmental, institutional, and community advisory boards, highlighting the shifting boundaries of expert status. In the same article, Epstein comments on the rise of other patient advocacy groups within biomedicine in the 1990s. He suggests that the programme of clinical trials is more open to external scrutiny than other fields of medicine, science, or technology, due to the situated knowledge of those involved in the trials. However, in the case of artefacts used by disabled people, lived experience becomes a major factor, both in the design of objects and in their adoption or rejection. Similar to cases of patient-led activism, analysis of users of technological artefacts provides insight into the user-expert relationship. In these cases, those who possess situated expertise become resistant to expert claim-making, and demand a greater role in the production of knowledge (Epstein, 1995). As a result, this role within knowledge production breaks down barriers between experts and non-experts.

3.3.4 – Conclusion

The divide between users and designers is prevalent when considering disabled people. Difference in power and authority resulted in the exclusion of disabled people from spaces of design. Consequently, designers explicitly, or implicitly, imbued artefacts with certain perceptions of disabled users. Exclusion from spaces of design occurred as disabled people's experiential expertise was not recognised or valued. By identifying how designers embed and shape an object's user, and by valuing disabled people's expertise concerning the artefacts they use, STS scholarship can further consider the structural and political forces which shape disabled people's actions, such as tinkering with wheelchair technologies.

3.4 – Chapter conclusion

This chapter has explored a range of concepts and ideas within STS research. A key focus of this chapter has been the user of technological devices and how the user is imagined by other human actors. Disabled people, as users of wheelchairs and other disability things (Ott, 2014), hold potent interpretive power over the evolution of these devices. The non-disabled designers created wheelchair objects with a specific conceptualisation of disabled people and imagined context of use. In practice, however, wheelchair users decoded the associations of inactivity embedded in wheelchair devices, whilst inscribing wheelchair artefacts with a new script, one which emerged from their lived expertise of wheelchair use. This chapter, therefore, uses STS concepts to highlight the agency and autonomy of wheelchair athletes as users of wheelchair devices. This expertise emerged from lived experience of wheelchair use and a desire to reshape the context in which these devices were used (Hamraie and Fritsch, 2019; Dokumaci, 2023). As part of this process, wheelchair devices were reinterpreted from medical devices to sporting equipment. In turn, new interpretations of wheelchair artefacts led to material design changes, which stabilised into new categories of wheelchair artefacts.

The topics and theories highlighted in this chapter present a range of epistemological and ontological perspectives. For instance, both SCOT and the concept of boundary objects outline that the meanings of technological artefacts are shaped by social processes and interaction. Ultimately, this suggests that material-human interaction, and any user agency that may derive from technological change, exists within the social world. At the same time, material changes to wheelchair technology occurred in a shared physical reality, exemplified by the stabilisation of sport wheelchairs as multiple distinct branches of wheelchair technology. Accordingly, the next chapter outlines these epistemological and ontological topics in the context of how the research was approached and conducted.

Chapter 4 – Methodology

This research investigates the historical evolution of manual sport wheelchair devices, with a key interest in the role athletes and wheelchair users played in shaping the technical and cultural identity of this technology. Chapter 2 established the expertise of users of technological artefacts, as both athletes and disabled people have significantly contributed to innovations in sports equipment or disability objects. This is particularly evident in previous scholarship concerning everyday and sport wheelchair technologies, as wheelchair users and athletes directed many key innovations in folding, sport, and ultralightweight wheelchair models. STS places similar importance on the user, as seen in Chapter 3. The user shapes socio-technical artefacts, by asserting their own interpretation of an object's meaning or use, which then creates new design variations for subsequent devices. Further, the analysis of users necessitates exploration of the social and political context in which artefacts are designed and operated, as designers imbue perceptions of marginalised groups into the design of devices, or do not recognise the expert knowledge held by the end user. Accordingly, the collective reinterpretation of wheelchair technology by wheelchair users for sport is key to this research, as this process informed a range of technological, economic, and political developments. As defined in the introduction, this research was centred around three research questions:

1. In what ways did different interpretations of wheelchair sport held by medical professionals and athletes influence the development of wheelchair technology?
2. How did manual wheelchair design evolve and stabilise to create different varieties of sport wheelchair technologies?
3. What was the socio-political and economic context and impact of technological change, and what consequence did this have on the autonomy and self-determination of wheelchair users?

This chapter outlines the theoretic and methodological approaches employed in this research in order to address the above questions. The first section will begin with an exploration of ontology and epistemology across history, STS, and disability studies, in order to consider the nature of reality, the truth content of accounts and evidence, and the relationship between the material and social. Furthermore, my role as researcher and positionality as a non-disabled person will be explored. The second section outlines the methodological background to the two qualitative research methods utilised to capture and contextualise the experiences of wheelchair athletes – oral history testimony, and archival and digital sources. The third section continues by outlining the practical methods of interview testimony and archival research I undertook and how these were adapted in response to the Covid-19 pandemic. The final section of this chapter outlines the method of analysis used in the research.

4.1 – Theoretical position

The fields of study this research impinges upon – namely historical research, STS, and disability studies – contain a range of ontological and epistemological positions. In order to contextualise the philosophical and methodological positions of this research, the following section will briefly outline the development of some ontological and epistemological stances within these fields. Primarily, this subchapter focuses on matters of historic knowledge production, the relationship between material and semiotic reality, and the value of experientially derived knowledge. The first three sections focus on one field of research each. The final section of this subchapter outlines the theoretical position taken in this research, the value of reflexive research - particularly in the context of investigating disability related topics - and my positionality as someone who is not a wheelchair user.

4.1.1 – Historical research

The creation of historical knowledge has classically been predicated on the historian using primary sources to present evidence about the past and establish historical truths (Bosi and Reiter, 2014). Tracing the academic development of historical research, Munslow (2000) identifies three epistemological and ontological eras of historical knowledge production. Modernism, emerging in the enlightenment era, informed the evidence-based practice of historical research. The epistemology of historical research was based on essentialism, empiricism, and positivism, espousing that historical knowledge was created or ordered by the observation of evidence by an objective or rational researcher (Munslow, 2000). To the modernist historian, the past is intrinsically knowable, and the historian acts to bring the content of the past (events, actions, and processes) to light.

However, challenges to this ontology and epistemology in philosophy and the social sciences influenced how reality, knowledge, and the self was conceptualised within historical research (Rüsen, 2017). Largely, these debates, as outlined by Munslow (2000), have centred around the role of the historian in creating historical knowledge. Reconstructionists, for instance, retained the objective stance of research found in modernism, maintaining that the historian should not draw on theoretical concepts to frame their analysis, and remain an observer of their subject to produce an objective and 'true' interpretation of the past (Munslow, 2000; Zeleňák, 2011). Constructionists, on the other hand, form an interpretation of the past as they process and conceptualise evidence, framed by concepts and frameworks from the social sciences (Zeleňák, 2011). Historians form hypotheses, which are tested by the analysis and application of sources. Historians play a creative role in interpreting sources against a conceptual frame to present and understand the past (Eley and Nield, 2007). For the constructionist, the past is therefore non-objective, co-created as a result of historical work (Munslow, 2000; Zeleňák, 2011). Constructionist ontology thus moves away from the empiricist's claim that reality is objectively knowable via the study of historical sources and emphasises the role of the historian in creating persuasive arguments about the past that are accepted as true by the reader.

Nevertheless, the constructionist historian still relies on the epistemological and ontological underpinnings of modernist thought, centring the content of the historical sources as evidence over the form (the structural design of the historical text) and context in which historical knowledge is created. Munslow (2000) outlines a third strand of historical methodology, the deconstructionist. Based in postmodern thought, this historical ontology and epistemology is rooted in the work of academics such as Foucault and Derrida, alongside some feminist and class-based re-conceptualisations of society and the past (Thompson, 2004). These approaches separate the past (the object of study) from history, 'the stories, analyses, and representations produced about the past' (Eley and Nield, 2007, p.67). Historical knowledge is, in turn, a narrative created by the historian based on traces of the past (or the sources which persist to the present) (Munslow, 2000; Eley and Nield, 2007). Historical knowledge cannot reflect empirical truth or objective reality but is a subjective interpretation of the past, shaped by the worldview and positionality of the historian (Thompson, 2004; Rüsen, 2017). History is not culturally neutral, and interpretation is naturally shaped by the perspectives, ideologies, and positionalities of those observing (Eley and Nield, 2007). Munslow (2000) outlines that this results in the aim of historical knowledge production shifting from outlining an objective truth about the past, to creating socially and politically conscious interpretations about the past for contemporary readers (Rüsen, 2017).

Influenced by developments in the social sciences, historical ontology and epistemology has shifted away from an objective interpretation of historic truth to an acknowledgement of the subjective narratives that historians create based on their interpretation of the past. This change has afforded the growth of historical narratives concerning disabled people and other marginalised groups, who are often left invisible in traditional historic evidence (Hirsch, 1995; Bredberg, 1999; Blackie and Moncrieff, 2022). Similarly, this conceptual approach mirrors developments within the field of STS, as scholars adopted subjective interpretations of reality and utilised historical narrative-making to chart the social and technological change of artefacts.

4.1.2 – Science and Technology Studies

In order to explore the historical and social context and consequences of science and technology, STS scholars draw on a range of interdisciplinary approaches and methods. STS research that explores historical case studies of technological development have been influential on the ontological and epistemological orientation of this research. Van Heur et al. (2013) outline that there is not a singular definition of ontology within the field of

STS but three distinct discourses which address key topics. Of these discourses, an early ontological debate within STS surrounding constructivism (reality as subjective, existing within human cognition) and realism (reality as objective, existing outside of human cognition) is of pertinence to this research.

STS developed in the later decades of the twentieth century, seeking to understand scientific and technological creations as social constructs. STS scholars in the 1970s and 1980s were engaged with epistemic questions concerning the creation of scientific knowledge and technological objects, such as how and why certain technologies became successful. The origins of STS are found in anti-positivist approaches to science, which turned to history and sociology to contextualise developments in scientific knowledge. Key scholarship in this area includes Kuhn (1962), who outlined that scientific development occurred due to shifts in scientific paradigms – the consensus of scientific values, cultural concepts, and methodological practices set by scientists in scientific work (Bird, 2000). Scientific knowledge is the co-construction of research methods and the socio-political and cultural context in which scientists reside. This concept formed the basis of key STS approaches, namely SCOT. Pinch and Bijker (1984) draw on the work of Kuhn (1962; 1970) and Bloor (1973) to suggest that technological artefacts were also socially constructed (as outlined in Chapter 3.1.2). Constructivism focuses on the role human actors play in constructing knowledge and reality (as seen in historical thought). Social constructivism, in turn, emphasises that social realities arise from consensus between individuals. In seeking to understand how pejorative or alternative uses of technologies emerge, SCOT examines social groups and the meanings they applied to technological objects (see Chapters 3.1 and 3.2). Ontologically, this theory asserted that reality is a social construction and explores how that reality was shaped by human interpretation (Morgan and Smircich, 1980).

Scholars employed a range of methodological approaches to explore the social realm of material objects. Pinch and Bijker (1984; 1989), for example, cited photographic evidence, primary and secondary books, newspapers, and other printed sources to contextualise the material and social development of bicycle technology. Cowan (1999) similarly drew on magazines and journals in investigating the industrialisation of the domestic sphere in the twentieth century. In these examples, historical sources are not used to assert a verifiable truth about the past, but to represent the worldviews of historic actors and to contextualise the time periods in which actors operated. Interview methodology has likewise been employed for this purpose. MacKenzie (1989), for instance, investigated the development of missile accuracy systems in the United States. The case study draws primarily on interview testimony from engineers, executives, military service members, officials, and others to investigate the technological, economic, political, and social factors of missile development (MacKenzie, 1989). Akin to material or documentary sources, interview data can be used to interpret the perspectives of social groups and the social context in which artefacts and systems evolved.

Critics argued that social constructivist approaches focused too much on human actors and not the material “stuff” of things (Pinch and Bijker, 2012). Ontologically, material-semiotic approaches, such as Actor Network Theory (ANT), and related concepts, including script theory, saw reality as constructed from the relationship between the material and the conceptual. The study of disabled people and disability objects within STS have emphasised the mutual reality-shaping conducted between humans and technology. Drawing on ANT, Winance (2006, p. 67) highlights the relationship between a wheelchair user and their wheelchair, writing that the process of adjustment creates a new ‘extended’ body which affords new possibilities and impossibilities. Indeed, disability and impairment can be interpretated as the result of the actor network (Galis, 2011). Moser (2000), contends that human actors are enabled or disabled by their relationships with other entities, including other human actors and material objects (specific assistive technologies or other objects and tools) and spaces. The material and conceptual work together to create the experience of disability.

According to Wyatt and Leydesdorff (2020), the foundational assumption emerging from the debate between constructivism and materiality is that reality is a socio-cognitive construct, defined (in part) by technology and science. The aim of the STS scholar is to show how technoscience shapes human perceptions of reality, and how human thought and ideology shapes technoscience (Wyatt and Leydesdorff, 2020; van Heur et al., 2013). Later interpretations of social constructionist approaches such as SCOT re-engaged with the ontology of material objects. As a result, scholars have suggested that SCOT does not endorse a particular stance on the subjective-objective spectrum, instead favouring a form of ontological agnosticism (Pinch and Bijker, 2012). Subsequently, scholarly uses of SCOT can explore the material qualities of objects, whilst prioritising the study of the social influences and consequences of technological artefacts.

STS's engagement with the social and material necessitates engagement with the political. Winner (1980; 1993) argues that technological objects enact forms of power and authority or require certain socio-political structures to operate. Ontologically, this shifts the consequences of ontological and epistemic debates into the political reality of disability. Scholars have explored how material and semiotic practices enact, construct, and define disability (Moser, 2006; Galis, 2011). Galis and Lee (2013), for instance, draw on ANT to show how certain groups of actors (disabled people) are framed as 'problems' and excluded from the design process. Research into the historical development of wheelchair technology similarly considers user exclusion from wheelchair design as emblematic of wider political concepts of medicalisation which devalue disabled people's expertise (Woods and Watson, 2004; Stewart and Watson, 2019). The emancipatory politics of disability studies must therefore be engaged with, alongside the socio-material ontologies of STS.

4.1.3 – Disability studies

Sociological and historical research into disability and impairment emerged following socio-political rejection of deficit models of disability which framed the disabled individual as 'abnormal', due to bodily or behavioural differences (Pfeiffer, 2002). The social model of disability, coined by British disability advocates in the 1960s and 1970s, alternatively identified the categorisation of disability as a social construct, whilst conceptualising impairment as a real material and socio-political experience (Feely, 2016; Watson, 2019; Rembis, 2019). Disability studies research, in turn, possessed an emancipatory purpose, aiming ‘to establish disability as a political issue to shift the focus on physical incapacity to the study of oppression and power’ (Watson, 2019, p. 129). Oliver’s (1992) emancipatory research paradigm drew from the ontological and epistemic basis of the social model, critiquing prior disability-related research which failed to acknowledge the struggles of disabled people or failed to provide practical suggestions for policy makers (Watson, 2019). In the late 1990s and 2000s, critical (Vehmas and Watson, 2014), post-structural (Feely, 2016; Pfeiffer, 2002), or postmodern (Pfeiffer, 2002) approaches to disability studies continued the political aims of disability research but contested the materialist focus of the social model (Vehmas and Watson, 2014; Feely, 2016). Drawing on Foucault and Derrida, scholars such as Corker (1999) and Goodley (2011) define both disability *and* impairment as socially constructed. These scholars focused on the cultural reproduction of disability, analysing the role of language in creating categorises of difference and oppressive power structures between disabled and non-disabled people (Vehmas and Watson, 2014; Feely, 2016). Whilst theoretically compelling, such approaches have been critiqued in turn for devaluing or ignoring the material experience of disability (Hugh and Paterson, 1997; Vehmas and Watson, 2014; Feely, 2016) and as having less use in disability advocacy (Pfeiffer, 2002; Vehmas and Watson, 2014).

Some disability scholars, accordingly, adopted different ontological and epistemological stances to relocate the material world and embodied experiences in disability studies and politics. For instance, Hughes and Paterson (1997) drew on phenomenology to argue for a ‘sociology of impairment’. This rejects the separation between body (material) and mind (society and culture) and places embodied and sensory experiences alongside social processes of oppression and exclusion (Hughes and Paterson, 1997; Blume et al., 2014). Likewise, Thomas (1999, p. 116), proposes an ontology between essentialism and constructionism, which maintains there are material (biological, genetic, and anatomic) differences between people, that are shaped by the social and physical environment over time and which can also gain cultural meaning (leading to discourses of abnormality or impairment). Such approaches bridge the material experience of disability with the sociological matters of discrimination and discursive construction of difference.

Recognition of the material realm identifies epistemological importance in bodily and material experiences of disability, reported by disabled people themselves (as researchers or subjects of study). Experiential knowledge has been identified by disabled scholars and activists as a way to contest structures of power and authority which devalue or exclude disability and disabled people (Michalko, 2002; Nijs and Heylighen, 2015; Hamraie, 2017). Both Hamraie and Fritsch's (2019) Crip Technoscience Manifesto and Dokumaci's (2023) theory of activist affordances, for instance, are formulated around the epistemic value of the material experience of disability, constructing analytical frameworks which centre disabled people as 'knowers and makers' (Hamraie and Fritsch, 2019, p. 7). This aspect of disability epistemology, moreover, has important interdisciplinary applications. For instance, Bredberg (1999) distinguished experiential accounts of disability (i.e., first-hand narratives) as a key type of a written resource for disability historians, and such narratives have been well utilised in recent historical research concerning disabled people, as outlined in Chapter 2.1.3 (Richards and Burch, 2018). Similarly, Nijs and Heylighen (2015) suggest that sociological disability research may draw on the ontological and epistemological stances of STS in refuting the value-free or objective production of knowledge which devalues non-empirical experiences. These approaches lend research about disabled people emancipatory significance, allowing scholars to consider disabled people's lived experiences alongside discriminatory power structures, cultural perceptions of impairment and disability, and socio-political barriers which exist in society. Indeed, Oliver (1992) indicated the significance of this approach, as he called for disability scholars to make research 'more relevant to the lives of disabled people'.

4.1.4 – Positionality

My ontological, epistemological, and political positions lead me to a nuanced stance on debates presented in this subchapter. For instance, I conceptualise reality as neither a knowable, objective status observable by human cognition, nor a pure extrapolation of social consciousness. Reality is the equilibrium between these two positions, recognising both the material impact of bodily experiences and physical objects, and human powers of cognition and interpretation. It is assumed a person's identity, experiences, and beliefs shape the way in which they interpret and interact with the material world. This ontological perspective also values the testimony of human actors, as its truth content does not necessarily have to match to a discernible, empirical reality, but to the social reality reported by the speaker. The power and authority of interviewees' lived experiences therefore take precedent in this research, as their testimony shapes the historical narrative that I am able to construct. Recognition of researcher positionality is therefore vital in the construction of the historical narrative presented throughout this research.

A researcher's worldview (their assumptions about ontology, epistemology, human nature, and agency) is shaped by their lived experiences, political or ideological allegiances, familial or cultural background, social class, race or ethnicity, faith, gender or sexuality, disability, and so on (Holmes, 2020; Rinaldi, 2013). Positionality influences how they interpret the research subject, and therefore requires researchers to engage in a process of reflection throughout research, and to disclose how they relate to the subject of investigation (Berger, 2015; Holmes, 2020). My positionality as a non-wheelchair user greatly informed my approach to research design and analysis. I consider myself to be an outsider to the world of wheelchair sport, as I am neither a wheelchair user, nor athlete or engineer, and was not known to these communities prior to the research. My lack of lived experience with wheelchair technology therefore necessitated examination of my own positionality. For instance, I lack knowledge of the material experience of wheelchair operation. Therefore, there may be epistemic concern towards the accuracy of my interpretation of the data related to the function, feel, or play of wheelchair technologies, particularly as wheelchair customisations was identified as an important topic following the data collection.

Due to my positionality, this research needed to be approached reflexively, challenging the thoughts and beliefs which arise from the limited scope of my own experiences. Reflexivity has become an important part of social scientific research in recent decades in response to debates surrounding researcher bias, and has emerged as an important part of qualitative research methods (Brown, 2022; Patnaik, 2013). Reflexivity acknowledges the researcher's role within knowledge production, and communicates this to other researchers or communities impacted by research (Ramazanoglu and Holland, 2002; Patnaik, 2013). Researcher reflexivity also identifies power relations, ethical judgements, and political values held by the researcher which may skew the research in certain directions (Ramazanoglu and Holland, 2002). Rinaldi (2013) writes that disability-focused research inherently calls for researcher reflexivity, due to the marginalised status of disability in society, and activism which seek to make disability and disabled people more visible. Drawing on an experiential epistemology, disabled people's experiences have the authority and power to disrupt accounts of disability or impairment formed by non-disabled people (Rinaldi, 2013).

My positionality as a non-wheelchair user therefore informed methodological choices throughout the research. For instance, I prioritised using direct or paraphrased quotes from interviewees in the thesis to ensure participants' testimony informed the analysis. Paraphrasing was only used to remove utterances and discourse markers, as to not input my own interpretation into the interview quote. Likewise, interviewees were made identifiable within the thesis and later publications (discussed in Chapter 4.3.1.3). Choices were made presuming knowledge is inherently linked to the identities and experiences of the knower. Outlining the identities of participants was accordingly important to validity of the research findings. Patnaik (2013, pp. 103-104) defines this intention as 'Epistemological Reflexivity', and suggests that such approaches risk reducing participant identities into 'replicable statistics.' Nevertheless, it felt appropriate to prioritise participants' testimonies due to the importance of individual user experience with wheelchair devices, and the societal and political context surrounding wheelchair sport and technology, which both emerged as the research continued. Epistemologically, I have therefore approached participant testimony as holding some form of communal or psychological truth, as participants reported on experiences I cannot share, but I continue to acknowledge the subjective nature of this data.

4.2 – Research methods

This research utilises a combination of qualitative research methods to address the questions initially posed by the research. A multi-method approach enables a piece of research to derive deeper and wider meaning about a subject. Different methods of qualitative research generate distinct types of data, which may supplement or corroborate the researcher's interpretation of the topic of study (Roller and Lavrakas, 2015). A muti-method approach is distinct to mixed methodologies, as the former refers to the use of multiple qualitative methods, whilst the latter refers to the use of both qualitative and quantitative methods within one piece of research (Roller and Lavrakas, 2015).

The two types of data collection - oral history interview testimony, and archival and digital materials – present contrasting approaches to historical knowledge production. In the archives, historians 'discover', process, and contextualise narratives about the past, whereas oral history methods generate first-hand accounts of the past from human actors (Bosi and Reiter, 2014). Both methods have been used within this research to conceptualise the perspectives of different groups concerning wheelchair sport and triangulate a coherent historic narrative concerning social, political, and technological development of sport wheelchair objects. This subchapter briefly outlines the development of oral history methodology and contextualises its use in disability focused research. The second section of this subchapter outlines other primary and secondary sources employed in this research, found either in archives or digitally. Both sections of this subchapter consider the relationship between oral history data and archival data in establishing knowledge and how these methods can be utilised in conjunction with each other.

4.2.1 – Oral history methodology

According to Abrams (2016), modern oral history methodology developed out of European traditions of folklore and ethnography collection which prioritised the spoken word, and new directions in social historical research which focused on the working classes. Oral testimony necessarily became the dominant avenue of data collection for researchers investigating marginalised or oppressed groups by the 1980s, as these groups were often absent from traditional historical sources (Thompson and Bornat, 2017). Oral history was primarily used as a method of data generation but later developed into a formal practice of 'recovery history', as researchers use oral history testimony to 'fill the gaps' of the historic record (Bosi and Reiter, 2014; Hajek, 2014; Abrams, 2016). Simultaneously, oral history grew as a form of analytic practice, as scholars engaged with the method to explore the nature of memory, subjectivity, and recall (Passerini, 1979; Abrams, 2016) or outline the role of orality and narrative in the making of history (Portelli, 1981). In recent decades, oral history methodology has expanded as an effective and accessible research tool used by academics, heritage institutions, local and community historians, activists, and other groups (Mulvihill and Swaminathan, 2022).

As a type of semi-structured interview technique, oral history methodology shares many similarities to other in-depth interviewing techniques utilised within social scientific research (Yow, 2005; Mulvihill and Swaminathan, 2022; Harvey, 2011). Hoyle (1972, p. 68) observes that oral history is comparable to elite or specialised interviewing approaches found within social science research, as the interviewer provides space for the interviewee to define and structure the account, and to not "inject his own personality or beliefs into the record" or "to not pass judgement on what is said." Oral history interviews differ from these approaches in their historic focus, as interview participants are asked to recall their own experiences, or memories of an event, community, organisation, or movement (Janesick, 2010; Kapiszewski et al., 2015). Oral historians bring together multiple participants' testimonies within an oral history project, constructing a broad generalisation of the historic context of the topic under investigation (Walmsley and Atkinson, 2000; Janesick, 2010). In this framework, researchers seek to investigate what is psychologically true for participants as opposed to objective fact (Yow, 2005). Oral history testimony therefore serves the postmodern interpretation of historical narrative making, which, in an individual's subjectivities, are interpreted by the researcher in the creation of new historical 'truths' (Beard, 2017).

Within the study of history, the ontological and epistemological turn towards the postmodern afforded the use of interviewee testimony as a valid source of historic data. Initial critics of oral history methodology refuted the validity of participant testimony, due to the fallibility of memory or bias of participants. Modernist historic research (which valued essentialism, empiricism, and positivism) drew on resources such as documents, which remained static and 'objective' in ways memory and recall could not. To some historians, written documents possessed a form of authority which could not be replicated by other types of sources (Mukerji, 2020). Constructionist and deconstructionist (Munslow, 2000) approaches, however, questioned the impartiality of historical knowledge, and thus, the assumed objectivity of historical sources. Portelli (1981) and Thompson and Bornat (2017), for example, point out that written or documentary sources traditionally used by historians are subject to the same biases as oral history testimony. Often, the physical documents left by those in positions of power were created with distinct bias, censored, or destroyed in order to maintain certain narratives (Thompson and Bornat, 2017). Oral historians subsequently argued that other historical sources were no more 'objective' than interview testimony.

Furthermore, oral historians assert that the inherent subjectivity of testimony allowed for alternative and rich historic insights. Whilst Portelli (1981) contends that oral history testimonies do contribute factual interest to the historic record, their potency comes in the articulation of meaning and beliefs held by participants, as opposed to the statement of facts. Oral history testimony concerning a strike, for instance, may add information about the dates, events, or material costs of the worker's actions. More significantly, oral testimony reveals the thoughts, emotions, and psychology of those involved (Portelli, 1981). Oral history practitioners thus embrace the subjectivity of the methodology, as the aims of its use are not to draw objective conclusions about the external world but to better understand the subjective world of individuals or groups of actors. Oral history gained increased credibility in the later part of the twentieth century, as historic and social science research shifted away from the study of the empirical to the subjective (Munslow, 2000; Thompson and Bornat, 2017).

Accordingly, modern oral history theory emphasises the subjectivity of the human actors involved in the production of testimony (Abrams, 2016). Mulvihill and Swaminathan (2022) write that oral history rests on different theories of the self which link the individual to the social world. The self is constructed by several identities, which are influenced by a range of social and cultural factors, such as race, gender, class, language, and so on (Mulvihill and Swaminathan, 2022). Akin to concepts of positionality, these identities shape how individuals experience events, disclose stories, or interpret testimony. In employing oral history methodology, researchers are seeking to explore this subjectivity in line with postmodern ontologies within historical research. Indeed, oral history theory also encourages the interviewer or researcher to consider how their own positionality impacts the generation of data from interviews. The way in which participant testimony is interpreted during an interview, or transcribed from audio to written word, is shaped by the subjective viewpoint of the researcher. Researchers now acknowledge the impact of their own subjectivity in oral history practice, as the interview process is necessarily moulded by this dialogic interaction (Abrams, 2016). Both researcher and participant bring their subjectivities to the interview, and conversation results in the creation of an intersubjective narrative (Abrams, 2016; Mulvihill and Swaminathan, 2022). As a result, oral history methodology encourages practitioners to consider their own subjectivity and how this may impact their interpretations of participant testimony. This is additionally important in the practice of research into marginalised groups or groups with specific lived experiences, as a researcher without 'in-group' status may lack certain knowledge which generates an alternative interpretation of participant testimony.

Oral history's historiographic use as a form of 'recovery history' also lends this approach to distinct historical and political significance as compared to other social science interview approaches (Kapiszewski et al., 2015). Researchers have used oral history methodology to generate 'new' data, filling gaps in the archive left by traditional sources (Hajek, 2014). Interest in marginalised or disenfranchised groups reflected a shift in traditional topics of historic study, and social historians and sociologists used interviews as a means of conducting 'history from below' (Abrams, 2016). Oral history methods thus became potent for feminist historians, as this testimony assisted in conceptualising legacies of oppression which included contemporary sexism (Gluck, 1977; Armitage and Gluck, 1998; Abrams, 2016; Gluck, 2013). This approach to women's history was similarly utilised in labour and working-class histories and subsequently created a model for the histories of racial and ethnic groups, learning and physically disabled people, and gay and lesbian communities, amongst others (Abrams, 2016). In the study of disability, oral history has been identified as a way to make disabled people visible in archives and collections, as the explicit representation of disabled people in traditional sources is often limited (Hirsch, 1995; Bredberg, 1999; Blackie and Moncrieff, 2022). The construction and control of memory is intertwined with socio-political power structures, and the creation of oral history sources provides an opportunity to reinterpret the past (Abrams, 2016). The visibility of disabled people, and representation of their voices and experiences, thus serves a role in disability advocacy (Brilmyer, 2020; Hirsch, 1995; Atkinson et al., 2006). The ability for interviewees from marginalised groups to relay their experiences 'in their own voice' and place value on their experiential expertise contains additional political importance (see Chapter 4.1.3) (Jennissen et al, 2023). This is exemplified by the practice of oral history by people with learning disabilities, who utilise the methodology as a form of self-advocacy and to address injustices facing people with learning disabilities (Walmsley and Atkinson, 2000). This utilisation of oral history methodology thus serves an important role within research into disability history, as this form of data generation creates new historic sources which address the invisibility of disabled people and their experiences in archival and heritage spaces.

4.2.2 – Archival and digital materials

Traditionally, historical research has drawn on a range of written or visual resources, such as books, documents, or photos, alongside material objects (Thompson and Bornat, 2017; Mukerji, 2020). These data sources may be found physically in local or state archives or museum collections, or digitally in online repositories or via social media websites. Akin to other forms of qualitative research, modern historians utilise materials from archives to narrow down a conceptual framework, make sense of a topic, event, or problem, and identify essential pieces of data to support their argument (Elena et al., 2010; Benzecry et al., 2020). The use of documents and other archival materials originally represented the nineteenth-century interpretation of historical science, in which the historian acted to generate historical facts or truths from evidence (Bosi and Reiter, 2014). However, the postmodern turn in modern historical research acknowledges the archive and its content as a process of social construction. Narratives about the past are shaped by the goals, positionality, and social reality of a primary source's author, and the socio-political stances of archivists and institutions (Brilmyer, 2020; Barrowcliffe, 2021). Indeed, archives can only capture a limited representation of reality, reflecting the biases of archivists, administrators, historians, and others with political or institutional authority (Benzecry et al., 2020; Skarpelis, 2020). Likewise, the historian engages with and interprets primary sources according to their subjectivities and positions (Koselleck, 2004, in Skarpelis, 2020).

Archive materials can be used alongside other forms of qualitative research, such as interview testimony, to triangulate an impression of historic social reality (Bornat, 2004). In this research, materials found in archives or online were employed to develop wider contextual knowledge about the research topic and identify information not referenced in oral history testimony. This, contrasted with the usage of document sources to verify the truth content of oral history testimony. As established, documentary or archival sources do not possess more objectivity or truth content than oral history sources. Moreover, this research sought to understand and report the field of contextual information which shaped users' actions and thoughts. As such, non-oral history data collection was used in places where oral history data was not appropriate or descriptive. Magazines. For instance, provided technical details of sport wheelchairs models, including measurements, contemporary advertisement language, and manufacturer details. Oral history participants generally reported widely on these topics, but the use of other materials proved alternative historical or mechanical details which were not captured in participant testimony, such as specific measurements or materials of wheelchair models. Similarly, certain individuals important to the history of sport wheelchair technology could not be interviewed for this research, so archival and digital materials assisted in addressing these gaps in knowledge.

However, archival research was limited due to the impact of the Covid-19 pandemic and resulting national lockdowns. This restricted my access to the collections of Paralympic history held by the NPHT and Buckinghamshire Archives until late 2021. At this point, I had already conducted oral history interviews. Physical archive materials were thus drawn on during a later phase of the research. Between the start of the PhD in October 2019 and November 2021, digital and online sources were utilised instead of physical materials from archives. One key resource, for instance, was wheelchair sports magazine *SPORTS 'n' SPOKES.* Lacking access to physical copies during Covid-19, a limited number of PDF copies were provided by the publisher, the PVA, over email. Digital copies of physical media, such as magazines and journals, or digitised photos, served the same methodological and epistemological role as physical archives despite the difference in medium, as this study was not concerned with the material qualities of these objects but their content. However, this data collection also drew on social media as a site of historical inquiry.

Social media sites provide comparable insights into the past, which historians may draw on for research purposes. Social media profiles, for instance, reflect a personal archive of the individual (Seyfi, 2017; Cannelli and Musso, 2021), whilst public debates reflect processes of collective memory formation (Garde-Hansen, 2009; Birkner and Donk, 2018; Hood and Reid, 2018). Social media sites such as Facebook and Instagram have been analysed - particularly in the fields of communication, archives, and memory - as sites where historical consciousness and narratives are formed, distributed, and reconceptualised (Carter, 2019; Cannelli and Musso, 2021). Whilst social media platforms are often presented as a way for individuals to document and archive their everyday lives as they occur (Sinn and Syn, 2014), these platforms can also be used in the presentation and dissemination of historical narratives. For instance, sharing and interacting with childhood pictures (Seyfi, 2017) or historical photos of local and national buildings (McKay, 2010) on social media websites acted to buttress autobiographical memories and historically contingent narratives about the self and acted to create communal bonds. Hood and Reid (2018), likewise, outline the potency of Facebook groups for the archiving of personal and communal history for local history projects, drawing on Ashmore's (2013) suggestion that Facebook groups operate as 'hybrid spaces' in which virtual communication adds detail and social networks to physical space. In the Covid-19 pandemic, Facebook groups thus provided virtual spaces in which personal and communal narratives about the past could be explored, and subsequently, can be interpreted as a form of archive (Carter, 2019).

These Facebook groups have thus been interpreted as an archive of sport wheelchair knowledge. Early into this project, I was granted access to Facebook groups run by previous wheelchair athletes, such as *Wheelchair Sports Veterans* and *History of Wheelchair Racing.* These groups were created by athletes to share memories of wheelchair sport events, and previous athletes (primarily from the United States) shared a range of personal images, biographies of other athletes, and memories of events. These groups were particularly active in 2020 and 2021, during the height of Covid-19 related restrictions in the United Kingdom and other parts of the world, suggesting that these groups served as an additional form of community exchange during the pandemic. It should also be noted that use of these Facebook groups served to address the absence of materials on this research topic within existing archives. Writing about Indigenous people in Australia during Black Lives Matter protests, Barrowcliffe (2021) demonstrates that archive and museum institutions failed to highlight or preserve narratives created by marginalised groups. Social media analysis and small community archives were highlighted as possible ways to preserve and represent counter-narratives which more accurately capture the experiences and histories of marginalised groups. From this lens, the Facebook groups concerning wheelchair sport may be interpreted as a form of community archive, in which narratives about athlete-led wheelchair modification are preserved.

To this end, the use of digital resources shares the epistemological stance of oral history methodology, as the vast majority of this data was shared or created by wheelchair athletes themselves. For instance, the wheelchair sports magazine, *SPORTS 'n' SPOKES,* was founded by the husband-and-wife team of Cliff Crase – wheelchair athlete, wheelchair sports organisation administrator and communications director for the PVA – and graphic designer Nancy Crase (Crase, 2015). In 1973, Cliffe Crase reportedly envisioned a sport-specific publication which would 'give voice to the thousands of wheelchair athletes in the US, actually the world, who had no central means of communication concerning competition, administration, and just plain news' (Crase, 2015, p. 5). Launching in 1975, the magazine reflected a community space for wheelchair athletes, with editorials and articles for the magazine written primarily by wheelchair athletes themselves. Similarly, data found in Facebook groups came from athletes' own personal collections or memories of events. As the online groups themselves were created by and for wheelchair athletes, they can be considered to be an 'in-group' space in which materials and experiences could be shared with peers. Information drawn from these communities thus reflect wheelchair athletes' interpretations and recollections of the past, akin to oral history testimony.

Conversely, not all sources presented the epistemology of disabled expertise. For instance, the rulebooks for the Paralympic Games between the 1960s and 1980s, or documents relating to the administration of sport wheelchair events, were created by non-disabled people within disability sport organisations. These sources are therefore acknowledged as containing different experiential and socio-political perspective than athlete-created resources. However, they are utilised in this research to outline alternative perspectives on wheelchair sport, investigating how different groups of actors interpreted and defined technological objects.

4.3 – Research design

This subchapter details the two methods of data collection employed in my research. The first section of this subchapter concerns my oral history method, which is split into five sub-sections: Interview format and Covid-19; Participant Information; Participant

Recruitment, Interview Design, and Data Management. The following section considers my archival and digital material data collection.

4.3.1 – Oral history method

The majority of oral history data collection took place between September 2020 and March 2021, conducted remotely due to Covid-19. During this period, thirty-eight interviews with a range of individuals were completed primarily over the video-calling platform, *Zoom*. Additionally, one further interview was conducted in June 2023. This section will detail different aspects of the interview processes, such as participant recruitment, remote interviewing, and interview design.

Oral history training was undertaken at three different points of the PhD programme. I attended an Oral History Society 'Introduction to Oral History' course in November 2019, which focused on in-person interviewing techniques. I also attended a remote interviewing session run by the Scottish Oral History Centre in May 2020, followed by an Oral History Society session conducted for NPHT in July 2020, which highlighted both in-person and remote interviewing techniques. These sessions developed my skills in conducting remote interviews for the project and provided guidelines for writing questions and creating transcripts. Additionally, this training was enhanced by drawing on secondary readings about oral history method and methodology, such as Yow (2005), Abrams (2016), and Bergen (2019). An application for ethical approval with the University of Glasgow was submitted and approved in July 2020 (Appendix G). Further, amendments to the ethnical review to capture updated copyright information was approved in September 2020 (Appendix H).

4.3.1.1 – Interview format and Covid-19

At the beginning of the project, I intended to conduct interviews in person with participants. However, due to the Covid-19 pandemic and resulting national lockdowns from March 2020, the research was shifted to conducting interviews virtually, utilising video-calling platforms such as Zoom and Microsoft Teams.

Prior to the Covid-19 pandemic, qualitative researchers largely discredited remote interview methods as an inferior way to gather testimony. These interviews were seen as less effective and were prone to technical difficulties as compared to face-to-face interviews (Deakin and Wakefield, 2014; Hanna, 2012; Payne, 2013). Similarly, Tremblay et al (2021) noted that data production may be impacted by a reduced ability to read non-verbal cues or contextual data. However, other authors assert there are no significant differences in the quality of information produced in remote interviews as compared to face-to-face interviews (Cornejo et al., 2023; Richard et al., 2021; Howlett, 2022). The widespread use of remote qualitative methods during the pandemic highlighted the advantages of this format. For instance, modern video-calling platforms allow for the synchronicity and spontaneity of face-to-face interviews to be preserved (Hall et al., 2021; Lawrence, 2020; Adom et al., 2020). Remote interviewing may also create a more low-pressure environment for some participants, as they can be conducted at home (Deakin and Wakefield, 2014; Adams-Hutcheson and Longhurst, 2017).

The recording of remote video interviews may incur additional practical or ethical considerations. Khan and MacEachen (2022) suggest that recording audio and video content from interviews may prompt participants to be more aware of what they report, or that interviewees' comments may be exaggerated or censored as a result of the recording. Further, recordings may include identifying material, which may make participants reluctant to agree to an interview (Rutanen et al., 2018). In this regard, remote video interviews share the same methodological and ethical concerns which may surround the recording of face-to-face or phone interviews (De Villiers et al, 2022). These considerations are important to ensure participant comfort and the reliability of interview data. Nevertheless, interviewees in this research were informed of recording upon contact, and gave consent to be recorded prior to the interview. It can be assumed that participants who agreed to the research were comfortable with interview recording. Recording provides practical benefits for the research, including self-defence against claims of misquotation from participants (Ritchie, 2014, p 105). More importantly, preservation is a fundamental element of oral history practice. Recordings ensure that interviewee testimony is added to the historic record, and that interview data may be used in other contexts. Oral history research differs to other qualitative interview approaches in which interviews may only be accessed or viewed by the researcher (Ritchie, 2014). Ritchie (2014, p 8) goes on to state that an interview becomes "oral history only when it has been recorded, processed in some way, made available in an archive, library, or other repository, or reproduced in relatively verbatim form for publication".

Recording interview data provides additional accessibility benefits for researchers. Recordings can be accessed multiple times, allowing the researcher to check data during analysis (Rutanen et al., 2018; Al-Yateem, 2012). As a dyslexic researcher, I would have struggled to retain rich interview data in my mind or to make sufficient notes in the moment. Remote interviews likewise presented advantages for disabled participants. Physical barriers, such as inaccessible transportation or public environments, were negated. This was a key advantage as the majority of the participants in this research were wheelchair users (See Chapter 4.3.1.2). In other contexts, some shortcomings of remote interviews may possess advantages for certain neurodivergent participants, such as the inability to maintain eye contact over video-calling platforms. It should also be noted that remote interviewing may impact the way that the identity of either interviewee or researcher is viewed within the interview environment. Remote video interviewing removed many social and physical markers of disability and impairment which negotiate interactions. Both parties entered the 'Zoom room' in a stationary position, negating the aspect of movement which may denote status as a physically disabled person – and thus identification as part of this in-group (Seymour, 2007). My status as a non-disabled person was disclosed prior to the beginning of the recorded interview, which may have impacted how my participant responded to me as a researcher (Brown and Boardman, 2011). Regardless, this impact on identification of disabled identity may be significant for those wishing to form connections with disabled interviewees based on shared lived experience – or indeed, participants and researchers who do not wish to be identified by their disability.

Overall, remote interviewing offered advantages for this research project. Foremost, remote interviewing removed any physical, logistical, and economic barriers to conducting interviews, as I no longer had to travel to my participants (Cornejo et al., 2023; Mwambari et al., 2021). Further, remote interviewing has been found to broaden the scope of participants included in research (Lobe et al., 2020). Initially, this project was focused primarily on the British context of sport wheelchair technology. However, secondary research emphasised that many significant technological innovations were made by American and European wheelchair athletes. If the research was restricted to in-person interviewing, the perspectives of athletes outside of the United Kingdom would be limited or lost, and the findings of the research would be less representative of the historic development of wheelchair sport and sport wheelchair technology.

Technical restrictions emerged due to the use of video-calling platforms. Infrequently unstable internet connections caused lag, which impacted the flow of conversation and lost small parts of participant testimony. Additionally, some participants struggled to access the video-calling platforms, leading to some interviews being conducted over the phone instead. Finally, three interviews were conducted in a written format. This approach was agreed upon at the request of the participants. One participant, for instance, requested this format as they felt uncomfortable with a verbal interview, as their cerebral palsy impacted their speech. In this circumstance, a list of questions was sent to the participant over email, formatted to match the oral interviews. Whilst this process could not maintain the synchronicity of a video, phone, or face-to-face interview, this flexibility in approach allowed the data collection to be accessible to a wider range of disabled participants.

4.3.1.2 – Participant information

Below, Table 1 provides a list of the participants interviewed for this research. All who agreed to be identifiable in this thesis.

Table 1 – List of participants interviewed for research.

Interviewee name	Nationality	Interview format	Interview date
Kallum Stafford-Baynham	British	Zoom	22/09/2020
Dan Chambers	British	Zoom	29/09/2020
Ian Thompson	British	Zoom	06/10/2020
Rory Cooper	American	Zoom	06/10/2020
Judith Hamer	British	Zoom	09/10/2020
Bosse Lindqvist	Swedish	Phone	12/10/2020
Jim Martinson	American	Zoom	13/10/2020
Tanni Grey-Thompson	British	Zoom	14/10/2020
AJ Jackson	British	Zoom	20/10/2020
Evan Clulee	New Zealand / Kiwi	Zoom	29/10/2020
Phillip Craven	British	Zoom	03/11/2020
Andrew Hodge	British	Phone	03/11/2020
Paul Cartwright	British	Zoom	08/12/2020
Andrew Hawtin	British	Zoom	09/12/2020
Peter Norfolk	British	Zoom	14/12/2020
Craig Blanchette	American	Zoom	15/12/2020
Gary Davidson	British	Zoom	15/12/2020
Maurice Hammerton	British	Zoom	18/12/2020
Danny Jarvis	British	Zoom	12/01/2021
Laurel Lawson	American	Zoom	19/02/2021
Emma Millward	British	Zoom	13/01/2021
Ed McGuire	American	Written response	First sent 15/01/2021, finalised on 25/01/2021
Jalle Jungnell	Sweden	Zoom	19/01/2021
Martin Morse	American	Phone	29/01/2021
Martyn Whait	British	Zoom	03/02/2021
Vincent Ross	British	Phone	25/02/2021
Adam Bleakney	American	Zoom	17/02/2021
Steve Hughes	British	Zoom	18/02/2021
Chris Waddell	American	Zoom	23/02/2021
Aaron Phipps	British	Phone	22/02/2021
Robert Tarr	British	Zoom	02/03/2021
David Constantine	British	Zoom	05/03/2021
Lily Rice	British	Zoom	01/03/2021
Martin Rooke	British	Zoom	02/03/2021
David Hall	Australian	Zoom	04/03/2021
Peter Huggins	British	Written response	First sent 26/02/2021, finalised on 12/03/2021
Abu Yilla	British	Teams	11/03/2021
Paul Clark	Canadian	Zoom	25/03/2021, 31/03/2021
Yasushi Ikeuchi	Japanese	Written response	First sent 06/06/2023, finalised on 06/07/2023

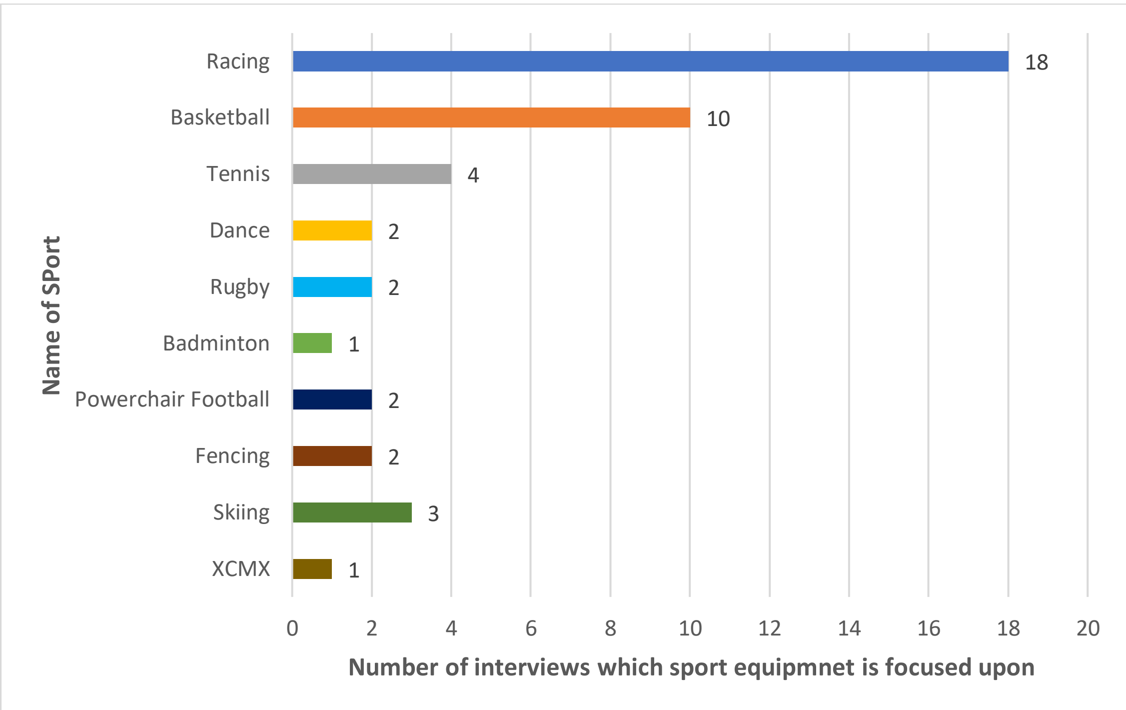
The majority of participants interviewed in this research can be categorised as disabled or wheelchair-using athletes. Primarily, this research was interested in the social groups involved in the development of sports wheelchair technology and the social and political consequences of these actions. Previous literature (LaMere and Labanowich, 1984) and scholarship (Stewart and Watson, 2019) emphasised the important work of wheelchair-using athletes in creating wheelchair technology. This was a broad category, containing a range of roles within the development of sport wheelchair technology. Some participants, for instance, were defined as 'lead users' (Shah, 2000), as they combined their experiential expertise with technical knowledge to create new variations on wheelchair devices ahead of wider market forces. Other athletes, however, had little to no personal involvement with technical innovation. Variation in these experiences highlights the nuances of user-led innovation in sport wheelchair technology. Accordingly, thirty-two out of thirty-nine participants were wheelchair users and/or wheelchair-using athletes.

The seven participants were categorised as non-disabled but were included in the research, due to significant involvement with sport wheelchair technology. During my data collection, I identified shifts in the modern wheelchair industry which needed to be considered. For instance, manufacturer acquisitions increasingly reduced the number of companies owned by wheelchair users and wheelchair athletes (more on this in Chapter 7.2). I struggled to identify relevant non-disabled individuals to approach for interview, such as workers from modern wheelchair manufactures. This was due to a lack of response from major sport wheelchair manufacturers and a lack of contact with workers in these companies.

Notably, participants were not asked explicitly if they were wheelchair users or if they identified as a disabled person or person with a disability. I was concerned that the phrasing of the question – such as the use of certain language around disability - or the question itself may have alienated potential participants. Instead, this information was drawn from participants' testimonies or other conversations with participants. Indeed, interviewees explicitly disclosed their impairment or referenced the fact they were, or were not, wheelchair users throughout the course of their interviews or other communication.

Similarly, it was important to represent a range of wheelchair sports within the research to explore differences between variations of sport wheelchair models. Figure 1 lists the sports which were significantly present in interview data, organised by each participant. Categorisation in Figure 1 was based off several factors. Foremost was the participant's primary sporting interest or relationship to technology. This would include, for instance, a participant's sporting background (for example, they were an athlete in this sport), involvement in industry (for example, they worked primarily with this type of chair technology), or due to their particular knowledge about the subject (for example, their role as a coach or trainer). Some athletes addressed multiple categories of sports within their interviews, so the resultant figure reflects the overall focus of interviews and any other significant data which was reported by participants.

Figure 1: Prevalence of wheelchair sports across interview data.



The most notable aspect of the numbers in Figure 1 is the high representation of wheelchair racing in the data. This could be interpreted as over-representation, particularly as other sports, such as rugby or fencing, feature substantially less in the oral history data. However, contextual data drawn from primary sources indicate that wheelchair racing was a popular athletic pursuit in the 1980s and 1990s. Moreover, the vast majority of willing participants I was able to identify, or had access to, were prominent in the field of wheelchair racing. This links to the consequences of snowball recruitment outlined in the next section, as wheelchair racers often recommended others from their sport. On the other hand, this representation may be emblematic of the technological legacy of the racing wheelchair. The racing wheelchair underwent the most dramatic re-definition of shape and function as compared to other sports wheelchairs (see Chapter 6.3.2.2). Furthermore, it is possible that the racing wheelchair was most attractive to those athletes interested in tinkering and improving their performance. For instance, the majority of user-founded manufacturing companies initially entered the industry to develop racing wheelchairs. In addition, two of the non-wheelchair user designers interviewed for this research focused exclusively on racing wheelchairs, citing their engineering interests in bicycles and cars as the source of their interest in racing wheelchairs. Consequently, there appears to be a distinct engineering interest in wheelchair racing technology, which merits this focus in the interview data.

A number of the participants interviewed for this research may be considered to be 'elites'. This use of the term is distinct to the word 'elite' being used to refer to high-level athletes, and is instead used to denote a specific type of interview with those of high status (Liu, 2018). Within literature related to elite interviewing, the definition of elite status has largely focused on proximity to structural power, such as policymakers, senior management, or board members (Lilleker, 2003; Harvey, 2011). However, the concept may be broadly defined to include actors who possess critical knowledge and prestige based on their social capital or experiences (Liu, 2018; Zuckerman, 1972). Within this research, elite status has been conceptualised as interviewees who possessed specific power over wheelchair technology due to positions within wheelchair manufacturing companies or disability sport organisations. Notably, this elite status is separate to those who possessed experiential knowledge, such as elite athletes who worked with wheelchair manufacturers, as this categorisation seeks to denote those that held forms of organisational, administrative, or economic power within the development of wheelchair technology. Fourteen interviewees may be categorised as elites accordingly, 7 of whom previously founded or ran wheelchair manufacturers, and 3 who worked within wheelchair manufacturers in positions of control over wheelchair design.

Wider demographic information about the participants was also considered. Of thirty-nine participants, only six were female. It is possible that this number may be representative of the gendered nature of engineering and manufacturing related employment (Wajcman, 1991). Participants generally commented that modern wheelchair sport was more gender diverse as compared to earlier eras of these sports. Indeed, four male participants who were active around the 1980s commented on gender differences in impairment-causing injuries. For example, these participants remarked that men were more likely to be injured due to war or motorcycle accidents, leading to a high number of men in these sports. Nevertheless, there are many prominent female athletes in a range of wheelchair sports and across different eras of these sports. A few women with significant involvement in the history of sports wheelchair technology were identified. However, these individuals were either unable to be interviewed or did not respond to inquiries. Such individuals have therefore been included in the research by other means, via the use of secondary literature or archival sources. The vast majority of named designers or manufacturers were men, as few women were named explicitly in primary and secondary sources. Indeed, one female wheelchair athlete interviewed commented that wheelchair design was largely male dominated. On the other hand, three of the six women interviewed in the research primarily spoke about modern or niche sports, such as WCMX (wheelchair motocross) or para dance sport (wheelchair-based Ballroom and Latin dancing). Therefore, it is possible that women’s contributions to sport wheelchair technology are located within specific sports which were not the initial focus of this project, and therefore, received limited attention. Further consideration of this topic may be pertinent to establish a significant link between gender, wheelchair sport, and technological development.

Additionally, only one participant can be categorised as non-white, although participants were never explicitly asked to define their racial identity or ethnicity. Akin to gender representation, it is possible that representation of racial diversity within wheelchair design has links with the wider exclusion of people of colour in design and manufacturing environments (Fouché, 2006). Similarly, the demographic spread of race and ethnicity within disabled and adaptive sports is not clear and is potentially linked to other social, political, geographic, and economic factors. Participant responses did not reveal any insights about racial or ethnic diversity in wheelchair sport, nor in relation to the development of wheelchair technology.

Finally, consideration of gender, race, and geography in the history of sport wheelchair development may be heavily impacted by socio-economic boundaries that privileged middle-class, white, cis-gendered men in western societies. This may contextualise the lack of non-white and non-male contributions to the historical narrative of sport wheelchair technology. Simultaneously, the economic barriers and reality facing disabled people also shaped access to sport and technology. Issues of class, wealth, and access to resources were not explicitly posed in the interview design. However, participants did bring up these factors, such as experiences of procuring appropriate wheelchair devices or taking out loans to start sport wheelchair manufacturing businesses. Future consideration of class, access to resources, and socio-economic realities of disability may therefore be powerful in other research on the development of sport wheelchair technology.

4.3.1.3 – Interview Ethics

Ethical issues concerning anonymity and accurately representing participant testimony were negotiated prior to, and during, interview data collection. Participants were given the option to be pseudonymised in the thesis or other uses of the data, in order to protect their privacy. This was deemed an important option during the initial design of the interview based on the ethical guidelines advised within oral history training.

However, no participants opted to be pseudonymised prior to their interviews. In the circumstance a participant did wish to be pseudonymised, the participant would be identifiable via a code only known by myself. Due to the lack of need for this code, I reverted to using the participant's full name, or initials. In retrospect, this development makes sense within the context of the research topic. The data collection did not probe at necessarily private or personal topics, and the emergence of any potentially difficult subjects were brought up by interviewees themselves. Furthermore, all the interviewees had public profiles of some description. The majority were known as athletes, engineers, or sport administrators. A smaller number possessed some form of elite status, serving as CEOs of companies, or could be defined as elites in other contexts, such as mainstream British politics. In this context, the content of this research was of little risk to touch on topics not already part of many interviewees' existing public profile as athletes or public figures. Following the interview, all participants were offered the option of pseudonymity again. Once more, no participant made this choice. Finally, participants were required to sign a third form for archival of the interview data with the National Paralympic Heritage Trust to make their interview accessible to members of the public following the end of the doctoral research. 31 of the 39 participants agreed to make their interviews part of a public record.

Interviewees were offered additional control over the content of their testimony. It was assumed that participants may speak to relationships with athletes, manufacturers, or other wheelchair designers within interviews, which they may not want on public record. Immediately following the interview, participants were asked if there were any parts of the conversation they would like to review or remove. No participants revoked specific comments immediately following the interview, although 3 specified they would want to see the transcript before consenting to the use of any quotations. Following transcription, the interview transcript was sent to the participant for review. At this stage, a small number of participants asked to remove certain comments from their interviews. One example included removing the mention of a specific wheelchair given to the interviewee by a manufacturer during their career in the late 1990s, as they were unsure if that gift was allowed to be public knowledge. However, the vast majority of the interviewees signed off on transcripts quickly following their distribution. This may imply that the ethical weight placed on participant control over the contents of the interview data did not match the reality of the contents of the data being collected.

The difference between expectations and reality within the research may be representative of the differences between procedural ethics verses ethics in practice. The original design of the interview data collection was focused on privacy and rights of the interviewees, and sought to account for any possibilities which could have compromised the research (Fletcher, 2021). In comparison, ethics in practice afford space for the researcher to be reflexive and make ethical decisions relating to participants during the course of the fieldwork (Shiraani et al, 2022). This includes an awareness of the consequences of choices that occur during the data collection (Simpson, 2011, p. 388). A key underlying impetus of this research was the intention to identify disabled individuals within the history of sport wheelchair technology. As the data collection continued, naming participants met this goal by identifying the role or experiences of specific individuals, whilst retaining an ethic of respect for the interviewee (Fletcher, 2021). Accordingly, the choice was made to name interviewees within the thesis and publications coming out of this research.

4.3.1.4 – Participant recruitment

As an outsider to the wheelchair sport community, I investigated secondary sources of information to identify interview candidates. Due to limited academic literature on the topic, web-based sources, online blogs and articles, and wheelchair manufacturer websites were utilised to identify relevant individuals to this history. Facebook groups, such as the *History of Wheelchair Racing*, also provided opportunity to identify, interact with, and recruit interview participants (Carter, 2019). Investigation into suitable participants also allowed me to locate contact details. However, in many cases, there was a lack of information regarding specific individuals. This was particularly notable due to the ad hoc nature of at-home wheelchair modification in the mid-twentieth century, or the anonymity afforded to employees in large modern wheelchair manufacturers, where the names or work of specific individuals was difficult to identify. Participant recruitment accordingly focused on notable wheelchair users who had been named in secondary sources and other literature, due to their involvement in the creation of sport wheelchair technology. Potential interview candidates were also identified via social media or contacts passed onto me by the NPHT.

Following this initial stage of participant recruitment, I relied on snowball recruitment, a common sampling method in which potential new participants were suggested for the research by existing participants or other contacts (Parker et al., 2019). This form of participant recruitment is seen as an effective way for researchers to gain access to new interviewees (Naderifar et al., 2017; Leighton et al., 2021), especially if they hail from under-represented groups (Tenzek, 2017). Snowball recruitment increased the scope of the interviewee cohort, facilitating contact with individuals who did not appear during secondary research, including those of whom I would otherwise be unaware, due to my 'out-group' status (Parker et al., 2019). Moreover, I found in practice, that new interviewees were more likely to respond to requests for interviews if they were suggested by another wheelchair athlete. It is possible that introductions or recommendations by shared contacts 'validated' the research, and me as the researcher, to other wheelchair athletes or engineers. However, snowball recruitment presented certain issues for the research. Snowball recruitment was contingent on the contacts and experiences of existing interviewees, resulting in a lack of variety (Parker et al., 2019). Wheelchair racers, for instance, primarily introduced me to other wheelchair racers, as these were the contacts they developed during their time as athletes. Wheelchair racers are consequently more prominent in the research data than other types of wheelchair athletes. Similarly, participants largely introduced me to other participants from the same country as themselves, leading to an over-representation of American and British athletes.

To this end, there exist notable gaps in the oral history data collection. As mentioned in the previous section, there was a lack of gender and racial diversity in the crop of oral history participants, and recruitment notably failed to capture testimony from athletes from East Asian countries. This was addressed by an additional written interview conducted in June 2023 with an employee of a Japanese wheelchair manufacturer. Moreover, some of these gaps in knowledge have been addressed by other data sources. For instance, oral histories conducted for other research projects which were publicly available have been accessed, in order to incorporate the perspectives of female wheelchair athletes and businesswomen. Similarly, secondary literature has been utilised to establish more information about wheelchair sport in Japan and other parts of East Asia. However, future research into this topic, utilising a similar research design or methodology, may consider placing increased emphasis on the perspectives of female, non-white, and East-Asian athletes.

4.3.1.5 – Interview design

Interviews were semi-structured and on average, interviews were around an hour to an hour and a half in length. Prior to the interview, a list of questions and topics of interest were drawn up for each participant. All interviews followed the same format and thematic focus but each was altered to suit the individual participant, based on prior conversation or research. For instance, if I knew a participant was significantly involved with a sport wheelchair manufacturer (for instance, as a business leader or engineer), questions would focus on this topic. However, other wheelchair users who did not have this experience would be asked thematically similar questions (for instance, if they had ever tinkered with their wheelchair devices). Examples of these topic guides can be found for retired wheelchair racing athlete and founder of sport wheelchair manufacturer Magic in Motion, Jim Martinson (Appendix B), wheelchair basketball coach and former Paralympian for Britain, AJ Jackson (Appendix C), and non-disabled wheelchair designer and manufacturer, Dan Chambers (Appendix D). Knowledge of participants was based on secondary and primary research, which was also used to identify relevant individuals for interview. Berkovich (2018) writes that positive qualitative research often involves appraisal of existing literature in order to generate effective data and to make sense of findings (Sobh and Perry, 2006). This process allowed interviews to target certain topics and themes based on the known experiences of the participant and record more detailed testimony from participants.

4.3.1.6 – Data management

Interview audio and video was saved to my computer following the Zoom interview and then uploaded to an external hard drive for security following University of Glasgow's data collection guidelines and ethical review. Transcriptions followed guidelines set out by the Oral History Society, as well as advice from my supervisors and the NPHT. Transcriptions were initially made using a web-based software called *Otter.ai*. Personal information about participants, such as email addresses, were kept on an electronic spreadsheet only accessible to the researcher.

4.3.2 – Archive and digital material data collection

Access to archival data was initially facilitated by my relationship with the NPHT as part of the Collaborative Doctoral Partnership. However, my ability to view these resources were limited, due to the Covid-19 pandemic, and consequently, archival data collection can be split into two categories. At first, data was researched and accessed digitally, utilising web-based sources. Primarily, this was achieved via social media, utilising Facebook groups such as *Wheelchair Sports Veterans* and *History of Wheelchair Racing.* Data from these groups included images, written documents, and memories of events (shared primarily as posts or comments). Any images or information drawn from this group was done with the permission of the original poster. Facebook groups also highlighted the social nature of wheelchair sport to me, and these ideas were later incorporated into the oral history interview questions and my perception of collaborative wheelchair technology development (see Chapter 5.2.3).

Another key source of information during Covid-19 were issues of wheelchair sports magazine, *SPORTS 'n' SPOKES,* copies of which were provided by the publisher, the PVA. Whilst I could only access a limited number of issues, they contained a range of opinion pieces, contemporary advertisements, and images of wheelchair models. Most significantly, the copies supplied by the PVA featured an annual survey of wheelchair models. Published between 1983 and 2009, the survey (initially called the 'Survey of Sport Wheelchair Manufacturers' in 1983 and 1984, and thereafter named 'the Annual Survey of Lightweight Wheelchairs' or other variations) featured a range of information about sporting wheelchair manufacturers and models. For instance, the 1983 to 1995 surveys featured tables of manufacturers' wheelchair offerings, comparing details including model dimensions, materials, features, and recommended uses. After 1996, the surveys simply listed information about manufacturers and the wheelchair models they offered. Notably, the surveys featured a mix of sporting and non-sporting wheelchair manufacturers, although this trend became more pronounced in the twenty-first century. Nevertheless, these surveys were a valuable insight into the wheelchair sport community and industry (more on this in Chapter 7.2).

Following the easing of Covid-19 restrictions in England, I was able to access physical archives more easily. In November 2021 to April 2022, I undertook an in-person placement with the NPHT, during which I had increased access to physical materials as part of the museum's archiving projects. These materials are split between diverse collections pertaining to different disability sport organisations. I primarily assisted with the initial organisation and cataloguing of the WheelPower collection and ongoing development of the NPHT's own archive. The WheelPower collection pertains a range of materials held by WheelPower, the national organisation for wheelchair sports in the United Kingdom. This exposed me to several relevant materials, such as paper copies of *SPORTS 'n' SPOKES* and *The Cord,* rule books and administrative materials pertaining to Stoke Mandeville (the original site of the Paralympic Games), and programmes and photographs of sporting events. Moreover, I was able to access additional materials pertaining to Paralympic and disability sport history held by Buckinghamshire Archives during this period.

Overall, a range of primary sources were accessed throughout the PhD, digitally and physically. These include:

- Magazines, newspapers, and journals, such as wheelchair sport publication, *SPORTS 'n' SPOKES*.
- Wheelchair supplier and manufacturer advertisements.
- Commemorative books and pamphlets about individual Paralympic Games or other sporting events.
- Administrative records, primarily rule books related to the national or international SMG and Paralympic Games, or technical sub-committee meeting reports.
- Interviews with wheelchair athletes held within other archives.
- Images and photographs supplied by interviewees and non-interviewees or found within archival collections.

4.4 – Analysis

Following the theoretical and practical background to this research, the following section outlines the method of analysis undertaken. This section begins with a brief restatement of reflexivity in qualitative research before outlining this research's use of reflexive thematic analysis to categorise research data. The subchapter ends with a brief explanation of my coding practice.

4.4.1 – Reflexive thematic analysis

Reflexive qualitative research requires the researcher to think about their presumptions, existing knowledge, and positionality, and how this impacts their research (Haynes, 2012). Alvesson and Skoldberg (2000) propose that reflexive research is based on interpretation and reflection. Interpretation refers to the influence of the researcher on the data, as conceptualisation of qualitative data will be shaped by the researcher's values, identity, and experiences. Reflection, however, comprises the researcher turning attention to themselves or other intellectual, academic, or cultural conditions which inform interpretation (Haynes, 2012). Drawing on my own positionality as a non-wheelchair user, the political ends of prioritising wheelchair athlete testimony, and the epistemological and methodological context of oral history research (Yow, 2005; Abrams, 2016), a reflexive analytical approach was necessary for this research.

Interview transcripts were analysed utilising a framework of reflexive thematic analysis, a method of qualitative analysis outlined by psychologists, Braun and Clarke (2006; 2013; 2020). This qualitative analysis method stems from thematic analysis, but with increased focus on researcher reflexivity. For example, Braun and Clarke (2020) identified that many researchers who utilised thematic analysis refer to concepts or themes in their data as 'emerging'. To the authors, this was problematic, as the language of 'emergence' implies pre-existing or objective knowledge that is 'discovered' by the researcher. The authors instead propose that concepts or themes identified in the end research are constructed by the collaboration between the researcher and the participant(s). Themes are therefore unique to each piece of research, created by the positionality of the researcher and participants, and their interactions.

Reflexive thematic analysis outlines a six-stage process for analysis, emphasising coding and theme generation, alongside an epistemological approach rooted in a qualitative paradigm. Braun and Clarke (2013) intend for reflexive thematic analysis to be used flexibly with a variety of methods and approaches, which allowed me to include archival data within the same analytic categories as interview data.

Braun and Clarke's (2020) six stages of reflexive thematic analysis are:

- 1) Data familiarisation and writing familiarisation notes.
- 2) Systematic data coding.
- 3) Generating initial themes from coded and collated data.
- 4) Developing and reviewing themes.
- 5) Refining, defining, and naming themes.
- 6) Writing the report.

4.4.2 – Experience of Reflexive Thematic Analysis

Data analysis roughly followed the structure outlined by Braun and Clarke (2020). I first familiarised myself to the interview data during the act of transcription. Notes formed during transcription were added to a separate document, which provided some basic links between interviewee comments to assist with code generation. In December 2020, these notes were used alongside my literature review and semi-structed interview questions guides to generate initial codes. For example, the broad codes 'user-led adaptations' and 'non-user led adaptations' were created to categorise instances of wheelchair sport innovations created by disabled people and non-disabled people respectively. This matched the key focus of my early interviews, which sought to expand on examples of user-made wheelchair modifications found in the literature. The data familiarisation process also promoted new codes to capture unexpected topics raised by interviewees. Examples of these codes were 'wheelchair selection', 'family/friends as innovators', or 'injuries'. This period of coding drew from the first ten interviews I transcribed. Coding in Nvivo software at this early stage helped me to familiarise myself with the initial data generated and allowed me to reflect on my interviewing technique.

Following the completion of further interviews and transcriptions in March 2021, I repeated this process with the entire interview set. When possible, interviews were coded immediately following transcription as to retain data familiarisation. Code names were also refined in this stage to streamline the way I organised data. For instance, I initially separated different types of sport wheelchair equipment into specific codes, such as 'Racing wheelchairs' or 'Tennis wheelchairs'. This approach initially helped me formalised my understanding of the nuances between different wheelchair varieties. However, I later decided to remove this categorisation as to streamline the codebook for more effective utilisation. Simultaneously, an additional series of unexpected codes were identified, including 'Gender', 'Race', 'Background in engineering', and 'Collaborations.' As these new codes formalised, I returned to previously coded interviews to code relevant data.

Code themes were initially theory-driven, such as a theme titled 'Social groups and Innovators' based on my use of SCOT. This approach to theme naming was also influenced by provisional chapter structure. However, by the autumn of 2021 I found that these themes did not match the way I discussed the research topic with interviewees within the data collection. I therefore decided to rename the themes to broad topics, such as 'Technology' or 'Designers'. This was also influenced by my archival research, starting alongside my placement with the NPHT in November 2021. I used the same code framework to organise data emerging from non-interview sources. The addition of archival data did not significantly change my code framework at this point in the research. In May 2022, following my placement, I restructured my code framework based on these streamlined themes, and defined a final analytic codebook.

4.4.3 – Codes

The software *NVivo 12* was provided by the University of Glasgow and utilised for coding. I also attended training run by NVivo's research centre in February 2021, which included a thematic analysis workshop. This assisted my understanding of how to utilise the software in each stage of the six aforementioned stages of reflexive thematic analysis. A table of the codes and associated sub-codes used in the research can be found in Appendix I.

4.5 – Chapter conclusion

This chapter outlined the theoretical position that informs this research, and the practical approach to data collection. Epistemologically, this research prioritises the lived experiences of wheelchair athletes, utilising their testimony to understand the social and political significance of sport wheelchair evolution. As I am not a wheelchair user, I have aimed to ensure that the voices and experiences of wheelchair athletes are centred within the presented narrative. However, I retain the position that reality is subjective, and present the participants' testimony as the communication of their experiences reflected through a reflexive framework. This has also afforded the utilisation of archival and digital resources alongside oral history data. The resources work to enrich the narratives presented in the oral history testimony. These sources also provide further contextual information about this subject, giving perspective into the medical interpretation of wheelchair sport and technology and contextualising the wider evolution of wheelchair sport and the wheelchair manufacturing industry.

The following three chapters outline the findings of the research. In order, the chapters explore:

- Medical practitioner and wheelchair users' interpretation of wheelchair sport and technology.
- Wheelchair athletes' impetus for modifying wheelchair technology for sport and the technological evolution of sport wheelchairs devices.
- Wheelchair users' role and agency in changes to wheelchair sport rules and the manufacturing industry.

Chapter 5 – Interpretations of wheelchair sport

Over the course of the twentieth century, manual wheelchair technology underwent a range of changes which benefitted active, independent wheelchair users. Wheelchairs became lighter, stronger, and more manoeuvrable, which greatly benefitted recreational and professional sport, alongside daily living. The social and historical context of the Paralympic movement and disability sport provides one perspective into how wheelchair devices were perceived by human actors and the impetus behind acts of technological innovation. SCOT reasons that groups of actors can be identified around shared interpretations of technological objects (Pinch and Bijker, 1984). Accordingly, this chapter establishes two groups of actors based on medical and competitive interpretations of wheelchair sport, to contextualise this impact on sport wheelchair technology.

This chapter is divided into two main sections, each exploring a relevant social group (Pinch and Bijker, 1984) and their interpretations of wheelchair sport. The first subchapter outlines medical practitioners' interpretations of wheelchair sport, their control over organisation and administration, and how this shaped wheelchair technology. Likewise, wheelchair users and athletes formed their own interpretations of sport and technology, based on their worldview, experiences, and competitive desires. The following subchapter outlines wheelchair athletes' interpretation of sport, and the impetus this created for new sport wheelchair technologies.

As will be shown, wheelchair sport serves many important functions and interpretations simultaneously. In this chapter, medical professionals' and athletes' interpretations of wheelchair sport are simplified as 'rehabilitation' and 'athleticism' in order to highlight the socio-political value of wheelchair sport. Indeed, athletes sought to assert their own interpretations of sport and technology in the latter half of the twentieth century as they opposed medical control over wheelchair sport administration and technology. This conflict emerges again in Chapters 6 and 7, as athletes modified their wheelchairs and protested against equipment regulations at sport events. In outlining different interpretations of wheelchair sport, this chapter highlights the political ideologies underpinning differing approaches to wheelchair sport and its role as a form of advocacy for active disabled people.

5.1 – Medical interpretation of sport

Modern wheelchair sport initially developed as part of new rehabilitation approaches following the Second World War. Veterans who were spinally injured or had amputations were encouraged to play sport as part of rehabilitation programmes, found at institutions like Stoke Mandeville Hospital, in Buckinghamshire, United Kingdom. The initial ideological interpretation of wheelchair sport was centred around its physiotherapeutic benefits. Sports events and administrative bodies were largely run by medical staff, such as the International Stoke Mandeville Games Federation (ISMGF) committee, the original international body for wheelchair sport. However, medical practitioners developed multiple interpretations for these activities, particularly around the aim of integrating wheelchair users into mainstream society, and the athletic appeal of these sports. In this period, regulations around wheelchair technology emerged, restricting the design and functionality of sporting wheelchairs between the 1950s and 1970s.

This subchapter aims to explore medical professionals' interpretations of sport and how this manifested in regulations regarding wheelchair technology. Unlike the athlete worldview, data used to capture the rehabilitative interpretation of wheelchairs has largely been interpreted from primary materials (meeting notes and event documents), secondary materials written by medical professionals (publications, speeches, and journal articles), and oral history testimonies of athletes. This is due to the lack of direct testimony that could be gathered from medical professionals of this era. Conclusions about medical professionals are thus more subject to the external interpretation of myself and other researchers, and the worldview of athletes. This does present methodological differences compared to athletes' own self-reported testimony utilised elsewhere in the thesis; however, archival and oral history data has been corroborated, where possible, to capture a consistent picture of the 'rehabilitative' interpretation of sport.

In a publication titled ‘Sport and Recreation for the Mentally and Physically Handicapped’, Dr Sir Ludwig Guttmann (1973, pp.208-209) outlined four objectives for wheelchair sport:

A. “Sport as a curative factor.
B. The recreational value of sport.
C. Sport as a factor in the psychological readjustment of the disabled
D. Sport as a means of social reintegration of the disabled into the community.”

This subchapter explores objectives A, B and D as they relate to the perception of wheelchair sport. The physiotherapeutic and medical benefits of wheelchair sport will be outlined in the first section. This is followed by a section concerning the reinterpretation of sport as a way to integrate disabled people into mainstream society. The third section considers the recreational interpretation of sport. Whilst there is overlap between these objectives, each is explored as a distinct interpretation. Each section also links this objective to wheelchair technology, focusing on regulations.

5.1.1 – Sport as physical therapy

In the 1940s, wheelchair sports were primarily known as a form of physical therapy for those with spinal cord injuries. During the Second World War, new rehabilitation programmes were created as combat and improvements in medicine left many injured veterans with mobility impairments. New rehabilitation programmes for paraplegics, quadriplegics, tetraplegics, and amputees included sport adapted for wheelchair users. In the United Kingdom, this originated at Stoke Mandeville Hospital, under Dr Sir Ludwig Guttmann. Guttmann undertook the role of director of the National Spinal Cord Injuries Centre, located at Stoke Mandeville Hospital in Buckinghamshire, in 1943 (Anderson, 2011). Here, Guttmann introduced numerous new approaches to the medical and rehabilitative treatment of those with spinal cord injuries, including sport (Brittain, 2012, p.2-3). Exercises began as simple games, as patients passed a ball whilst remaining in their beds on the wards (Anderson, 2003, p.465). Guttmann outlined that individual sports such as darts and snooker were introduced by 1944, alongside team sports like polo, badminton, and basketball (although this was more similar in play and rules to netball) (Guttmann, 1973; Labanowich and Tiboutout, 2011, p.18; Anderson, 2011). This was later accompanied by archery, table tennis, swimming, field events, and other sports (Guttmann, 1973).

In the United States, treatment of spinal cord injuries was pioneered by Dr Donald Munro, who based his rehabilitation programme on the work of Dr George Deaver (Silver, 2003, p.128; Flanagan and Diller, 2013, p.357). In the 1940s, Deaver utilised sports including basketball and table tennis, alongside physical exercises and other games, highlighting another early use of sport in rehabilitation (Silver, 2003, p.128; Flanagan and Diller, 2013, p.357). Moreover, early instances of wheelchair basketball have been identified in rehabilitation and hospital wards from 1945 onward, primarily driven by patient interest in the non-adapted version of the sport (Davis, 2020; Labanowich and Tiboutout, 2011, pp.6-17). Yet, the origins of wheelchair sport in the United States are often associated with Dr Tim Nugent. Nugent was tasked with the establishment of a rehabilitation and education programme at the University of Illinois, which included bowling, basketball, and swimming as part of activities available to students (Reagan, 2017). From the late 1940s onwards, wheelchair sport was facilitated nationwide by the PVA, who established wheelchair basketball teams at several Veterans Administration hospitals (Labanowich, 1995). Interviewees from other countries, such as Sweden and New Zealand, have also identified their early interactions with sport as a result of rehabilitation programmes and medical recommendation. Indeed, interviewee and secondary data outline the international trend of wheelchair sport being played in rehabilitation wards and hospitals in many other nations - Japan, Israel, Argentina, Canada, and Australia, amongst others- due to the quick recognition of the rehabilitative benefits of wheelchair sport for recently injured patients (Frost, 2020; Ohry and Silver, 2006; Bailey, 2008; Labanowich, 1995).

Wheelchair sport accordingly developed within a rehabilitative paradigm, as these activities functioned to assist physical therapy. Guttman and Mehra (1973, p.159) wrote that archery "proved ideal for training those muscle groups above the level of the spinal cord lesion, in particular, the arm, shoulder and trunk muscles". These muscles were naturally developed by the action of drawing the bowstring and were important to assist individuals in holding themselves upright (Brittain, 2012, p.3; Guttmann and Mehra, 1973). Moreover, Guttmann identified sport as key in developing patients' strength, co-ordination, and endurance, as well as helping to overcome fatigue (Guttmann, 1973). Physical exercise was vital to the health of patients, and sport assisted in the development of specific muscles. However, sport had greater utility than exercise regimes, due to the aspects of competition and play. In a paper titled "Reflections on our philosophy of sport for the disabled", Dr Gershon Huberman (1983), physiotherapist, and founder and first director of Israel Sport Centre for the Disabled, reasoned that disabled people "consciously or subconsciously … will try to avoid physical exercise, particularly when this may be accompanied by discomfort or even pain." Sport, therefore, encouraged "the handicapped [to] want to become active themselves."

The medical objective of disability sport can be found throughout the early decades of Guttmann's work. Anderson (2011, p.143), for instance, outlines how paraplegic and quadriplegic patients were examined at Stoke Mandeville to test temperature regulation, the effects of postural changes, and sexual functionality. Similarly, the SMG, established in 1948 and the precursor to the modern Paralympic games (Brittain, 2012; Bailey, 2008), featured distinct medical presence. Bailey (2008, p.21) lists how scientific meetings concerning medical treatment and techniques were held in conjunction with the games at Stoke Mandeville as early as 1952. This continued into the development of international games which mirrored the Olympic cycle, beginning in Rome in 1960 (Bailey, 2008). Scientific meetings were held at the 1964 Games in Tokyo (The Cord: International Journal for Paraplegics, 1964, p.20-24), and the 1972 Games in Heidelberg, highlighting how the Games assisted in the proliferation of new medical information about spinal cord injuries across the globe. A book published in advance of the 1972 Games pointed to the scope of these meetings (International Stoke Mandeville Games Federation, 1972c, no pagination):

> "Approximately 200 doctors, mostly specialists in the treatment and rehabilitation of paraplegics, are expected to attend the congress in Heidelberg. Some of the most important topics of the meeting will be: heart and circulatory diseases of paraplegics, inner secretionary disturbances resulting from spinal injury and the possibilities of sport therapy and sport for the disabled in the treatment of paraplegia."

Disability sport was therefore a new avenue for the progression of medical research. The growth of the SMG and sport's medical benefits prompted the formal organisation and administration of disability sport. Joan Scruton (1998), the general secretary of the ISMGF outlined in her autobiography and history of the Paralympic movement that, beginning in 1952, Guttmann liaised with hospital staff, physiotherapists, and trainers in creating the rules of the SMG. In 1959, Guttmann and Scruton founded the ISMGF, 'placing themselves at the helm' of the organisation (Mallett and Sikes, 2021, p.4) and promoting medical control over wheelchair sport. For instance, physiotherapist Charlie Atkinson became the chairman of the ISMGF's Technical Committee in 1962, which oversaw rules enforced and equipment used in each sport (Scruton, 1998). Moreover, Labanowich and Tiboutout (2011) state that technical committee members were hand-picked by Guttmann, who served as the deciding voice during meetings (International Stoke Mandeville Games Federation, 1958-1974).

The organisation of the ISMGF enforced a medicalised view of sport, and there is no evidence that disabled athletes were part of the ISMGF decision-making process (Labanowich, 1987). Indeed, primary and secondary sources suggests that physicians, in particular Guttmann, were authoritarian and paternalistic in their administration of sport (Halfman, 1979; Bailey, 2008, p.19; Labanowich and Tiboutout, 2011; Sainsbury, 2018). Brittain (2011, p.1174), for instance, cites an incident at the 1979 general assembly of the International Sports Organisation for the Disabled (ISOD), in which a blind delegate questioned if the ISOD "was an organization of disabled [people] or an organization for disabled [people]". Guttmann reportedly answered by dismissing the delegate's question, and stating they should 'not make impertinent remarks' (Brittain, 2011, p.1174).

Consequently, Bailey (2008) states that medical professionals predominantly treated disabled patients paternalistically, not interpreting them as athletes.

Figure 2: Photo of Basketball, played in travaux wheelchairs. c1950. ©WheelPower Stoke Mandeville Stadium Archive.

The medical model of sport was reflected in approaches to wheelchair technology. The armchair-like Travaux wheelchairs shown in Figure 2, provided to Stoke Mandeville by the Ministry of Pensions in 1944, were heavy, and cumbersome (Woods and Watson, 2004; Anderson, 2011; Guttmann, Undated). These devices reinforced the configuration of wheelchair users as patients, requiring staff to push the user across the hospital grounds (Anderson, 2011). To independently propel the devices themselves, a patient had to build up sufficient strength and dexterity. This was achieved via strength training and apparatus within physiotherapy rooms at Stoke Mandeville Hospital, and the introduction of sports such as netball and basketball which required the user to propel the chair across the court (Anderson, 2011; Bailey, 2008). As everyday wheelchair devices became lighter in weight, spurred on by the popularity of the American wheelchair manufacturer E&J

(Woods and Watson, 2004), lighter wheelchair devices were adopted at Stoke Mandeville (Guttmann, Undated). Even with new devices, sport continued to be beneficial in training the physical ability to operate wheelchairs and in developing skills which would assist in everyday life. Between the introduction of wheelchair sport in the 1940s, to the emergence of sport specific wheelchairs in the late 1970s and 1980s, the majority of wheelchair users operated the same wheelchair for everyday life and sporting activities. Sport possessed physiotherapeutic and practical benefits which served the everyday use of wheelchair devices, as illustrated by British wheelchair basketball coach and retired athlete, Maurice Hammerton (59), during interview:

> "…the skills that you learn on a basketball court, or (…) in any sports environment, really, do help you in day-to-day living. You know, falling out of your wheelchair, for instance. You're going to do it in daily life. So you need to know how to deal with it, not hurt yourself, get up when you fall out. Those kinds of things, you learn pretty quickly when you're playing wheelchair basketball because it tends to happen quite a bit. But you know, just the technique as well, the technique of being able to push efficiently and quickly and safely, you know, knowing how to turn the chair, how to make it go forwards and backwards, it's fairly basic. But the more you do it on the basketball court, then the more it's bound to help you in daily life as well."

Developments in wheelchair technology were therefore closely linked to wheelchair sport and its physiotherapeutic benefits. The medical establishment of the ISMGF subsequently had little interest in advancing wheelchair technology for the purpose of sport. In a speech concerning technologies used in the treatment of paraplegics and tetraplegics given in the early 1970s, for instance, Guttmann (undated) outlines the benefits of lighter wheelchair devices for everyday use but makes only passing reference to athletic benefit or sport performance. Chapters 6 and 7 later show that the ISMGF were resistant to significant technological changes despite the advancements created and tested by athletes. Regulations were enforced, which restricted innovations that were specific to sporting use, such as anti-tip wheels which prevented users from falling out of chairs, but also prevented leaning backwards to mount pavements (see Chapter 6.3.1). Wheelchairs were therefore devices that could be used *in* sport, not devices made *for* sport. The ISMGF also resisted small-scale adjustments. Records from ISMGF Technical Committee meetings between 1960 and 1974 highlight a repeated concern over factors including footrest height, cushion thickness, and use of leg straps (International Stoke Mandeville Games Federation, 1958-1974). Whilst these regulations were implemented to ensure fairness between players (as considered in Chapter 5.1.3), this could also be interpreted as the desire to control the shape, function, and meaning of wheelchair devices. Indeed, medical professionals at Stoke Mandeville controlled the evolution of international wheelchair sport and used this to promote rehabilitation and medical research.

Wheelchair sport was introduced as part of a wider programme of rehabilitation methods, with distinct medical aims. Sport was used by medical and rehabilitation professionals as a means of exercise, muscle development, and skill training, all of which were important for the long-term physical health of patients. Regulations concerning wheelchair sport and technology can be understood as a manifestation of this ideology, restricting wheelchair design to that which would benefit rehabilitative aims. Due to their interpretative framework as medical professionals, physicians and physiotherapists at Stoke Mandeville and other hospitals held a medicalised interpretation of wheelchair sport and technology.

5.1.2 – Societal integration and international growth

For medical professionals, wheelchair sport served an additional function of societal integration. Alongside physical therapy, sport assisted with the social rehabilitation of recently disabled veterans into mainstream society, assisting the injured patient in returning to the workforce and becoming part of the community. This interpretation of wheelchair sport had a significant impact on the growth of the Paralympic movement, as disability sports events and methodologies were exported globally.

Sport, alongside programmes of employment, skill development, and independent living training, were used to prepare disabled people to integrate into society following medical treatment. This new approach to rehabilitation was intended to make recently disabled individuals productive members of society following the Second World War. Indeed, Joan Scruton stated that Guttmann's aim was to turn 'a severely disabled person into a taxpayer' (Scruton, 1998, p.19; Anderson, 2003, p.462). Sport served this social and economic goal in the aforementioned training of wheelchair users, enabling them to be independent members of society (Anderson, 2003). Sport also developed confidence and team-working skills, and encouraged socialisation. Medical professionals saw sport as the gateway to employment and social integration (Guttmann, 1976; Borsay, 2013). In a 1983 paper titled "Reflections on our philosophy of sport for the disabled" Israeli physiotherapist Gershon Huberman (1983) wrote:

> "[The disabled person] can transfer his newly developed capacities from the field of sports to the competition of making a living; that from being a well-liked and useful member of a team, he can switch to being a well-liked and useful member of his community."

Sports such as archery were originally prioritised, as wheelchair users could compete equally with non-wheelchair users, promoting ideas of integration (Brittain, 2012; Guttmann, 1973; Guttmann and Mehra, 1973). Such practices also served to reinforce the political weight behind rehabilitation, which helped injured people 'return' as active, contributing members of society. The use of sport by Dr Tim Nugent at the University of Illinois in the United States served a similar purpose, as he hypothesised that audiences would recognise what disabled students could contribute to society via their participation in team sports (Brown, 2008, p.175). Nugent accordingly established a wheelchair basketball team, the Gizz Kids, in the early 1950s, providing wheelchair users with an equivalent non-academic activity to other opportunities on the Illinois campus (Reagan, 2017; Brown, 2008, p.175). Seeing the rehabilitative benefits of wheelchair sport, medical professionals in the United States and United Kingdom aimed to proliferate wheelchair sport across the globe (Guttmann, 1976; Polley, 2011).

The most explicit example of adopting the social rehabilitation interpretation of wheelchair sport can be found in Japan and other parts of Asia. Frost (2020) explores this in his research regarding the history of disability sport in Japan. He states that in the lead up to the 1964 Tokyo Paralympic Games, promotional literature constructed the goal of the Paralympics to be “The social rehabilitation of the physically disabled… Sports are one means for attaining this sort of rehabilitation, and therefore, each country is seriously promoting these kinds of events” (Frost, 2020, p.36). Sport was presented as a way for disabled individuals to build self-confidence that would assist their reintegration into mainstream society. Significantly, concepts of competitiveness or athleticism were underplayed by promotional materials. Later in the promotional literature, for example, flyers stated: “For the Paralympics, the goal wasn’t about winning competitions” (Frost, 2020, p.37). This diminishment of athletic achievement by the organisers suggests that heavier emphasis was put upon the societal, psychological, and medical benefits of disability sport. Indeed, in a commemorative publication about the 1964 Games, Hiroshi Kanda, the then Japanese Minister for Health and Welfare, referenced these aspects of disability sport but made no comment on the recreational or competitive aspect of the Games (International Stoke Mandeville Games Federation, 1964, pp.10-11):

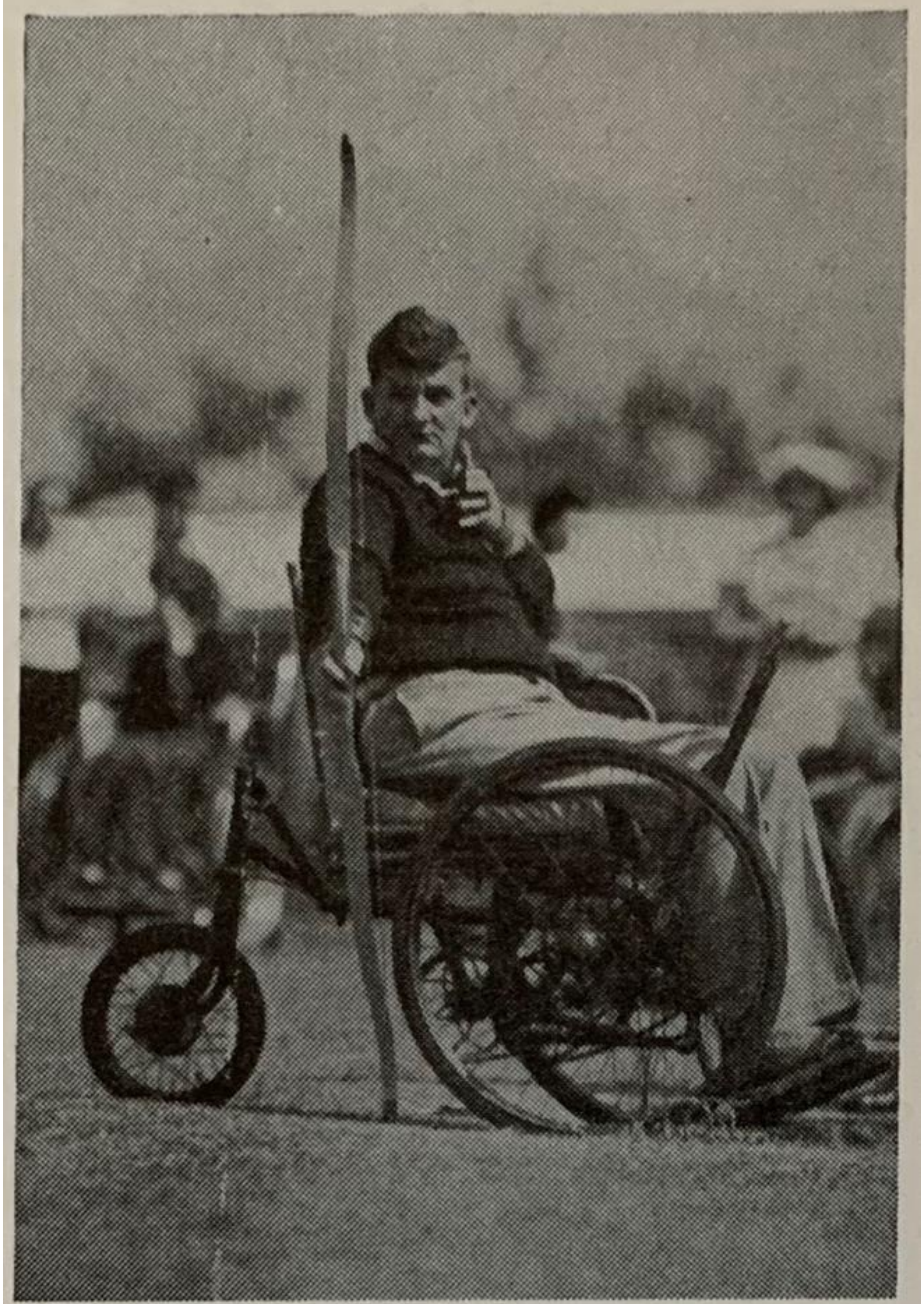
> "The sports not only increases physical strength and restores functions but are indispensable for rehabilitation of the disabled by inspiring them with the will to regain self-confidence and re-enter society as fully independent people."

This interpretation of disability sport is reinforced elsewhere in Frost’s research, which outlines a nationalistic rhetoric found in other promotional materials for the 1964 Games. It was argued that other countries had seen much success with sport as a new form of rehabilitation, and these benefits needed to be brought to Japan, for the good of Japan’s disabled population and national pride (Frost, 2020, pp.40-48). This logic progressed into the development of other disability sports events in Asia. Coinciding with the International Year of Disabled Persons by the United Nations in 1981, an annual wheelchair marathon was established in Oita, Japan, by Dr Nakamura Yutaka, who assisted in bringing the Paralympics to Japan (FESPIC, 1985). Wheelchair racing was promoted by medical professionals as the exercise targeted muscles in the upper body and assisted circulation in the lower body. By the 1983 event, the race was held under the joint sponsorship of the ISMGF (Oita International Wheelchair Marathon, 1983). A leaflet about the 1983 event outlined that the race's purpose was social rehabilitation (Oita International Wheelchair Marathon, 1983):

> "The aims are to promote the physical and psychological rehabilitation of the wheelchair-bound disabled persons by taking part in the marathon, asking for the participation of overseas and Japanese competitors and to call forth the independent will of the disabled to the society by joining the social economic activities positively."

Dr Nakamura also established the pan-Asian Far East and South Pacific Island (FESPIC) Games following the 1964 Paralympics, as he thought sports events focused on that region would spread awareness of the benefits of sport for disabled people. The first FESPIC Games were held in 1975, and during the Games' closing remarks, Nakamura reinforced this rehabilitative end goal: "Sports are important. However, employment is even more important. Let's work together to promote rehabilitation!" (Frost, 2020, pp.67-68).

Figure 3: Australian athlete John Keith O'Connell. (The Cord: International Journal for Paraplegics, 1960, p.6) ©WheelPower Stoke Mandeville Stadium Archive.



"Slim" O'Connell.

Wheelchair regulations assisted with the international proliferation of sport. Secondary and interviewee data reference that differences between wheelchair models varied considerably at early international competitions such as the Stoke Mandeville and FESPIC Games. *The Cord*, a journal published at Stoke Mandeville Hospital by and for patients, published photographs of sport events which provide insight into international differences in wheelchair design found in the 1950s and 1960s. Figure 3, for instance, showcases Australian athlete John Keith “Slim” O’Connell using a wheelchair with two large propulsion wheels at the front of the chair, and a single large protruding rear wheel. Whilst there was no standard for Global North nations, data suggests that athletes from countries in the Global South often only had access to wheelchairs of degraded quality or no wheelchair devices at all. As such, standard wheelchair models were supplied to athletes who required them during international sports events. Bailey (2008, p.28), for instance, gives a specific example of this during the 1964 Paralympics, as the American team were able to loan chairs to athletes from the Philippines to allow them to compete. Moreover, retired British wheelchair athlete and engineer Vincent Ross (69) recalled the differences in wheelchair design between nations in wheelchair basketball, highlighting the inequality between Global North and South nations:

> “We used to get people […] from Brazil and they [came] without wheelchairs, some of them. And when they got to Stoke Mandeville, they'd run round finding chairs for them to use. […] [Athletes from] Africa and South America, turned up with virtually no equipment at all […] people were pushing round on little trolleys on the floor and walking with very rudimentary callipers and crutches, and that sort of thing. […] there was a big difference between the haves and the have nots, basically.”

Practically, it was difficult to enforce standardisation of wheelchair models for each sport across nations. Within the ISMGF Technical Committee meetings of 1964 and 1970, Australian and Maltese representatives respectively raised the possibility of wheelchair standardisation (International Stoke Mandeville Games Federation, 1958-1974). In both instances, it was decided this goal was not practical but that it was ‘an ideal’ in principle. The inability to implement wheelchair standardisation rules likely reflected the wide variety of wheelchair devices used internationally, different commercial and political systems of wheelchair provision, and environmental and economic disparities across nations. Conceptually, wheelchair standardisation had practical benefits for competitive equality and shared rehabilitative approaches. However, it was not the aim of the ISMGF or similar organisations to provide wheelchair equipment for sport and rehabilitation purposes, but to assist in the reintegration of disabled people into the society in which they lived via sport (Anderson, 2003). Wheelchair regulations thus needed to be broad enough to afford a variety of wheelchair devices from different countries, whilst enforcing rules to ensure fairness between competitors (Guttmann, 1976, p.92). Rules for wheelchair basketball and racing introduced in the early 1960s, therefore, dictated limited aspects of wheelchair design, such as the number of wheels, the height of the seat, or the amount of lift a cushion could provide (International Stoke Mandeville Games Federation, 1960a; 1960b; 1958-1974). Recalling his experiences at international events in the 1970s and 1980s, retired Canadian wheelchair racer Paul Clark (63) commented on the balance between international differences in wheelchair devices and competitive equity.

> "The reason for those rules was to try and keep all countries as equal as possible. [Some] countries back then [didn't have the] technology that Canada[, the] United States […], or Europe had. […] the idea was to allow some of these countries […] to actually use their day-to-day chair and compete equitably with others, from other richer nations. […] they could do those simple modifications as well. And so it was a way of trying to equalise the playing field […] understand that it was... well meaning, but it was very limiting."

Societal reintegration was an important interpretation of wheelchair sport for medical professionals and governmental authorities. Alongside the medical benefits, the impact of disability sport on employment and social integration encouraged the international proliferation of disability sports events. In turn, the ISMGF needed to introduce wheelchair regulations which balanced the variations in wheelchair technology internationally. This ensured that the aspect of social rehabilitation could still be maintained as the games grew in scope. Such regulations limited athletic ability, as stated by Clark above. Nevertheless, this form of restriction matched the interpretation of sport as a recreational, not competitive, activity.

5.1.3 – Recreational sport

Whilst medical professionals prioritised wheelchair sport as a form of medical and social rehabilitation, the recreational and play aspects of sport also held significance. As shown in the previous sections, the structure and appeal of sport helped to motivate patients' involvement in physical exercise. Moreover, the rapid development of the SMG and other sport competitions, and the development of regulations for sports suggests that medical professionals in control of these programmes also placed value on the recreational aspects of sport. Divisions between the recreational and competitive interpretations of wheelchair sport emerged during the 1970s and 1980s, and differences between administration in the United Kingdom and United States highlight international differences in the competitive aspects of wheelchair sport.

Wheelchair sport developed quickly as an athletic endeavour whilst within a rehabilitative context. In 1948, the first SMG were held between paraplegic patients from Stoke Mandeville Hospital and the Star and Garter Home for Injured War Veterans at Richmond, Surrey (Brittain, 2012, p.5; Bailey, 2008). This was, in essence, an archery demonstration, with each team made up of eight athletes. In subsequent years, the Games developed rapidly, expanding to one-hundred-and-thirty athletes by 1952, hailing from a range of British and international teams, most of which were based in spinal injury units and rehabilitation centres (Brittain, 2012, p.13; Guttmann, 1976, pp.24-32). The 1960 Games in Rome featured four-hundred competitors, and the 1968 Games increased to seven-hundred-and-fifty competitors (International Stoke Mandeville Games Federation, 1972c, no pagination). Non-academic histories about the origins of the SMG are eager to highlight the enthusiasm from medical professionals for the recreational aspect of sport – this includes Susan Goodman's biography about Guttmann (1986), or Joan Scruton's autobiography and history of the movement (1998). The rapid development of the Games is also indicated by the physical development of Stoke Mandeville. Additional spaces for athletes' accommodation were constructed beside the hospital from mid-1950s to the 1980s (Air Mail, 1956), for instance, and Stoke Mandeville Stadium, the first sports centre designed for disabled athletes, was opened adjacent to Stoke Mandeville Hospital in 1969 (Guttmann, 1976, p.5; Department of Education, 1975). The growth of the SMG into an international event, the expansion of competitions worldwide, and the increase in scope and event types, also implies an athletic interest in wheelchair sport from the organisers.

However, the primary purpose of wheelchair sport for the ISMGF appeared to remain in the rehabilitative benefits of sport. This ensured that sport within the medical interpretation could only be recreational, as suggested by Guttmann's own words quoted in this subchapter's introduction (Guttmann, 1973). As found in the previous section, these statements served to devalue any competitive aspects of disability sport. Remarking on the number of competitors at the 1976 Games in Toronto, Canada, a statement found within a book recapping the event summarises the combined mix of recreational and rehabilitative attitudes found within the organising committee: "Not all of them were winners as far as medals were concerned, yet all were big winners just by competing" (International Stoke Mandeville Games Federation, 1976, no pagination). Such descriptions point to wider debates between those who interpreted disability sport being viewed as an imitation of sport – the aim of which served wider medical, economic, and rehabilitative goals – or elite, competitive sport in and of itself (Sainsbury, 2018). These debates continued as the Paralympic movement contended with other issues, such as the geopolitical debate concerning South African participation during the Apartheid era (Mallet and Sikes, 2023; Brittain, 2011; Bailey, 2008) or the inclusion of Paralympic events within the Olympics (Seoul Paralympic Organizing Committee, 1988a, p.3; Bailey, 2008). Throughout this period, it was largely athletes and disabled people within sports organisations who aimed to push disability sport away from the realm of medicine and rehabilitation.

Focusing upon wheelchair sport, Bailey (2008, p.20) highlights that the administration of wheelchair basketball in the United States was fundamentally different to the ISMGF. In the United States, many wheelchair basketball teams were linked to specific rehabilitation wards or acted as part of rehabilitation programmes such as the Illinois Gizz Kids. However, the organisation and administration of wheelchair sport featured increased involvement of disabled people. Dr Tim Nugent, Head of the Rehabilitation and Education Programme at the University of Illinois, was one of the founders of the National Wheelchair Basketball Association (NWBA) in 1949. The NWBA was formed by a combination of wheelchair basketball teams following an invitational national wheelchair basketball tournament held at the University of Illinois. The tournament was organised by Nugent in 1949, who recognised the social and medical rehabilitative value of sport competitions (Labanowich, 1995). Unlike the ISMGF, the NWBA was democratic (Bailey, 2008, p.20) and featured the involvement of players in key positions of the Executive Committee following Nugent's ideal that disabled athletes directed the evolution of the sport. (Labanowich, 1987). Following this principle, Nugent stepped down from a position of leadership in 1950, and was subsequently appointed as Technical Advisor to the committee, although he forfeited voting privileges as someone who was not a current or former athlete, nor a disabled person (Labanowich, 1995). The six teams which formed the NWBA were a mix of teams that were formed in Veterans Hospitals, where sport had been used as part of physiotherapy programmes, and 'homegrown' teams, formed by wheelchair users who wanted to keep playing basketball after their rehabilitation (Labanowich, 1995). American wheelchair basketball, therefore, developed with the explicit voices of players, unlike the ISMGF, in which the Technical Committee was driven by non-disabled medical practitioners (Labanowich and Thiboutot, 2011; Bailey, 2008; International Stoke Mandeville Games Federation, 1958-1974**;** Gold Cup, 1976).

This difference between administrations may be reflected in the origin of wheelchair regulations. Whilst the regulations of the ISMGF were developed to align with the concepts of social rehabilitation explored in the previous section, Thomas LaMere and Stan Labanowich (1984) outline that American wheelchair basketball players directed early regulations. The Kansas City Bulldozers wheelchair basketball team, for instance, first adopted rules in 1950 that required athletes use a "standard make" wheelchair, which was "propelled with the hands" and had footrests at standard heights. Whilst these rules did allow for some flexibility, they were later refined by the NWBA to specify a particular type of wheelchair. Between 1952 and 1953, the NWBA specified that the "official wheelchair" to be used was "the Everest and Jennings Standard Universal model or a chair meeting the same specifications, measurements and quality" (LaMere and Labanowich, 1984). Figures 4 and 5 showcase wheelchairs of this variety in use by American wheelchair athletes.

Figure 4: Photo of Basketball, played in E&J style wheelchairs. c1950. ©WheelPower Stoke Mandeville Stadium Archive.

Figure 5: Photo of Flying Wheels Basketball team players, played in E&J style wheelchairs. c1950. ©WheelPower Stoke Mandeville Stadium Archive.

These regulations ensured competition and fairness within sport, whilst prioritising the best wheelchair for sporting activity available at the time (this concept is explored in Chapter 6.1.1). By the 1950s, E&J was one of the biggest international wheelchair manufacturers on the market, gaining popularity for their folding wheelchair models which were comparatively the lightest wheelchair model available at the time. These chairs became increasingly popular with wheelchair users across the globe (Woods and

Watson, 2004; Williamson, 2019), as they allowed for increased user independence and for the chair to be stored easily in a car (Williamson, 2019, p.81; Tremblay, 1996, p.154). Indeed, E&J chairs were specifically provisioned by Canadian rehabilitation programmes in the 1940s on the advice of John Counsell, a wheelchair user and veteran, due to their improved mobility over other wheelchair models of the era (Trembley, 1996, pp.154-155). Accordingly, these chairs were better suited to sport than other chairs on the market at this time. The regulations of the NWBA thus followed the desires of athletes, who wanted to maximise their performance in basketball and advance a competitive interpretation of wheelchair sport (this concept is developed in Chapter 5.2.4).

The medical interpretation of sport framed sport activities as recreational, ultimately serving the purpose of rehabilitation. Medical administration ensured these values would be embedded into the SMG and other events as disability sport grew in popularity internationally. However, a competitive approach to wheelchair sport was found within American wheelchair sport organisations, who democratically afforded space for players' voices and ensured the use of the best available wheelchair technology for sport. These developments reinforce that medical interpretation of wheelchair sport varied internationally and organisationally.

5.1.4 – Conclusion

The medical interpretation of wheelchair sport had significant ramifications for wheelchair technology regulations and athletes. The actions and writings of medical professionals such as Guttmann show that sport was perceived as a tool of physiotherapy, social rehabilitation, and recreation. For this social group, wheelchair sport was therefore an extension of rehabilitative work. However, it would be reductive to argue that all medical professionals or sport administrators equally matched the zeal of Guttmann, or that their interpretation of sport remained static or similar across different nations and organisations. Nevertheless, medical interpretations of disability sport, centring on Stoke Mandeville, have largely been homogeneously grouped to reflect the principles of rehabilitation and recreational sport. The next subchapter explores later shifts within the evolution of disability sport, as internationally, athletes expressed frustration with the administrative control held by medical professionals at Stoke Mandeville and asserted their own interpretation of wheelchair sport as athletic competition.

5.2 – Wheelchair athletes' interpretation of sport

Wheelchair athletes developed their own interpretation of disability sport, as athletes identified political and social meaning in their athleticism and emphasised wheelchair sport as elite competition. Based on the technological frames in SCOT, the social, political, and experiential differences of athletes led to alternative perceptions of wheelchair sport and, in turn, wheelchair technology. Indeed, disabled people's perspectives on wheelchair sport formed by athletes also led to challenges to sport administration and the medical ideologies at their core.

This subchapter outlines four interpretations of wheelchair sport, reported by interviewees, all of whom competed in wheelchair sports such as basketball, racing, or rugby, in the late 1970s to the late 1980s or early 1990s. Supporting data was identified within archival and secondary sources, the majority of which was either written by athletes or reported the words of athletes. These sources highlighted the physiological, psychological, social, and political benefits of wheelchair sport, contextualising the appeal of competitive events. Athletes' desire for competitive sport ultimately served distinct political goals and led to significant change within the organisation and governance of disability sports. These interpretations indicate the motivation and circumstances behind the technological development of sport wheelchair devices.

5.2.1 – Sport as rehabilitation

This section explores the interpretation of wheelchair sport as a method of rehabilitation and how this narrative was presented throughout interviews with wheelchair athletes. Due to the implementation of sport in medicine, many interviewees began their interview with the rehabilitative aspects of wheelchair sport, as it framed their own introduction to these sports after they sustained spinal cord or other mobility-related injuries. For instance, Bosse Lindqvist (62), a retired wheelchair racer and wheelchair designer from Sweden, commented that the physical benefits of sport helped him to regain a sense of control following an accident which caused a spinal injury:

> "I had my accident when I was nineteen years old […] I'd have to take a nap in the middle of day to be able to be up until ten o'clock in the night. For me, when I was getting out of hospital, the reason I started with wheelchair racing, when I started back in '78 and training, it was just to be able to get my purpose back."

For Lindqvist, sport provided distinct medical and psychological support, improving his stamina but also providing meaning and purpose following his injury. This physical and psychological support appeared to become a vital part of Lindqvist's life, as later in the interview he detailed an intense daily training regime. Literature into modern disability sport emphasises the physical and psychological benefits of physical activity (Martin, 2013). Groff et al. (2009), for example, suggested that disabled individuals with strong investment in sport and athletic identity gain significant psychological benefits from sporting participation, as compared to those with less investment. Similarly, a meta-analysis conducted by Smith et al. (2018) found physical activity provided a range of physical benefits for disabled adults. Vitally, these benefits appear to exist across impairment groups, as shown by participants born with conditions such as spina bifida. Whilst not part of rehabilitation programmes, the impetus to play sport had similar physiological and psychological roots for these athletes. Baroness Tanni Grey-Thompson (51), for instance, was born with spina bifida and took up wheelchair sport as a young child. She spoke about how this was due to the physical benefits of sport beyond the racetrack:

> "…my parents very much encouraged me to be physically active, because... my father was an architect, and he knew how inaccessible [the] world was because he helped build it. And he recognised that being physically active was massively important to me

being able to live in this inaccessible world, so from the age of five and six, I started being active in my chair…"

This comment was akin to parts of the medical interpretation of sport explored in the previous subchapter, as sport was originally introduced in hospitals and rehabilitation wards to assist injured veterans in preparing for independent living and employment. Some interviewees emphasised the connection between wheelchair sport and employment, such as former wheelchair tennis player Peter Norfolk OBE (60):

> "Well, I had a motorcycle accident in '79, 1979 on Boxing Day, and I basically went back to work after I rehabilitated at Stoke Mandeville. Obviously, at Stoke Mandeville... it was very pro-sport, get back into sports, get exercise to get rehab."

Norfolk's comment indicates that in the immediate environment of the rehabilitation ward, sport was understood by athletes as a method of rehabilitation and social re-integration, with a focus on employment. However, Norfolk's later career in tennis, and establishment of a wheelchair supply company which sold sports wheelchairs, implies that this perspective altered over time, or took on multiple interpretations. Indeed, other interviewees initially framed their introduction to sport for its rehabilitative benefits, only to later highlight non-rehabilitative engagement with sport. This can be seen, for example, in interviews conducted with Rory Cooper and Vincent Ross. Cooper (60), an academic, engineer, and retired American wheelchair racer explained:

> "I became involved (in sport) when I was in the rehab hospital. I initially got involved because I had the good fortune to have Andy Fleming as one of my recreational therapists. …he, […] introduced me to wheelchair basketball."

Ross (69), a British wheelchair designer and former wheelchair athlete, likewise commented:

> “While I was in [the] spinal unit in Southport, there were quite a lot of people that came in and out that were involved in wheelchair sports. I was stuck in bed for quite some time, about eight weeks. So I saw them out the window of the intensive care ward […] playing basketball on outside courts […] what I did notice though after a while, was a lot of people that came in who were involved in wheelchair sport seemed to lead active lives. A lot of the people I saw who [came] in and out and not done anything once they had their injury were very ill and quite often died while they were in hospital. So I was quite keen after a while to get involved in some form of wheelchair activity or sports anyway.”

Following the above statements, the two interviews continued to show that both Ross and Cooper continued to play sport beyond its rehabilitative context. Cooper (60) stated:

> “[I] went back to college, I got re-introduced to wheelchair sports through a gentleman named Tim Davis […] So Tim and I started a wheelchair basketball team in San Luis Obispo, California; the SLO Motion Riders, and I convinced Tim that we should train to do a marathon. […] In 1982, Tim and I did our first marathon […] Tim and I wound up doing most of the race together, and then he kind of faded towards the end, and so I won my very first marathon and I was hooked.”

Whilst Ross (69) outlined:

> “So once I actually was up and about, [I was] gradually involved in wheelchair sport, usually table tennis, archery, and then eventually a little bit of wheelchair basketball. Once I actually left the spinal unit, I got involved with the local team, which was based at the... spinal unit, and started training, playing and went along to the National Games at Stoke Mandeville for the first time in 1974. … within a year […] I got more and more involved [with wheelchair basketball] and […] carried on with other sports including fencing […] and then got a little bit involved in wheelchair racing, and […] slalom. So I got more and more involved in wheelchair sport…”

The transition between rehabilitation to recreational enjoyment and competition is most noticeable in Ross' statement, as his initial interest into sport was explicitly linked to his recovery. Yet, Ross' continued involvement with local wheelchair sport, and later manufacturing of sporting wheelchairs, indicates an appeal beyond simple rehabilitation or recreation. Indeed, many interviewees continued to play their chosen sports at grassroots or professional levels for many years after their rehabilitation. Interviewees thus spent more interview time speaking of sport as a recreational or athletic pursuit, particularly as many described competitions they attended or how their sporting wheelchairs developed.

Yet, the extent to which generalisations can be made from these statements is unclear. Partially, this is because interviewees were aware of the focus of the research into sporting wheelchair technology. This may have encouraged interviewees to report on sport as competitive or athletic endeavours before the interview even started. As well, recruitment for the research was more likely to attract those who identified as elite athletes, or who remained involved with sport, as they continued to play their chosen sports and use or develop equipment for this purpose. It is possible there were a sizeable number of wheelchair users who did interpret sport purely as a form of treatment and therefore no longer pursued it following the end of their rehabilitation. Such perspectives are not addressed in the interview cohort for this research, by nature of the focus on sport technology.

Nevertheless, it is notable that interviewees who reported the rehabilitative benefits of sport often did so in ways which aligned with the benefits of sport as rehabilitation explored in Chapter 5.1. This suggests that wheelchair users still valued the rehabilitative role of wheelchair sport, particularly in their own experiences. In some cases, sport provided a sense of control over an injury or presented the most effective route to rehabilitation. Sport has clear medical benefits, which interviewees did acknowledge. Yet, they were also quick to outline other interpretations of sport, as the following sections will explore.

5.2.2 – Socio-political and gendered interpretations of sport

Disability sport refutes ableist and disablist attitudes which impact disabled people culturally, socially, and politically. Scholarship highlights how non-disabled sports can stimulate social change, challenging discrimination within individual sports (Long and Spracklen, 2011; Carrington et al., 2016) or within wider society. Using the example of athlete activists, Kaufman and Wolff (2010) argue that sport embodies certain characteristics, such as interdependency and responsible citizenship, which can facilitate progressive social change. Likewise, Shapiro (1993) argues that ‘sporty’ style wheelchairs became popular as a result of the disability rights movement in the United States, as this style of wheelchair refuted disablist perceptions of wheelchair users as inactive. Accordingly, disabled people interpreted wheelchair sport as having significant social and political consequences. This section highlights these interpretations, as interviewees spoke on the wider impact of sport on their self-confidence and gender identity.

Interviewees outlined that sport developed confidence and demonstrated self-sufficiency, as Swedish wheelchair designer and retired wheelchair athlete Bosse Lindqvist (62) stated:

> “I should say, in [the] beginning [of] the 80’s... for us, wheelchair racing was one thing to [help] be accepted in society, to show people even if you're in a wheelchair, you can do sport, you can go fast, you [can] live on your own, you [can] drive your own car, you do racing, you are training ten times a week. For us, it was a way of showing people that even if something happens to you […] you still can be active [and] you still can do a lot of things.”

Some interviewees spoke explicitly about how sport challenged their perception of their own disability. Abu Yilla, Clinical Assistant Professor of Kinesiology at the University of Texas at Arlington, played wheelchair basketball in England in the mid-1970s. Yilla had attended a specialist school, Chailey Heritage Craft School for Crippled Children, where they “played a lot of activities and made-up games”. Yilla (64) only discovered wheelchair basketball at Hereward College in Coventry in his late teens, and started to attend wheelchair basketball games following this.

> "…because I'd grown up in a school, for kids with disabilities, we're kind of isolated from the able-bodied population. And for me, I kind of always thought subconsciously that able-bodied people were better, which was kind of the message that was sent at the time. And I remember Pete (a wheelchair basketball player who took Yilla to training sessions and basketball competitions) telling me, one time he said, 'Abu, there's more cripples walking around than you'll ever see in a wheelchair.' And that kind of reframed my mind a little bit. And then, in my early experience of international wheelchair basketball for the first time, I saw people with disabilities actually in charge, the American team had wheelchair users as their coaches […] When I started playing wheelchair basketball, then I found that in particular at tournaments and so on, there were fully equipped adults who were rounded individuals."

Yilla presented sport as a space of belonging and identity formation (Maher et al., 2023). A functionalist interpretation of wheelchair sport may suggest that this environment acts as a socialising tool, reinforcing valuable behaviours (for example or physicality or leadership) and providing role models to embody said behaviours (Malcolm, 2016). This underlines the communal and emancipatory significance of sport organisations or teams led for and by disabled people (Bailey, 2008, p.20; Labanowich and Thiboutot, 2011). Moreover, Yilla (64) spoke to another aspect of confidence building, as wheelchair basketball helped to assert traditional traits of masculinity.

> "…we'd go to tournaments, drink too much and pick up girls! And that's really... in a lot of ways, politically incorrect. But it was kind of how I got a sense of my manhood, straight up. …Because in that environment, I was competing physically, with others, without constraint, which you couldn't really do anywhere else in society. Plus, [there] were girls coming out... to see the tournament, maybe pick up the guys."

Yilla's comments suggest that the appeal of wheelchair basketball, rugby, or racing were in the physicality of the sport, which made it encouraging to young disabled men in particular. In Yilla's testimony, wheelchair sport provided an outlet, allowing young disabled men to act in socially acceptable ways which reinforced their male identity. Other scholarship has noted that athleticism and physical ability and sport has become a marker of masculinity (Connell, 1995). Disability sport, therefore, presented the opportunity for physically disabled men to negotiate this aspect of their male identity and conform to hegemonic concepts of masculinity (Smith and Sparkes, 2002; Sparkes and Smith, 2003). This aspect of disability sport can be similarly identified elsewhere historically. According to Anderson (2011, pp.57-58), ex-servicemen from the First World War perceived sport as a way to re-assert their masculinity following impairment and was utilised by the British ex-servicemen home, St. Dunstan, to 'restore a sense of masculinity' in the 1920s. To this end, sport was socially potent in its role in constructing or reconstructing gender identity for disabled men throughout the twentieth century.

This is not to imply, however, that women did or do not compete in these activities or were alienated by gendered interpretations of sport. Nevertheless, when asked about gender diversity within wheelchair sport, interviewees generally reported there was a higher frequency of male athletes during the 1970s to the 1990s. A few interviewees presented the narrative that men were more likely to be injured, such as retired Scottish wheelchair basketball athlete, Gary Davidson (56):

> "It was mainly men, no doubt about it. And that was only because of, you know, different things. … you know, like wars, and things like that, you know, mostly then it was men."

Former American athlete and engineer Rory Cooper (60) presented a similar narrative, whilst acknowledging prominent female American racing athletes, such as "Sharon Hedrick, Candice Cable, Ann Cody, and Jean Driscoll". Indeed, many male interviewees who competed in wheelchair sports between the 1970s and 1990s, including Cooper, named wheelchair tennis athlete Marylin Hamilton as a prominent female figure in the history of wheelchair technology, as co-founder and public face of the lightweight wheelchair brand Quickie (see Chapter 7.2.2.1). Cooper also asserted that disability sport was not immune to gender disparities found globally in non-disabled sport. This sentiment was shared by former wheelchair racer Baroness Tanni Grey-Thompson, as she considered differences in media coverage of men and women's sport, and British wheelchair basketball athlete Judith Hamer, as she reflected on inequalities in contemporary wheelchair sport. Nevertheless, Cooper went on to reframe the question of gender around common experiences of ableism and disablism shared between disabled men and women:

> "[…] both men and women were encouraged to participate as part of their rehab programs. We participated side by side, and the other thing is, if you're the underdog - and I'm a man, so I can't speak for the women, but I can speak from my personal experience - we all had a common enemy... We were all treated pretty poorly by society, and... we all had a common goal of being respected as athletes and […] as people."

This narrative presented by Cooper therefore suggests that both female and male disabled people faced similar social and political barriers, which could be challenged via disability sport. This may be accurate to experiences of self-confidence and independence, and the perception of capability, which addressed wider societal stigmas facing many disabled people. However, interpretations of sport which were specifically masculine, such as that of Yilla, highlight a specifically gendered socio-cultural gap which wheelchair sport fulfilled. Alongside broader societal standards which identified DIY activities and engineering as 'male activities' (Smith, 2011; Wajcman, 1991; Sherrill, 2017), this gendered interpretation of sport may account for the high number of disabled male athletes who were involved in wheelchair design. Sport challenged ableism and disablism in wider society, whilst reinforcing traditional masculine traits for male wheelchair athletes.

5.2.3 – Community and competition

This section outlines the importance of wheelchair sport as social events for athletes and the impact this had on the development of wheelchair technology. Leisure activities are noted to be of great importance in the formation of community groups, particularly within functionalist interpretations of sport (Atherton, 2009; Malcolm, 2016). This has been identified in the history of other disabled groups, such as British Deaf communities in the mid-twentieth century (Atherton, 2007; 2009). Wheelchair athletes interviewed in this research highlighted the social appeal of sport. Sport facilitated the formation of communities, as wheelchair users shared experiences and knowledge with each other. Socialising was also vital for the technological development of wheelchairs and the athletic advancement of sport overall. Communal and social factors appealed to many and served as an important factor in the continued engagement with wheelchair sport beyond the rehabilitation ward. However, the competitive interpretation of wheelchair sport diminished some aspects of exchange and community formation.

Building on the concepts of social identity explored in the previous section, sport activities led to community formation and social participation (Duyan, 2007). Interactions with other wheelchair users inspired confidence in young disabled people, for instance, as noted in Abu Yilla's previous testimony (see Chapter 5.2.2). Yilla commented that engagement with wheelchair basketball helped to challenge his own negative perceptions of his impairment, as he was able to see wheelchair-using adults as independent individuals, or in roles of leadership within teams. This experience also reinforces the socio-political importance of sport, as it allowed disabled people to see people like themselves in roles of authority, which they may have been denied in other parts of society. Beyond this, wheelchair sport provided environments in which disabled people could share their experiences and develop connections with others of similar circumstances. Former British wheelchair rugby athlete Robin Tarr (56) outlined his personal experience:

> “The social aspect is huge. I mean, when I started playing the sport, it was purely... social, you used to go to a Leisure Centre, we'd talk for a bit, we played the sport, we'd have a laugh, then we go for a few beers, we'd talk about adaptations for cars, and living with a disability […] you mix with people like yourself, that you can learn from, and it's giving them confidence and strength. It has a multitude of benefits, (…) it's not just the competition. […] my early days, a lot of time... was predominantly going out and having beers […].”

Comments such as Tarr’s stress the importance of socialising within the appeal of wheelchair sport, as sport helped to establish communities of active wheelchair users. This aspect of community building is shared with other non-disabled sports (Edwards, 2017; Collins, 2016). However, sharing aspects of lived experience had increased significance for disabled communities (Atherton, 2009). Williamson (2019) details how disabled women in post-war America used a disability-focused magazine to detail experiences, share advice, and provide details of modifications to the home or home-made accessibility aids. Likewise, advice sharing can be found within the pages of wheelchair sport magazine *SPORTS ‘n’ SPOKES*. Article subjects encompassed sport wheelchair selection (Yilla, 1997), purchasing (Cooper, 1988), fit (Cooper et al., 2002), and maintenance (Gullet, 1997), amongst others. Social exchange was part of the atmosphere of sporting events, as athletes would discuss the advancement of wheelchair technology and other athletic developments, such as pushing techniques. Former wheelchair racer and head wheelchair racing coach at the University of Illinois Martin Morse (66) touched on this topic, as discussions with fellow athletes encouraged his later interest in challenging wheelchair sport administration.

> “One thing that (the) National Games and Stoke Mandeville had in common was they always had a social tent that was open after the competition each evening. […] everybody was talking about either how to make the chairs better, or how to make their bodies better. Always talking about training - and the sharing of ideas…”

The social atmosphere of competitions provided environments in which athletes could exchange ideas and develop a shared interpretation of wheelchair sport and technology. It is notable that comments by Morse and Tarr imply a recreational interpretation to these events in the 1970s. As explored in Chapter 5.1.3 and later shown in Chapter 5.2.4, wheelchair sport events were largely interpreted by organisers as recreational activities as opposed to competitive events, particularly at Stoke Mandeville. The interpretation of sport as a social activity appeared to diminish as the competitive interpretation of sport progressed in the 1980s and stabilised in the 1990s and 2000s, following the establishment of the IPC in 1989 (Polley, 2011; Bailey, 2008). For example, wheelchair sport events provided opportunities for athletes to share ideas and collaborate on wheelchair design, as American engineer and former racing athlete Rory Cooper (60) commented:

> "I would go to a race and see something new, and look at it is and say, 'You could do this better if…' A lot of us, would feed off each other to make designs better and just kept going from there."

By the late 1980s, competition, professionalism, and emerging commercialisation altered the atmosphere of events. Former American wheelchair racer Craig Blanchette, for instance, recalled placing a sheet over his devices at events in the 1990s as a form of strategy and psychological intimidation. This practice also worked to hide Blanchette's wheelchair from other competitors, to keep his designs a secret for as long as possible. Relatedly, in a newspaper article about wheelchair racing technology at the 1988 Seoul Paralympic Games, American wheelchair athlete Phil Carpenter commented that racers used telephoto lenses to analyse competitors' wheelchairs from afar (Seoul Paralympic Organizing Committee, 1988c, p.4). This practice seemed to emerge as elite wheelchair athletes established their own manufacturing firms (see Chapter 7.2), suggesting that there was a commercial advantage to secrecy. These changes suggest that aspects of community building around wheelchair sport and technology became less prevalent as the competitive interpretation of wheelchair sport took hold.

Interpreted through a social lens, wheelchair sport provided an environment in which communities of disabled athletes could be formed. Importantly, advice and ideas about independent living, sport, and technology could proliferate, creating shared technological frames (Lin and Silva, 2005). The social interpretation of sport, however, changed as elite athletes pushed for competitive interpretations of wheelchair sport and technology.

5.2.4 – Competitive sport

Beyond rehabilitative or social benefits, sport appealed to wheelchair users due to their interest in recreational or competitive sport. Competition is a fundamental criteria of sport activities, providing tangible outcomes to participants, and motivation for engagement in the form of winning or losing (Woods and Butler, 2020). Some wheelchair users may have been inclined towards this interpretation, having played sport before an impairment causing injury, whilst others born with conditions such as spina bifida were introduced to sports. Moreover, the shift towards competitive sport embodied athlete frustration with medical control over sport and wider changes in the Paralympic movement. As Brandmeyer and McBee (1986, p.182) summarised: “In the 1970s emphasis shifted from the original investment by health professionals in recreational sports for rehabilitational therapy to competitive sports for athletic prowess.” This section outlines that many wheelchair users were drawn to the athleticism of wheelchair sport and sought to move sport away from medical control and recreational activities to elite events.

Some interviewees reported an interest in wheelchair sports based on their existing interest in non-disabled sport. Following an injury sustained during the Vietnam war, American double amputee Jim Martinson (73) did not play sport as part of his rehabilitation.

> “…athletics was something that I really loved growing up, and I didn't know that I'd actually find sports... with the disability. […] I came across some folks […] playing wheelchair basketball. And this was in 1971 […] and I absolutely fell in love with it. […] I

met the guys and I liked it. I always wanted to beat everybody on the court. And so that was probably part of my... competitive nature. I grew up playing sports, I was always competitive."

Desire to compete led to technological innovation, as athletes worked to maximise their performance within the accepted rules (Seoul Paralympic Organizing Committee, 1988c, p.4). Canadian wheelchair racer Paul Clark (63) spoke of this when outlining his personal motivation to make new wheelchair devices:

> "…but for me, it was always the imagination of 'How can I go faster? How can I make this chair work better?' I mean, my mind was completely occupied with this whenever I was not doing my studies […] that was my whole motivation. I want to go faster. I want to be the best."

Many interviewees who competed in wheelchair racing were involved in sports such as cycling or motorcycling before sustaining injuries. Former British wheelchair racer Ian Thompson (66) stated that "wheelchair racing was a lot more like cycling" as compared to other wheelchair sports, indicating why it appealed to him. This previous involvement in similar athletic activities may also explain the impetus for wheelchair users to interpret wheelchair sport as competitive events. Seeing the similarities to established non-disabled sports, wheelchair users felt that wheelchair sport should be treated with the same competitive mindset. Furthermore, prior experience of other sporting technologies contributed to this interpretation. Thompson outlined why he began to adapt his wheelchair:

> "I was a cyclist, […] very much into mechanics, I think I built my first pair of wheels when I was about thirteen. […] always interested in taking things apart and trying to put them back together without too many spare pieces left at the end. And so the wheelchairs, yeah, I kind of adjusted mine a little bit with some washers and things like that. But partly what you're doing is you're learning the skills of what is possible to actually change."

The attitudes reported by interviewees reflected the growing competitive interpretation of wheelchair sport, in which athletes sought to reject the recreational view of disability sports held by medical professionals. As shown in Chapter 5.1.3, medical staff who controlled the ISMGF primarily saw sport and events recreationally, prioritising the medical and rehabilitative benefits of events such as the Paralympics. Whilst player-led sports administrations in America - for example the NWBA and National Wheelchair Athletics Association (NWAA) - seemingly recognised the competitive desires of athletes, Stoke Mandeville controlled the regulations and priorities of the Paralympics and other international events for a range of disability sports categories until the formation of the IPC in 1989 (Polley, 2011; Bailey, 2008; Frost, 2020). Many athletes wished for wheelchair sports to move beyond recreational competition – or more specifically, away from Stoke Mandeville and towards the Olympics (Brandmeyer and McBee, 1986).

By the 1980s, wheelchair and other disability sports had started to disconnect from their medical roots. A book recapping the 1980 Paralympic Games in Arnhem, the Netherlands, conducted a survey of athletes from the eighteen competing nations, tracing how disabled people were introduced to sport. Published by the organising committee, a narrative emerging from the book and survey within focuses on the lack of medical interest in sport. Reportedly, 54% of respondents were introduced to sport by friends or family, whilst only 8% were encouraged by medical staff to take part (International Stoke Mandeville Games Federation, 1980a, pp.114-115). The accompanying interpretation reads:

> “A distressing picture of disinterest from the medical profession [is found], especially where the useful effect of sport for handicapped people has already been scientifically and conclusively established […] A doctor who urges a handicapped person to take up sports not only promoted the health of that person but also helps his or her integration into society. Let’s get to work NOW!”

The call to action presented prioritises the interpretation of sport as a means of medical care and social rehabilitation (seen previously in Chapter 5.1). However, the data shows that events such as the Paralympics resonated with disabled people who approached sport external to a rehabilitative context. This shift can be demonstrated in athlete dissatisfaction with the administration and organisation of the Paralympics and International Stoke Mandeville Games. In 1979, an article printed in the official Journal of the Dutch Sports Organisation for the Disabled questioned the adequacy of Stoke Mandeville and ISMGF administrators for organising international sporting events. The author, Henk Halfman (1979), highlights the poor organisation of the International Stoke Mandeville Games and frames them as recreational sports events without competitive value: "The Tournament gives the atmosphere of a big international meeting of handicapped people who play Games […] the top athletes amongst the handicapped sportsmen […] have a right to a more worthy treatment". Similar organisational complaints were voiced at the time by athletes, for example Dutch wheelchair basketball player Henk Makkenze (International Stoke Mandeville Games Federation, 1980a, p.9), and Canadian wheelchair racer Paul Clark (undated). Both highlighted that poor organisation limited the competitive desires of athletes, reflecting the growing division between athletes and the medically-situated organisers.

Athlete action against administration emerged in the 1970s and 1980s, prominently seen in wheelchair basketball. Throughout the 1980s, for instance, athlete Sir Phillip Craven and sport scientist Horst Strohkendl, developed a functional system of classification to replace the medical system of classification (Labanowich and Thiboutot, 2011). The medical system was based on the examination of athletes on hospital examination tables, away from the court, and by practitioners "some of whom possessed little knowledge of wheelchair basketball" (Labanowich and Thiboutot, 2011, p.79). Asserting their own substantive expertise and lived experiences, Craven and Strohkendl's functional system was based on the ability of a player in a wheelchair on the court, and was importantly more effective at detecting athletes who aimed to cheat the classification system for an advantage (Craven, 1994; Labanowich and Thiboutot, 2011, p.80). Issues with the administration and regulations of wheelchair basketball were clear in Craven's testimony, as he framed restrictive rules as a result of medical professionals' only possessing interactional expertise in sport. In the below quote, Craven (70) reflected on wheelchair standardisation rules which restricted athletes' abilities during basketball games:

> "And they had a rule – of course set by medical people – that everybody had to play in the same chair. […] But those were the rules. Same for everybody. Well, that meant it fitted nobody, except maybe one in 100 people. So it was stupid. But that's [what happens] when you don't have sports people organising your sport... and the people who play the sport."

Craven's use of the word 'sport' in this quote implicitly implies the competitive interpretation of these activities. To Craven and other like-minded athletes, medical staff lacked the knowledge or expertise required for the competitive realisation of wheelchair and wider disability sports. Later in the interview, Craven (70) – who became the first President of the independent International Wheelchair Basketball Federation in 1993 and second President of the IPC in 2002 - stated that his interest in athlete-led sports administration came as he sought to challenge the medical interpretation of sport.

> "I got into the administration and really combating the way that medical doctors ran the Games, ran the Stoke Mandeville structure, and really most of them had no idea about sport. They were medical doctors, and I think that that's [why] the sport never went, in their minds, beyond wonderful rehabilitation."

The work of athletes such as Craven in the 1980s emerged as wider shifts within the Paralympic movement shifted disability sport away from medical establishments. Debate over South African participation in the Paralympics due to apartheid highlighted the organiser's view that disability sport was recreational, existing to serve medical aims (Sainsbury, 2018; Brittain, 2011). The ISMGF and related organisations promoted South African participation, following Guttmann's ideology that games should be accessible to all disabled people (Mallet and Sikes, 2021; Brittain, 2011). This stance was based on the argument that disability sport did not count as 'real sport' (Sainsbury, 2018; Mallet and

Sikes, 2021), reinforcing the primary medical interpretation of sport as a means of physical and social rehabilitation. In fact, the issue of South African participation forced disability sports into the same geopolitical scrutiny faced by the International Olympic Committee, promoting disability sport to a similar status (Bailey, 2008). Indeed, Sainsbury (2018, p.53) writes that the external pressures of South African participation in the 1976 and 1980 Games, combined with the death of Dr Sir Ludwig Guttmann in March 1980 (and thus the easing of his 'iron will'), afforded athletes more space to advocate for their interpretation of international sports events which prioritised competition. By the mid-1980s, athletes and coaches called for reorganisation, proposing that national and international disability sport organisations be linked and democratically organised, and that athletes would be classified based on functionality (Labanowich et al., 1984).

The shift from recreation to competitive sport was a political stance, as wheelchair athletes wanted to move beyond the purview of the hospital, assert the athletic potential of wheelchair sports, and provide opportunities for themselves within administration. Sport thus became a source of advocacy for these athletes, as they reconstructed themselves from patients to active agents and highlighted their athletic abilities. In 1988, Jens Bromann, President of the International Co-ordinating Committee of World Sports Organisations for the Disabled (which became the IPC in 1989), commented that when he was a goalball athlete, he "was looked upon more as a disabled person than as a sports-man" (Seoul Paralympic Organizing Committee, 1988a, p.3). In the article, Bromann expressed his frustration that media coverage conformed to the rehabilitative and recreational interpretation of sport. Later in the article, he stated: "I want sports for the disabled to be a genuine part of the sport movement." American wheelchair racer Rory Cooper (60) highlighted this ideology for wheelchair sport as he spoke about his role in challenging wheelchair sport administration in the late 1980s.

> "Most of us realised we wanted to advance the sport, and we wanted to show off our talents and our abilities. We wanted to participate in road races and marathons, so we could do it with other people. […] We had the exhibition 800 and 1500 meter [events at the Olympics], because we wanted people to see it as a sport."

Moreover, Cooper highlights the political implications of this shift in the ideology and administration of disability sport, as the move to competitive sport represented a form of disability advocacy.

> “It was actually a disability rights thing. So the sport changed from a medical model of helping people with disabilities, to a model of participation and independence, led by people with disabilities. […] at first, we had to declare our independence, then we could welcome other people back. […] we turned around and said, 'Well, we want to participate in sport, and we want to advance the sport as far as we can, so that we can be seen as athletes.’”

Division between the recreational and competitive interpretations of disability sport were central to the organisational and ideological evolution of the Paralympic movement. Medical professionals saw sport and international events as recreational, ultimately serving rehabilitative ends. In the 1970s and 1980s, however, disability sport began to move away from the field of medicine, driven by disabled athletes who wanted their sports to be recognised as elite athletic events on par with the Olympics and other non-disabled sports. Within wheelchair sport, this change was partly embodied by changes in wheelchair technology. Yilla (2004, p.32), for instance, equates the development of rigid wheelchair frames for sport with the functionalist interpretation of wheelchair sport asserted by athletes such as Craven. As will be shown in Chapters 6 and 7, the creation of sport-specific wheelchair devices by lead users embodied athletes’ desire to advance competitive wheelchair sports.

5.2.5 – Conclusion

Wheelchair users found distinct social and political importance to sporting activities, establishing their own interpretations of wheelchair sport. Sport provided psychological benefits, identity affirmation, and community building, all of which influenced athletes’ interpretation of disability sports as something distinct from the medical sphere. Indeed, as wheelchair sport grew, many wanted to distance these events from their medical origins. The growth in the competitive interpretation of sport developed alongside wider changes within sports administration. These factors resulted in athletes advocating for representation within governance organisations, and the rejection of the medical ideology behind the original Paralympic movement. This new technological frame formed the basis of the social group who reinterpreted wheelchair devices as elite sporting equipment and modified existing wheelchairs to match their competitive goals.

5.3 – Chapter conclusion

Athlete and medical practitioner interpretations of wheelchair sport diverged due to differences in perspective and power. Certain aspects, such as the physiological and psychological benefits of sport, were shared between these social groups. However, Guttmann and other medical practitioners used their interactional expertise to ground sport activities in medicine and rehabilitation and proliferate a recreational interpretation of sporting activities internationally. Sport was primarily a means of physical and social rehabilitation, which was treated differently to non-disabled sport. Disabled athletes asserted a new approach as their competitive desires were undermined. Disabled people wanted their sports to be treated comparatively to non-disabled sports events, as a wider symbol of political and social equality. Competitive wheelchair sport allowed athletes to highlight their capabilities, challenging wider societal stigmas around impairment, and assert their substantive expertise as athletes. Disabled people advocated for their interpretation of wheelchair sport to protest medical ideologies which reduced athletes to patients.

From this technological frame, disabled athletes can be identified as a critical social group as they reinterpreted the equipment used in sport. Wheelchair technology contained a disability script that embodied a medical interpretation of disability and restricted competitive sport. Athletes therefore modified existing wheelchairs and created new active and sport-focused wheelchair devices to better suit their competitive desires. The next chapter traces the technological changes wheelchair devices underwent, materially embodying wheelchair athletes' interpretation of wheelchair sport.

Chapter 6 – Technological evolution of sport wheelchair devices

Wheelchair design was stagnant by the mid-twentieth century. For practitioners and engineers, the purpose and function of wheelchair design was fixed, and not open to the suggestions of users (Brubaker, 1986; Woods and Watson, 2004). These devices were unsuited to athletes' interpretation of competitive wheelchair sport. Based on their technological frames (Bijker, 1993), athletes accordingly took innovation into their own hands (Stewart and Watson, 2019; Brady, 2023). This trend marked the opening of interpretative flexibility as users modified their existing devices, or created new ones, and developed new forms and functions for wheelchair artefacts. Patterns of closure, stabilisation, and the re-opening of interpretative flexibility can be observed as specific varieties of sport and active everyday wheelchair models came to the market. The eventual stabilisation of these designs created new sub-categories of manual wheelchair models, focused on particular sports, and codified the concept of distinct sport wheelchair models.

This chapter draws on concepts of technological flexibility, closure, and stabilisation present in SCOT – previously outlined in Chapter 3.1.2 – to chart the evolution of sport wheelchair devices. Wheelchair athletes' substantive expertise and status as agents of sociotechnical change (Kline and Pinch, 1996) is also established in this chapter, as athletes drove innovation and modification. The chapter begins with an exploration of wheelchair devices used during the initial development of wheelchair basketball. This subchapter considers initial American standardisation rules in the mid-twentieth century for the E&J standard universal model, and later athletes' reported frustrations with these devices. This subchapter also considers the limitations of these wheelchair models as everyday wheelchairs, due to the use of the same wheelchairs in sport and daily life. The second subchapter considers a range of generalised modifications undertaken by athletes for sporting use, with a focus on wheelchair basketball and wheelchair racing. This subchapter is split into four chronological sections, as wheelchair modification evolved from the removal of certain design features to the creation of new wheelchair frames, and changes to chair shape and functionality. The last subchapter considers the stabilisation of sport wheelchair technology. This is explored in the transition from multi-purpose chairs to the evolution of multiple distinct sport wheelchair models used in wheelchair tennis, racing, and rugby. Finally, this subchapter considers the impact of wheelchair customisation and design practices on the stabilisation of modern sport wheelchair models.

6.1 – Opening of Technological Flexibility

The development of sport wheelchair technology began as wheelchair users and athletes assessed the wheelchair models available to them, and identified the inadequacies of contemporary devices for their competitive interpretations of wheelchair sport. In basketball, athletes required devices that enabled rapid movement across the court, were responsive for manoeuvring and passing the ball, and were rigid enough to withstand contact. As detailed in Chapter 5.1.3, athletes identified that certain models of wheelchairs were more suited for sport and active daily life by the 1950s. This led to the emergence of early standardisation rules, stabilising the initial form sporting or active wheelchair technology took. However, subsequent generations of athletes still identified problems with these wheelchairs. These models were heavy and unresponsive, and restricted both sport and independent daily use (Stewart and Watson, 2019). The identification of these problems opened technological flexibility, as wheelchair users sought to address the limitations of these chairs for sport and everyday life. In this process, the boundary between sport and everyday wheelchairs became blurred, due to the benefits of basketball modifications for daily use.

This subchapter explores this initial period of technological development, contextualising later modifications and designs which wheelchair users created. This subchapter aims to do this by considering the wheelchairs which were initially used for sport, how athletes reacted to these devices, and the wider benefits of technological change. The first section details the initial preference towards E&J wheelchairs amongst athletes, and the regulations established in wheelchair basketball to standardise the use of this type of wheelchair. The second section discusses the limitations of E&J style wheelchairs, as a later generation of athletes identified technological problems with this design and resisted standardisation rules. The final section highlights the inadequacy of the E&J design for daily use, and the thin divide between sport and everyday chairs at this time.

6.1.1 – Wheelchair design and initial standardisation

In the initial decades of wheelchair sport, athletes worked to identify the best existing model for competitive purposes. Early wheelchair models were inscribed with ableist assumptions of wheelchair users, and configured wheelchair users by limiting active and sporting uses of their wheelchairs (Woods and Watson, 2004; Stewart and Watson, 2019). However, athletes quickly identified E&J wheelchair models as the best option for use in basketball, and as noted in Chapter 5.1.3, this preference was solidified in NWBA rules by the 1950s. Athlete preference can thus be understood as an initial form of technological stability.

Early into the establishment of wheelchair basketball in the United States, the Everest and Jennings Standard Universal model was the lightest wheelchair available (Labanowich and Thiboutot, 2011). Contemporary athletes recognised the advantages of these wheelchair models over others. Labanowich and Thiboutot (2011) outline the success of US, Canadian, and Israeli teams in basketball in the 1950s and 1960s due to their use of E&J products, which were lighter than wheelchairs used in the United Kingdom and other parts of Western Europe (Tremblay, 1996). A key incident leading to E&J wheelchair stabilisation came in a 1955 game at Stoke Mandeville, between the American Pan Am Jets team and British wheelchair basketball players from Stoke Mandeville Hospital and the Lyme Green Settlement. The Travaux wheelchairs used by British athletes weighed between 27kg and 36kg (60-80 lbs) whereas the E&J models weighed around 25kg (55 lbs) (Labanowich and Thiboutot, 2011, p.237). As well, the large propulsion wheels were placed at the rear of the E&J device, affording the user a better pushing position and greater manoeuvrability and responsiveness (Labanowich and Thiboutot, 2011). Consequently, the American team had a significant advantage over the British teams, and easily won each game.

E&J wheelchairs were seemingly designed in a way that better suited the nature of wheelchair basketball, and became widely adopted by athletes across the US, indicating closure amongst wheelchair athletes. This led to NWBA regulations which restricted basketball athletes to chairs similar in shape and dimensions to the E&J chair (LaMere and Labanowich, 1984) and prevented any powered or lever-operated chairs from being used (Labanowich and Thiboutot, 2011, p.239). Paul Stones, a member of the American 1960 Paralympic Basketball team, recalled the attitudes towards different wheelchair designs in correspondence with Labanowich and Thiboutot (2011, p.46):

> "And the wheelchairs! There were chairs of every description. I vividly remember a South Rhodesian athlete with a chair that was chain-driven by hand cranks and a Belgian athlete who played basketball in an upholstered chair that looked like something you would find in your living room. I can't imagine how heavy that one must have been and how hard it must have been to [manoeuvre]."

Standardisation regulations appeared to have been introduced to ensure fairness and to prevent the type of technological advantage experienced at Stoke Mandeville in 1955. LaMere and Labanowich (1984) state that regulating wheelchair technology allowed sport to focus on athletes' abilities, rather than the differences between wheelchair varieties. Athletes also found the technological specifications of the E&J wheelchair presented certain advantages beyond basketball. The lighter weight and mobility were preferable for active everyday use, and wheelchair users accordingly compared other wheelchair designs to the E&J model (Woods and Watson, 2004; Williamson, 2019). E&J wheelchairs also held advantages for other sports. Comparing NHS provided wheelchairs to the E&J model, British wheelchair racer Paul Cartwright (56) commented:

> "If you had a standard [NHS] wheelchair, it was pretty difficult [to use for racing]. But then all of a sudden, people realised - In fact I realised - that if you could get hold of the Everest & Jennings chair, which was again an everyday wheelchair, it had a bigger [rear] wheel. It was a much better wheelchair all around. I think it had a 24-inch (rear

wheel) whereas standard wheelchairs had a 20-inch or maybe a 22-inch, I think. And of course, you could get a bit more power out of the Everest & Jennings wheelchair than you could out of the standard wheelchair that was being provided [at] that time."

Stabilisation occurred as preference for the E&J style was accepted across other social groups, such as sports administrators, medical professionals, and engineers (Bijker, 1995, p.87). For instance, the company's dominance in the American and non-European international markets ensured that many wheelchair users already used E&J's products, making closure and stabilisation economically advantageous (Tremblay, 1996, Borisoff, 2010). Other wheelchair producers, for example, Stainless or the British Ministry of Health, began to produce wheelchairs which imitated E&J's design in the 1950s and 1960s (Woods and Watson, 2004; Labanowich and Thiboutot, 2011). This trend is also indicated by changes to new ISMGF rules introduced in the 1960s and 1970s (see Chapter 5.1.2).

Differences in wheelchair designs internationally led to inequality in sport, preventing sport from reflecting athletes' abilities. Athletes created an early form of technological stabilisation, as these wheelchair designs were identified as the best devices for their interpretation of wheelchair sports, which impacted rules and subsequent wheelchair design. Later generations of athletes began to identify problems with these devices, leading to resistance to these standardised chairs, and the re-opening of technological flexibility.

6.1.2 – Limitations of Everest and Jennings wheelchairs

A new generation of athletes, wishing to further competitive sport, identified limitations of the E&J wheelchair. In this section, athlete testimony is used to outline technological problems and manufacturer stagnation which resulted in the re-opening of technological flexibility for athletes. Fifteen of twenty[8] relevant interviewees made some type of negative reference to medically designed and/or hospital provided wheelchairs. These testimonies came from active wheelchair users who competed in wheelchair basketball, racing, or other wheelchair sports between the mid 1970s and early 1990s.

Generally, interviewees first used medically designed wheelchairs for athletic purposes, including the Everest & Jennings Standard Universal Model, or other comparable designs. These wheelchairs were acquired or provided by institutions or healthcare providers as part of their rehabilitation. Despite slight variations in these wheelchair models, all interviewees highlighted similar frustrations with these devices, due to the restrictions they placed on their athletic abilities. Former British wheelchair athletes Robin Tarr (rugby), Sir Phillip Craven, and Maurice Hammerton (basketball) all highlighted design aspects which limited their athletic abilities. Tarr (56) commented on the weight of the wheelchair:

> "…when I first had my accident, the hospital issued me with a chrome Everest & Jennings wheelchair, it was around 56 pounds in weight. So [a] huge lump of a chair to push around. […] at that point they didn't [get damaged in games], you just couldn't propel the chairs the amount of speed [like] today."

Craven (70) also referenced the problem of weight, but expanded on other design issues found with the front caster wheels:

> "The other problem […] was that you got quite a lot of vibration on your casters, [which] were seven inch […] once you got up a certain speed, it started vibrating […] so you had to fine tune them, because they still had to spin, but they mustn't spin too

[8] From Table 1, number includes Abu Yilla, David Constantine, David Hall, Gary Davidson, Ian Thompson, Jalle Jungnell, Jim Martinson, Maurice Hammerton, Martin Morse, Phillip Craven, Paul Clark, Paul Cartwright, Peter Norfolk, Robin Tarr, and Vincent Ross.

> much. You know, there mustn't be any play. And even then you had to look to, 'Well, is this caster completely round, or is it slightly off centre?' Because they weren't purpose built at all. So there's a lot of things you had to work out and maintain, you had to maintain them in top condition, you know, and that went on until the late 70s."

Wheelchair manufacturers such as E&J did not configure their products for sport activities, so active users like Craven had to regularly repair and adjust their wheelchairs for continued athletic use. When commenting on weight, Hammerton (59) similarly recalled that E&J wheelchairs were not intended for sport:

> "They didn't work very well, they were very heavy, and just weren't very good at all. And when we complained about them, the attitude was basically […] 'these are to get you from A to B, they're not really typically [made] to play sport.' And so that was what we were up against in those days […] a big metal, stainless steel frame, really heavy."

Further problems associated with E&J wheelchairs were found in other interview testimony and secondary literature. In an interview conducted for the Smithsonian Museum, Marylin Hamilton, co-founder of the lightweight wheelchair brand Quickie, referred to the E&J wheelchair she used following her accident as a "80-pound dinosaur" (Hamilton, 2021, p.10). In the May 2000 issue of Basketball News, Phillip Craven retrospectively described the E&J chairs as "gladiatorial" and specified that the placement of the rear wheel axel and the folding mechanism limited manoeuvrability and turning speeds (Labanowich and Thiboutot, 2011, p.244). These problems impacted performance in court sports - basketball, rugby, and tennis - where the responsiveness and manoeuvrability of the player were of great importance. Moreover, these devices presented specific limitations for certain sports. For instance, weight impacted acceleration in racing, whereas athlete safety was a significant concern in contact sports such as basketball or rugby. Robin Tarr (56) reflected on athlete injuries in early wheelchair rugby games in the 1980s:

> "The main injuries [were] to yourself rather than the chairs, players were having broken toes and cracking heads from falls and things like that, because obviously, your feet [were] protruding from the chair, so they [were] getting caught in people's chairs. You were […] falling from your chair, because there's no adequate strapping. So you're going out sideways and backwards."

The inadequacies of these wheelchair models for recreational or competitive sport were thus a recurring complaint in the data, and emerge as the key reason behind athlete-led innovation and flexibility within wheelchair design. Importantly, some interviewee testimony regarding this inadequacy concluded that this was because sport was a not a primary consideration to designers for these chairs, as seen in Hammerton and Craven's previous quotations. This indicates that existing wheelchair technology was fixed, inscribed with a specific purpose, and intended for inactive users. This disability script (Ravneberg and Söderström, 2017; Olaussen, 2010) made the device inflexible to alternative uses, and constrained users' athletic desires. Athletes continued to face these technological problems as designs did not change to match the new use case of recreational or elite-level sport.

A lack of innovation in wheelchair design and manufacturing was identified in the United States from the early twentieth century, caused by a fear of medical rejection of new designs (Brubaker, 1986; Stewart and Watson, 2019) and the near-monopolistic control of E&J over the American and International manual wheelchair market by the 1970s (Borisoff, 2010; Shapiro, 1993, p.216). A range of wheelchair designs were explored by British government ministries in the mid-twentieth century. However, these models were created following the input of medical professionals, and often ignored the perspectives or suggestions of wheelchair users, thus limiting positive developments for the end user experience (Woods and Watson, 2004). Interviewee testimony indicates athlete frustration with technological stagnation. Former wheelchair racer, designer, and founder of wheelchair manufacturer Magic in Motion, Jim Martinson (73), commented:

”…we'd say, 'All the rest of the world […] they're building […] cool stuff.' You know... flying airplanes… [but the] wheelchair guys [said] 'Well, we'll just keep doing that 60lbs wheelchair.' […] That's what... really caused me to build the racing chair, going 'This is stupid. Why [are] they [selling] a 60lbs [wheelchair?]“

Alongside medical professionals who governed wheelchair sport regulations (see Chapter 5.1), manufacturers such as E&J restricted athletes’ interpretation of competitive sport. Speaking about standardisation rules which favoured E&J wheelchairs in basketball, Craven commented:

“… of course, all the developments were not by... if Everest and Jennings were the main company at the time, they didn't do any of the innovation. It all came from players.”

Athlete frustration with performance and stagnation of wheelchair design thus prompted new interpretations of these devices. Users desired wheelchairs which could accommodate their active lifestyles, including sport and independent mobility. Subsequent acts of tinkering, modification and creation enacted by athletes emerged due to deviations from the existing approach to wheelchair technology and design, based on athletes’ lived experiences of using these devices. This new interpretation, in turn, led to new designs, as the form and function of wheelchair devices reflected users’ sporting desires.

6.1.3 – Sport modifications for daily use

Beyond sport, technical stagnation had an impact on the everyday use of wheelchair artefacts. Interviewees, along with primary and secondary data, outlined that in the early era of wheelchair sport, users used the same device for sport and day-to-day life (Stewart and Watson, 2019). This indicates that problematic elements of these chairs, such as the weight or rigidity, also impacted everyday use of wheelchair models. Modifications for sport and everyday use were interconnected, as initial changes to weight and responsiveness benefited multiple use-cases. The following section considers the connection between sport and everyday use, to outline the wider impact of sport wheelchair modification, and the lack of specific wheelchair models at this time.

From the inception of wheelchair sport in the 1940s to the 1980s, the vast majority of wheelchair users operated the same wheelchair in sport and everyday life. Modifications made for sport had to consider the non-sporting use of the device. For example, many athletes temporarily removed brakes to reduce weight during games, and re-attached them for non-sporting use (Stewart and Watson, 2019, p.12). Other athletes chose to remove breaks and other unnecessary features, such as armrests, as a permanent weight reduction. Stewart and Watson (2019) note that these modifications carried multiple social interpretations beyond weight removal, but fundamentally the technological change benefited both sport and everyday function. The inadequacy of wheelchair technology in non-sporting contexts thus influenced users' new approach to design. Speaking about a later time period, Paul Clark (63), a retired Canadian wheelchair racer, recalled that his desire for modification came as a result of general frustration with everyday wheelchairs. But significantly, these thoughts benefited his later interest in racing wheelchair technology:

> "At the time, there [were] very few modifications or sports available for disabled [people]. And for me, I didn't know anything about sports. […] I was [wheeling] to and from my school […] in my wheelchair, and being frustrated with my chair tracking so much toward the curb, and not staying in the middle of the road, and the front wheel bobbling, and not being able to go faster. And this was the impetus in starting some designs to go faster…"

Other interviewees commented on the symbiosis between every day and sport wheelchairs, as many of the sporting modifications could be integrated into everyday use. Former British wheelchair tennis athlete Peter Norfolk OBE (60) expressed this idea briefly, when he compared tinkering with his wheelchair as compared to the bike he rode before his motorcycle accident:

> ”Used to hate tinkering with the bike. I never used to deal with punctures. It [wheelchair modification] was because I liked it. I liked the chairs, and because I was using it all the time, I transferred a lot of [it] into my day chair as well.”

In professional engineering environments, the benefit of sporting modifications was also apparent. Bosse Lindqvist (62), former wheelchair athlete and wheelchair designer, similarly highlights this overlap that emerged in his employment as an engineer for Swedish assistive technology company ETAC:

> “The things we [were] putting on our racing chairs, that [used] to make people's everyday living- we picked up things from the racing chair, like camber on the rear wheel, to make the chair go straighter, to be more stable when you’re pushing it. …we took a lot of technology from racing, and put it into regular chairs. And that I could say we did [that] from beginning of the 80s until [the] mid 90s. We picked up a lot of things [at the] end of ‘80s, because at that time we could [transfer] thing[s] from a racing chair, put it on the regular chair, but later on the racing chairs were getting more extreme [than] regular chairs.”

Sporting modifications therefore carried technological importance beyond the court or racetrack. Rear wheel camber, for instance, angled the large back wheels of the inward at the top, creating a more stable wheelchair and a better pushing angle for users (more detail on this modification is provided in Chapter 6.2.2). Camber had practical benefits in both sport and everyday life. For instance, increased stability provided by the profile of the cambered wheels reduced both chair and user falling to the floor upon impact. Other sporting innovations had benefit in the everyday use of the device, such as weight reduction, the removal of the folding mechanism, and changes in seat and frame materials.

Wheelchair users and manufactures began to reclassify sport modifications as lightweight models. This can be observed in the pages of wheelchair sport magazine *SPORTS ‘n’*

SPOKES. The magazine hosted an annual wheelchair survey from 1983 to 2009, listing different wheelchair models available to consumers. In 1983 and 1984, the survey had a distinct sport focus, reflected in the title '1984 survey of Sport Wheelchair Manufacturers' (Crase, 1984). In 1985, part of the title was changed from 'Sport Wheelchairs' to Lightweight Wheelchairs', to reflect the growing consumer audience for active wheelchair devices (Crase, 1985). In the introduction to the 1985 survey, *SPORTS 'n' SPOKES* managing editor Nancy Crase (1985, p.31) outlined changes in consumer preferences, stating:

> "As the sport wheelchair phenomenon spread, manufacturers were asked by buyers for features that were not normally available on their sport chair models, but would be useful in everyday use of the sport chair."

This change indicates the wider benefits of sport modifications, and their acceptance by wheelchair users as solutions to the problems of existing wheelchair design. Chapter 6.3 therefore considers the evolving status of wheelchair categorisation, as the division between sport and everyday use became more apparent in the late 1980s and 1990s.

As athletes rejected technological standardisation in sport, and began to modify their chairs, new developments benefited other uses of their wheelchairs. Several innovations could still be transferred to everyday wheelchairs, as indicated by Norfolk. Lindqvist's final comment about racing wheelchair technology, however, highlights that sport wheelchairs were developing into their own, sport specific, branch of wheelchair technology. Over time, athletes gradually began to create specialised equipment, which could no longer be used for both sport and everyday use.

6.1.4 – Conclusion

Innovation in sport wheelchair technology started as athletes evaluated the usefulness of existing wheelchair designs for their interpretation of sport. Whilst early athlete-led standardisation rules imply a preference for the E&J-style design, later re-appraisal resulted in modifications which better reflected athletes' desire for competitive sport. Moreover, changes to wheelchair design benefitted the everyday use of these devices, providing additional significance to these modifications. As athletes continued to advocate for their competitive interpretation of wheelchair sport, changes to wheelchair designs afforded improved sporting performance and everyday use, encouraging further modification and innovation. The next subchapter details the modifications implemented by wheelchair athletes in more detail, highlighting significant alterations to manual wheelchair technology, and the eventual creation of sport-specific wheelchair models.

6.2 – Innovations for sport

Having identified problems with existing wheelchair technology, interpretative flexibility again opened for wheelchair users. This subchapter seeks to chronologically outline some of the modifications created by wheelchair athletes as reported by interviewees and identified in visual sources and other primary and secondary data. This will demonstrate how wheelchairs used in sport evolved across the later decades of the twentieth century, and athletes' role as users within technological innovation (Kline and Pinch, 1996; Oudshoorn and Pinch, 2003). Interviewees indicated that technological development was based around trial-and-error testing and incremental changes. However, by relying on interviewees recollections, the 'key' or most significant alterations may be identified.

The subchapter is split into three sections. The first highlights the initial removal of unnecessary design features, which benefited both sport and everyday use. These acts are analysed as acts of 'world-making' and political expression, as athletes altered existing devices to fit their goal of competitive sport. The second section explores radical shifts in wheelchair design, focusing on the introduction of lightweight rigid wheelchair frames and rear wheel camber. The development of the rigid frame showcases the non-linear development of sport wheelchair devices, as competitive advances were not universally adopted until combined with other design features. The third section considers the interconnected nature of small design adjustments to frames, wheels, and seating positions, which impacted weight, balance, and manoeuvrability. This final section additionally highlights the growth of sport-specific modifications, as athletes adjusted their devices for different sports. This subchapter largely focuses on the style of manual sport wheelchairs used in basketball and racing events.

6.2.1 – Removal of unnecessary parts

An early type of modification carried out by wheelchair users was to minimise, modify or remove parts of their medically provided wheelchairs that were not considered necessary (Labanowich and Thiboutot, 2011). These modifications could be understood as 'world making' (Hamraie and Fritsch, 2019; Dokumaci, 2023) actions as wheelchair users altered the physical affordances of medical wheelchair devices to enable improved athletic performance. These acts of modification had additional significance, as removing parts allowed athletes to reject medical ideologies inscribed into wheelchair devices, and assert the need for customisation in design.

Initial modifications to E&J style wheelchairs highlighted by interviewees included armrests, back rests, and back-facing push handles. British wheelchair basketball players Abu Yilla and Vincent Ross described initial modifications made to their NHS provided wheelchairs. Yilla (64) stated:

> "When I started, we'd get like, almost hospital looking chairs. And then we'd have to cut off the side guards, cut off the brakes, cut down the backs. Cut [and] sew the canvas. To make it suitable for basketball."

Likewise, Ross (69) commented:

> "The chair you used all the time, you just made some modifications to it for wheelchair sport, which was mostly things like, taking the brakes off, taking the armrests off, maybe cutting the back rest down a little bit so it wasn't so far up your back."

Design features or parts of existing wheelchair models such as backrests limited athletic performance. High back rests reportedly restricted the twisting of the upper body, particularly for those with more upper body movement. In basketball, this obstructed the ability to shoot and pass to teammates, leading many to cut down their backrests to their level of need. Similarly, lower armrests allowed for the player to reach out for the ball more easily (Labanowich and Thiboutot, 2011, pp.242-243). Former wheelchair basketball player Sir Phillip Craven recalled removing armrests to make moving the basketball easier:

> “I'd cut down the armrests, because you didn't need them, [if they were] up too high... that protected the ball if it was on your knee, but it then stopped you from moving it off quickly and all that, so yeah, relatively low armrests - if you had armrests at all…”

Beyond providing specific benefits in basketball, parts were removed to reduce the weight of medically designed wheelchairs (Labanowich and Thiboutot, 2011, p.243; Stewart and Watson, 2019). Weight reduction made chairs more manoeuvrable, quicker, and improved handling. This practice did not eliminate the heaviness of such wheelchair models entirely (Labanowich and Thiboutot, 2011, pp.243-244), and future wheelchair models employed new frames, materials, and wheels which eliminated issues associated with earlier models. The material qualities of medically provided wheelchair devices therefore only afforded specific actions that athletes could take (Hsu, 2008). Removal of features including armrests or the general reduction of weight altered the affordances of the wheelchair, enabling athletes to make their worldview of competitive wheelchair sport a reality.

These actions held further significance. Firstly, the removal of unneeded parts demonstrated a rejection of medicalised design, which emphasised safety and comfort. For example, armrests were utilised as a safety barrier, to prevent users from falling out of their chairs (Stewart and Watson, 2019, p.12). Whilst useful for some users, not all required armrests. Design choices were implemented without, or with a disregard for, the input of wheelchair users. Additionally, retired American wheelchair racer Martin Morse (66) indicated that the removal of features such as push handles exemplified the new world-view associated with sport equipment, demonstrating a deliberate choice to differentiate these models from medical designs.

> "In order to be legal in the NWAA you had to have push handles on the back. Like, it's not an [everyday] chair, you're not going to need anybody to push you anywhere [...] when the rule was changed in 1981, everybody took a hacksaw to them and cut them off. It was excess weight."

The removal of push handles also carried an implied rejection of negative perceptions of disability, which constructed users as incapable and dependent on others. A lack of push handles removed the physical affordance associated with these thoughts, allowing the device and user to be conceptualised differently. Morse indicates this above, as he implies that an athlete using a racing chair did not need - or want - to be pushed around in their wheelchair. It should be noted that interviewees did not generally make an explicit political connection to these actions, and they were generally highlighted for their performance benefits. Nevertheless, this framing is in line with the re-interpretation of disability sport described in Chapter 5. Removing push handles represented the prioritisation of competitive sport over medicalised interpretations of wheelchair devices and disabled people (Yilla, 2004). Whilst athletes themselves did not use this language at the time, basketball coach and administrator Stan Labanowich and former wheelchair athlete Armand Thiboutot (2011, p.242) retrospectively defined these early acts of modification as "an expression of self-determination", indicating the political significance underpinning wheelchair modification.

Secondly, the removal of unnecessary parts was also tied into the later need for athlete customisation in wheelchair design (see Chapter 6.3.3). Initial modifications did not suit all athletes. Sir Phillip Craven, and former Swedish wheelchair basketball player and wheelchair manufacturer Jalle Jungnell, both highlighted how the reduction of back rests favoured wheelchair users with more upper body stability. Craven (70) stated:

> "And Jerry [Kinsella], of course, my best mate […] he had some limited movement in his upper legs, he was a polio, but he had very good trunk muscles. So I had my NHS wheelchair. And I thought, well- Jerry, of course, could sit upright without any back support, really, because he had all those muscles. And at that time, I wasn't aware of that, so I just took a hacksaw to the back of my chair, and then realised that I couldn't even balance in it!"

Jungnell (67) similarly explained :

> "When I started playing basketball, all the Everest & Jennings we had, the only thing people did … was to cut the backrest. So I remember the polio guys and the amputees who had very good balance […] they cut the backrest to maybe 10 centimetres or something. And then they could lean back, when breaking or when turning […] I'm a high paraplegic, I can't do that."

As athletes defied manufacturer and medical design in order to improve their athletic performance, differences in individual functionality resulted in wheelchair design becoming personalised to the end user. Certain modifications could be shared and standardised between athletes and across sport wheelchair models, but simultaneously had to match the athletes' functionality. This is akin to the shift from medical to functional classification in basketball (Craven, 1994; Labanowich and Thiboutot, 2011, p.80), as the competitive interpretation of sport emphasised disabled people's athletic capabilities, as opposed to their medical classification.

The removal of features deemed unnecessary by users served a multitude of competitive benefits. Firstly, this practice spearheaded the design philosophy of customisation, as recognition grew that one design did not benefit all wheelchair users. Secondly, for those who could remove those design features, these modifications reduced weight and improved mobility, altering the affordances of the device, and leading to better performance. Finally, the removal of these parts also served a political dimension, as users figuratively rejected design features which embodied negative attitudes towards disabled people. This initiated the athlete-led development of wheelchair devices with a specific sporting purpose.

6.2.2 – Rigid or box frame chairs

One of the most notable technological developments by the late 1960s and 1970s was the introduction of rigid or box frame wheelchairs. Interviewee and secondary sources frequently highlighted this innovation, due to the dramatic evolution in performance these types of chairs provided. Athletes created these new designs, centring their substantive expertise in the evolution of both sporting and everyday wheelchair models. Designs incorporated innovations such as wheel camber directly into the frame, whilst utilising new, lighter materials (Stewart and Watson, 2019). However, the benefits of the rigid frame design were not initially accepted when first introduced in the 1960s. This section considers the non-linear acceptance of active wheelchair design, as the rigid frame can now be identified as one of the most significant innovations in the history of sport wheelchair technology.

Rigid or box frame chairs were designed to replace wheelchair frames which often incorporated folding mechanisms. Athletes reported frustration with folding wheelchairs, partially as the mechanism impacted rigidity and manoeuvrability in sport, as commented by Sir Phillip Craven:

> "The folding chair had a tendency, when you pulled on your left wheel to turn left, the frame would tend to slightly fold with the folding mechanism, and it wouldn't swing around as fast."

Athletes sought to develop new wheelchair frames, which removed the folding mechanism, instead creating a fixed box shape. This made the chairs more stable and less prone to breakages. The creation of new wheelchair frames also provided designers with the ability to integrate other developments, including changes to rear axle positioning which benefited balance and user control. This was an important development, as prior modifications were made onto existing chair frames, and thus had to work around the limitations of a design unintended for sporting use. New wheelchair frames, alternatively, could implement competitive modifications into the initial design of the device. Firstly, chairs could be built without arm rests, high back rests, or push handles. Secondly, these chairs could be custom made to users' needs, and adjustable aspects such as the rear wheel axel placement could be built directly into the frame. Thirdly, aluminium, titanium, and other new composite materials were used for these frames, which were lighter and more durable than steel frames commonly built by previous wheelchair manufacturers.

The first version of the rigid style frame was developed by American basketball athlete Loral 'Bud' Rumple and Joseph Jones in the late 1960s (Craven, 1994**;** Stewart and Watson, 2019). According to Labanowich and Thiboutot (2011, pp.245-247), the 'Rumple Chair' weighed around 16kg (35 lbs), around 11kg (25 lbs) less than the E&J chairs used by American athletes at the time. Rumple's chair eliminated unnecessary parts including armrests and push handles and altered the position of the rear wheel axel. Further significant innovations included anti-tip casters at the back of the frame, which prevented players falling out of their wheelchair when tilting backwards (anti-tip wheels are explored in more detail in Chapter 6.3.1), and rear wheel camber. Camber refers to the angle of the wheel, in which the tip of the wheel was closer to the athlete and the bottom of the wheel spread outwards from the user, giving the chair a larger footprint and wider profile. Camber provided greater lateral stability and improved handling due to the lowering of the sitting position, and also gave users a better pushing angle and greater hand protection during collisions with other players. Significantly, camber also altered the visual profile of the wheelchair, creating a distinct shape for active wheelchair models to embody. American basketball players who used the Rumple chair, such as the Detroit team, saw increased victories against other basketball teams (Labanowich and Thiboutot, 2011, p.247; LaMere and Labanowich, 1984) highlighting the distinct performance advantage this new wheelchair design provided. The Rumple chair was thus revolutionary for basketball, embodying the functional competitive interpretation of sport which emphasised sporting use over medical design philosophies (Yilla, 2004).

Figure 6: Denver Branum in a Rumple Wheelchair, c. late 1970s. Labanowich, S. and Thiboutot, A. 'Tip' (2011), p.246.

However, the Rumple chair was not widely adopted by American wheelchair athletes (Labanowich and Thiboutot, 2011, p.247). Despite the issues of folding mechanisms in sport, and the Rumple chairs' performance advantage, many athletes were reportedly concerned that the wheelchair could not easily be transported. Retired wheelchair athlete and former wheelchair designer Marty Ball recalled that athletes had to fully assemble the wheelchair at competition venues (Ball, 2002, p.31):

"It was amazing to see his teams enter a gym with suitcases, open them, take out various lengths of pipe, then assemble those pipes into basketball wheelchairs."

The device could not be easily or quickly folded to fit into a car, an issue for players traveling for games, or wanting to use the Rumple chair beyond the court. This indicates that athletes' interpretation of sport wheelchairs was not simply based on competitive advantages, but also the practical use or transportation of the device.

Later innovations in rigid wheelchair design drew from Rumple's inventions, but solved issues of transportation and adjustment that prevented earlier athletes from adopting the device. Dissatisfied with wheelchair frames on the market, American wheelchair athlete Jeff Minnebraker experimented with making wheelchair frames out of aluminium in the early 1970s, a version of which can be seen in Figure 7 (Labanowich and Thiboutot, 2011, p.250). Unlike the Rumple chair, Minnebraker's wheelchairs included a quick-release rear axle which allowed for the rear wheels to be removed, aiding transportation. Minnebraker's wheelchair also included a plate on either side of the wheelchair with multiple corresponding holes to allow for the position of the rear wheel axel to be altered. This was important for adjusting the manoeuvrability of the wheelchair, changing the centre of balance for different users, and function, as different types of balance was more advantageous on the court than in everyday use. In 1976, Minnebraker started Quadra Wheelchair Inc with fellow athlete Brad Parks, building wheelchairs in Minnebraker's garage (Vogel, 2012).

Figure 7: Jeff Minnebraker using one of his first rigid style chairs to play tennis. c1977. Bunting, S. (2001), p.10.

Minnebraker's Quadra wheelchairs were more readily accepted than Rumple's wheelchairs years prior. From the athletic perspective, Labanowich and Thiboutot (2011, p.251) state that Quadra wheelchairs faced less resistance as Minnebraker's team were not 'seen as competitive.' Whilst the Detroit team's success showcased the competitive potential of sport-intended wheelchair design, the lack of athlete uptake may imply it was not seen as fair or equitably competitive. Therefore, advantageous wheelchair designs needed to be introduced in way fair to a wider audience of players – possibly observable by the fact that Quadra sold their wheelchairs reportedly at a loss to ensure wheelchair users could access them (Vogel, 2012). However, other wheelchair users and athletes created similar modification to Quadra within the same time period, suggesting that internationally athletes had more access to competitive modifications. Swiss wheelchair athlete and designer Rainer Küschall, for instance, created the Varioblock system in the mid 1970s, which allowed for the rear axle to be adjusted akin to the Quadra chair, reportedly offering between nine and twelve different potential wheel axel positions (Küschall, R., 2011; Newman, Undated) Likewise, Dutch athlete Henk Makkenze experimented with cambered rear wheels (Labanowich and Thiboutot, 2011, p.251). Former British wheelchair basketball athlete Sir Phillip Craven (70) described the impact of camber on Makkenze's performance in the mid 1970s:

> "He was the only player with this chair. And it was amazing how... the manoeuvrability of it was just unbelievable."

Importantly, athletes often collaborated with or copied one another (as highlighted in Chapter 5.2.3). Swedish wheelchair racer and wheelchair designer Bo Lindqvist, for instance, stated that he would try designs he saw in the wheelchair sport magazine *SPORTS 'n' SPOKES*, partly as "[There were] a small amount of chairs we could receive from the US [in Sweden]." Moreover, British wheelchair athlete and wheelchair designer Vincent Ross (69) commented he was inspired to make an aluminium box-frame wheelchair after observing American teams at the 1979 Gold Cup, an international wheelchair basketball competition now known as the World Wheelchair Basketball Championship (Gold Cup, 1976):

> "…at that competition, there [were] a lot of American players who had chairs that had been made out of aluminium tubes. And when I saw those chairs and the way they performed, and had a go in a couple of them, when we came home from the Gold Cup, I decided I'd make one for myself."

Ross went onto build several of these rigid, lightweight wheelchairs for other British basketball athletes for the 1980 Paralympics. This allowed more athletes to use and observe these wheelchairs, leading to the acceptance of these modifications for competitive use. Former British wheelchair basketball athlete Maurice Hammerton (59) outlined the advantages of the wheelchair made by Ross for the 1980 Paralympics:

> "…it was just so much better, and much lighter than what [I was] used to playing in. And it was the rigid frame. So, instead of folding up, it was just the box frame […] that was a revelation really, playing in that. […] It was very boxy, very square, very rugged looking aluminium. Not particularly elegant, but very effective. Very light. And I don't remember the weight, but it was probably about half the weight of what I've been used to using before. And just so much more manoeuvrable."

However, Phillip Craven (70) indicated that adoption of the rigid frame may have been dependent on the implementation of other modifications alongside the new frame. He stated that by the 1980s, a French wheelchair manufacturer had begun to sell box frame wheelchairs, but that this model lacked rear wheel cambering. He commented:

> "…the cambering came in slightly later. ...I didn't [have a box frame], I kept to my E&J because it wasn't that big a difference, because the cambering hadn't come in, you know. So, it was really the cambering and the positioning of the rear axle that really made the biggest difference."

Craven (70) later outlined the improved performance of his Quadra wheelchair, which he purchased in 1980, as these models incorporated rear-axle changes and camber into a rigid frame:

> "…the manoeuvrability that [the Quadra] would give me, I mean, once I went past three guys, just by... and I can't move my hips, but I just did a bit with my upper body. And I went left, then I went right, and they couldn't believe it and went into the key to score – and I think they all bought one after that."

Acceptance of these wheelchair designs happened as multiple athletes across the globe experimented with similar designs and innovations, and a range of beneficial modifications were implemented at similar times. This links to the non-linear model of technological development found in SCOT (see Chapter 3.1) (Bijker, 1995). The innovations of the rigid frame wheelchair could be accepted once multiple problems were addressed. In the 1960s, Rumple and Jones began to address the technological or performance problem at the core of athletes' reinterpretation of wheelchair sport. However, the problems of competitiveness and access to a range of innovations were solved as new wheelchair models continued to be designed and distributed.

The significance of the rigid frame wheelchair can be observed in the application of these sport-intended designs for active, everyday wheelchair users. As examined by Stewart and Watson (2019), the evolution of everyday wheelchair devices drew heavily from innovations introduced in sport. Sport innovations solved problems experienced by wheelchair users off the court, leading to the creation of the 'ultralightweight' wheelchair (Stewart and Watson, 2019). As will be explored in Chapters 6.3 and 7.2, wheelchair users established businesses to repackage sport technologies for non-athletic audiences. This underscores the significance of the rigid wheelchair design, as it functions as a critical development point for multiple varieties of manual wheelchair devices.

6.2.3 – Wheels, positioning, and seating

Alongside rigid wheelchair frames, athletes experimented with a range of other modifications across the 1970s and 1980s which impacted athletic performance. Building on the last section, many of these modifications had interconnected benefits, reinforcing the importance of tinkering and experimentation to the non-linear development of sport wheelchair technology. In implementing these changes, athletes began to identify the need for different wheelchair designs for different sports.

Interviewee data highlights a range of modifications across wheelchair sports, which included:

- Changing the size of the front and rear wheels. Larger rear wheels (and front wheels in racing) have less rolling resistance, increasing speed. Court sports such as basketball reduced the size of the front wheels to ensure manoeuvrability.
- Cambering of wheelchair rear wheels. This could be achieved by modifications to the rear wheel axel, such as adding washers to create an imbalance and angle the

wheels. Figure 8 shows an alternative method, which utilises a thin metal plate called a camber bar which could be added to the ‘X’ shape mechanism of folding wheelchair models, altering the crossing point of the bars to make the bottom of the chair angle outward. Figure 9 shows extreme cases of camber in the late 1970s employed by racing athletes Garry Kerr and Brad Parks.

- Increasing the size of push rims on the rear wheel, allowing for easier pushing position.
- Altering the position of the rear wheel axel, which sacrificed balance to make the wheelchair more responsive in basketball and other court sports.
- Creating new seating positions for specific sports. Upright sitting positions for court sports were reinforced with new seat cushion materials. Figure 10 shows that some racing athletes would cut seat canvas and modified seats to allow for athletes to sit lower in the wheelchair, creating improving pushing positions. Later, bucket style seats were added to dedicated racing wheelchairs.

Figure 8: Image of camber bar, with pen for scale. Shared with permission of Paul Clark.

Figure 9: Garry Kerr (right) and Brad Parks (left), in modified wheelchairs for racing. Early example of cambered wheels. c1979. Shared with permission of John Brewer.

Figure 10: Example of seat modification for racing. c1979. Shared with permission of John Brewer.

Interviewees’ comments suggest the combination of modifications introduced by athletes had an interconnected impact on performance. These modifications were often mentioned together in interviews, implying their implementation occurred at similar points in time. The below comments by British wheelchair tennis player Peter Norfolk OBE and American wheelchair racer Martin Morse highlight the role of experimentation to identify the best performance for the user. Describing the initial wheelchair he used for racing, Morse (66) commented:

> “…within about a couple of weeks of owning [my first wheelchair], I started modifying it. Going to lighter rear wheels, experimenting with different steering mechanisms. … I experimented with ways to adjust the toe-in-toe-out of the rear wheels, made sure the front wheels were rolling straight, {tried various types of tyres and wheel bearings to

find the pair that rolled the best.} I experimented with different strapping systems…"

Norfolk (60) provided a similar statement, invoking his personal experience of changes to his mobility, which required a new wheelchair configuration for his career in tennis:

> "I spent many years keep on adapting to find the right height, the right bucket, the right straps, tyres, wheels, bearings. […] as your game changes, you need the chair to do different things."

It could therefore be inferred that athletes simply experimented to find the correct adjustments to solve a range of issues. Within basketball, for instance, many modifications altered balance, weight distribution, and manoeuvrability. British basketball athlete and wheelchair designer Vincent Ross (69) explained the relationship between these factors when experimenting with wheel positioning:

> "The further you move the wheels forward, the more manoeuvrable the chair becomes, because your weight is […] right in the middle of the chair. […] But that makes it very easy to go over backwards. So you have to have a balance between where you could sit with the wheels as far forward as you could get them, but you wouldn't fall out backwards very easily."

Other modifications which altered balance included changes to front and rear wheel sizes, or the adjustment of the rear wheel axle (Labanowich and Thiboutot, 2011). Adjustments to the axle position greatly improved balance, altering the placement of the wheels to the users' centre of gravity and seating position. Interview data reported that this modification additionally benefitted pushing techniques and wheelchair manoeuvrability, as athletes had better reach to their rear wheel push rims. Beyond safety, improvements to balance therefore assisted athletes in compensating for the heavy weight of non-rigid wheelchair models. Weight was also reduced via the introduction of thinner wheels and tubular tyres, which helped increase responsiveness to users' inputs.

Wheelchair racers similarly used multiple modifications to solve problems for their sport. Like basketball players, racing athletes aimed to reduce weight, but this was targeted to different areas of the wheelchair. Swedish racer and wheelchair designer Bosse Lindqvist (62) outlined changes made to his wheelchair to reduce weight and rolling resistance:

> "You took away the arm rest [and] the backrest, you kept down the backrest height… You changed the footrest, [added] simple plates so you could change the centre of gravity of a chair, so you [could] get the rear wheel [in] a little bit [of a] better position and you could take away weight from the front end to get the chair a little bit lighter [and] roll easier."

Racers thus used a range of modifications to reduce the weight of the chair in specific areas. Alterations in seating positions, similarly, improved balance and provided more efficient transfer of energy between the users' arms and the rear wheels. When describing racing chair modifications implemented in the late 1970s and early 1980s, Canadian wheelchair athlete Paul Clark (63) highlighted the benefits of the bucket seat design, which brought the base of the seat lower and allowed the athlete to move their knees closer to their chest. This seating position benefited Clark's balance:

> "But for me, [the bucket seat shape] helped me with stability […], side to side, but it also allows for a better use of any abdominals [I] have…"

He continued, stating that the new seating position improved his propulsion of the wheelchair:

> "It would also slim up my hips slightly so that I could bring my wheels closer together, because the narrower I could have my chair, the better I could get a push all around the wheel."

The multitude of performance benefits that emerged from modifications across basketball and racing indicates the interconnected nature of wheelchair modifications. This points to a non-linear development of sport wheelchair technology, as athletes explored multiple routes of innovation. Indeed, as athletes experimented, approaches to design for specific uses emerged, solving design problems facing athletes in different sports. As will be shown in the next subchapter, this led to the specialisation of wheelchair models for specific sports, alongside the distinction between sport and everyday wheelchair models.

6.2.4 – Conclusion

By the middle of the 1980s, wheelchair athletes had redefined wheelchair technology. Modification to medical style wheelchairs led to the creation of lighter and more manoeuvrable devices. Wheelchair athletes asserted their self-determination, modifying their wheelchairs to fit their competitive interpretation of sport. Moreover, the majority of these modifications benefited everyday use of these devices, which continued to be an important concern whilst athletes used the same wheelchairs in sport and everyday life. Indeed, the creation of rigid wheelchair frames further redefined wheelchairs as devices that could be used by active and competitive disabled people. Technological flexibility allowed athletes to decode the assumptions about wheelchair use embedded into existing wheelchair models, and encode the idea of active and competitive disabled people (Mackay et al., 2000). This marked the closing of technological flexibility, opened by athletes' identifications of problems with medical devices for sport or active lifestyle purposes. For elite athletes, continued innovation also encouraged the creation of sport-specific equipment, unburdened by the constraints of non-sporting use. Manual wheelchair designs thus did not remain stable, as athlete further optimised sports wheelchairs for specific athletic uses.

6.3 – Stabilisation and customisation

From the mid 1980s, wheelchair athletes and designers began to create sport-specific wheelchair models. This shift represented a significant step in the re-interpretation of wheelchair devices. Originally, interpretative flexibility opened as users desired lightweight, active manual wheelchairs that enabled sport and active daily use. However, the closure of athletes' problems did not automatically lead to the final stabilisation of wheelchair devices, and elite-level athletes identified that sport-specific models would enhance their athletic performance. Within this process, new approaches to wheelchair manufacturing and design occurred, building on the modifications previously developed. The categorisation of wheelchair models altered accordingly, separating sport and everyday wheelchair technology, and formalising sub-categories of sport-specific wheelchair models.

This subchapter explores the stabilisation of sport wheelchair models. The first section utilises the example of the anti-tip wheel to consider athletes' preference for sport-specific wheelchair models, particularly in basketball, and the stabilisation of sport-focused equipment. The second section then examines the evolution and stabilisation of three different types of sport wheelchair varieties: tennis wheelchairs, racing wheelchairs, and rugby wheelchairs. Finally, the third section examines the importance of end user customisation for sport wheelchair models, and the impact this had on the technological stability of these devices.

6.3.1 – Sport wheelchair specification

The continued development of sport wheelchair technology necessitated the distinction between sport and everyday wheelchair models. New modifications introduced by athletes greatly benefited sport, but restricted day-to-day use if too extreme. This section focuses on the introduction of anti-tip wheels in basketball and other court sports as an example of this type of modification. The advantages and implementation of features such as anti-tip wheels or extreme rear wheel camber demonstrate that the distinction between sport and everyday wheelchair models was necessary for elite athletes.

Active wheelchair users not involved with competitive sport wanted everyday wheelchair models that benefited from sport developments including weight reduction and slight wheel camber. Separate categorisations of wheelchair devices emerged, initially perceivable in wheelchair manufacturer advertisements and changes to the *SPORTS 'n' SPOKES* annual surveys (see Chapter 6.1.3). In the 1980s, manufacturers such as Quickie began to sell ultralightweight wheelchairs to active everyday users (Stewart and Watson, 2019; Williamson, 2019). The 'sporty' and colourful design of the Quickie and similar wheelchair models appealed to disabled people who disliked their heavy, hospital provided chrome wheelchairs. In the US, Shapiro (1993, p.213) links this trend to the American disability rights movement, as sport designs allowed users to see wheelchair devices as a source of pride. Advertisements for other wheelchair brands including Swede 24 (Simonds, 1985), and Steepers (1983) show that by the mid-1980s sport and everyday wheelchair models were offered as distinct products.

These wheelchair models were almost identical in design. Swedish manufacturer ETAC, for instance, sold the Swede brand of wheelchairs. Figure 11 shows a sales flyer from the mid 1980s for the Swede Champ (their active everyday wheelchair) and Figure 12 shows the Swede F2 (their generic sport wheelchair). Aside from their visual similarity, these advertisements detail that the basic design of each models shared the same materials (Steel frame, nylon upholstery), rear wheels (24-inch quick release with pneumatic tyres and stainless-steel hand rims), and frames (rigid frame chair with adjustable footrest and 3 degrees of rear wheel camber) (Simonds, 1985). The only differences between the models were the increased adjustability of the sport wheelchair's backrest and rear wheel axle balance, and the larger front caster wheels. The minor technological distinctions between generic sport and active everyday wheelchairs of this time indicate the wheelchair's role as a boundary object, which can be classified differently based on interpretation of function and purpose. In this instance, manufacturer and consumer interpretation of sport modifications separated active wheelchairs into sport and everyday categories– ultimately allowing sport-specific wheel modifications to further benefit elite athletes’ competitive desires.

Figure 11: Advertisement for the Swede Champ. Simonds, (1985). ©WheelPower Stoke Mandeville Stadium Archive.

Figure 12: Advertisement for the Swede 24 F2. Simonds, (1985). ©WheelPower Stoke Mandeville Stadium Archive.

As disability sports transitioned away from the administration of medical professionals in the late 1980s and early 1990s (see Chapter 5.2.4), sport-specific technical modifications further transformed wheelchair sports. Anti-tip wheels, for instance, presented major benefits for court-based sports – notably basketball, rugby, and tennis. Athletes across these sports made many references to falling out of their chairs, either due to poor balance or collisions. When describing the wheelchairs initially used for rugby, for instance, former British wheelchair rugby player Robin Tarr (56) commented:

> “They [were] the chairs that we would use […] every day, but they [were] also the chairs that we'd use for sport. … So you had no stability, so there's no strapping, we didn't wear gloves, and there was no anti-tips on the chair. So, the main aim of the game was actually staying in the chair more than anything else.”

These issues to player safety were initially addressed by changes to axle positioning and camber, as previously discussed in Chapter 6.2. However, basketball and tennis athletes experimented with attaching an additional caster wheel to the back of their wheelchair to provide greater stability and balance as early as the Rumple chair in the 1960s (Labanowich and Thiboutot, 2011, pp.245-247). The anti-tip wheel further afforded designers to re-consider axel positioning and other features to ensure optimum performance, as stability was less of a concern. Former wheelchair basketball athlete and wheelchair designer Vincent Ross (69) explained the benefits of anti-tip wheels:

> “The anti-tip wheels made- it was almost impossible to go out backwards. So you could have the chair set up to the optimum performance, rather than stability and safety basically.”

Moreover, retired wheelchair basketball athlete Abu Yilla (64) highlighted how anti-tip wheels altered athlete performance for those of different classification groups:

> “People started putting the additional wheel in the back. What that allowed people like me, who had lower classification point […] we had to have our back wheels a bit further back, so that it's stable, because we can't use our core to force the chair down. So if your […] main wheel is too far forward, you'd tip [over…] someone came up with the idea of the fifth wheel on the back of the chair. And, again, unexpected consequences. When higher class athletes put that wheel on the back, they could then tilt sideways and backwards as well, using the fifth wheel, and [traditionalists,] wanted to ban that additional wheel.”

Anti-tip wheels therefore made wheelchair sports more competitive, allowing lower point players - athletes with limited trunk movement – to stay in their equipment and take advantage of more responsive wheelchairs. For higher point players with more trunk movement, anti-tip wheels allowed players to create new movement techniques, changing how basketball was played. As a sport focused modification, anti-tip wheels greatly benefited athletes' abilities, either by enhancing the abilities of lower-point players, or adding new techniques to the sport.

Restrictions on anti-tip wheels, on the other hand, highlight the tension between sport and everyday use. Wheelchair basketball regulations enforced by the ISMGF from as early as 1972, for instance, state that "No additional wheels" were to be allowed on basketball athletes' wheelchairs, and infringement would result in banning from the game (International Stoke Mandeville Games Federation, 1972a). Specific restrictions under the ISMGF explains part of the earlier importance of modification of balance via wheel axel placement (see Chapter 6.2), as users could not rely on additional wheels. Such rules continued until wider changes in disability sport administration occurred (see Chapters 5.2.4 and 7.1). The reason for the restriction on anti-tip wheels may be linked to the advantage of tilting some athletes could perform, but as Yilla indicates this was unintended, so it can be assumed these techniques emerged after the introduction of the modification.

Anti-tip wheels ostensibly challenged the medical logic behind wheelchair sport, which prioritised sport as a way to train patients in using their wheelchair (see in Chapter 5.1.1). Anti-tip wheels limited the use of modified wheelchairs outside of sporting contexts. Independent mobility was restricted as users could not 'pop up' onto raised surfaces such as pavements. When describing a wheelchair he modified, British wheelchair athlete and designer Vincent Ross (69) highlighted how the development of camber and anti-tip wheels created a distinct category of wheelchairs that could only be used in sport.

> "[I] made it into a chair that I could play basketball in, and [use] as an everyday chair. But then once the angle on the wheels got relatively steep, you couldn't really use the

basketball chair as an everyday chair. So you sort of had to have two chairs then. [...] these days, a basketball chair is that big that you can't get it through any doorways, and they've got a little anti-tip wheels on the back now, which means you can't get the foot wheels up in the air to get up and down a curb, but even over a little obstruction, so they're great on smooth flat floors, but they're [not] any good for anything else. So basketball chairs became just a piece of sporting equipment. […] the modifications that you could do restricted [everyday wheelchairs] quite a bit."

Elite athletes began to show preference for distinct sporting equipment as they afford additional performance benefits. Initially, anti-tip wheels were removable modifications, temporarily fixed to the back of chairs using metal bolts or latches. This allowed the user to alter the chair based on the context of use. However, athletes found that permanently welding anti-tip wheels to their chairs were more beneficial for durability and performance, as highlighted by former British wheelchair tennis athlete Peter Norfolk (60):

"Then we just [attached] a bracket on the back as an anti-tip. That didn't work very well, because it just used to bend - you used to fall out a lot more…"

Australian wheelchair tennis athlete David Hall (51) added that the shift to permanent anti-tip wheels benefited other performance aspects of the wheelchair:

"The reason for that was that you could even cut down more weight, you know, by welding it onto the frame so you didn't have to worry about nuts and bolts, and you know clips and clamps, and all that kind of stuff…"

Permanent sport modifications therefore reinforced the separate categorisation of sport and everyday wheelchairs, which enabled elite wheelchair athletes to further enhance their athletic abilities. By the 1990s, basketball athletes began to regularly use sport-focused wheelchair models, which featured cambered rear wheels and anti-tip wheels, alongside foot and leg strapping and alternative footrests to everyday wheelchairs. Figure

13 showcases nine female basketball athletes in such wheelchairs, at an unidentified international event in the early to mid 1990s. The use of the same style wheelchair by these athletes at a competition implies the stabilisation of type of wheelchair design better suited for competitive wheelchair basketball.

Figure 13: Great Britain Women's Wheelchair Basketball Team, c. 1990s. ©WheelPower Stoke Mandeville Stadium Archive.

In this period a form of active wheelchair technology stabilised for the average active wheelchair user. Closure for wheelchair athletes occurred as technical problems, such as weight or fragility, had been addressed, and wheelchair technology began to shed its medicalised associations (Williamson, 2019, pp.192-193). Stabilisation occurred as manufacturers and other social groups recognised the benefits of lightweight wheelchair technology, and the 'ultralightweight' category of everyday wheelchair was created. From this point, sport wheelchairs became specialised, serving the specific function of athletic competitions. The anti-tip wheel and extreme rear wheel camber highlight that elite athletes needed to categorise sport-only wheelchair devices separately to expand their athletic capabilities. For elite athletes, sport-specific wheelchair equipment thus existed separately to everyday models within a distinct branch of wheelchair technology.

6.3.2 – Sport-specific wheelchair frames

As wheelchair technology became more specialised, athletes and designers could focus on sport-specific innovations. Different varieties of sports chairs began to be created, primarily in the 1990s, which were specifically designed to accommodate the techniques and culture of their sports. These designs reached states of technological stability following trial and innovation, suggesting sport-specific models solved issues associated with multi-purpose designs. Moreover, it could be observed that the category of 'sport wheelchair' conceptually evolved as sport-specific wheelchair models stabilised. Based on the structure of cognitive categorisations in SCOT outlined by Humphreys (2005), sport wheelchairs initially existed as a subordinate category of the basic concept of 'wheelchair'. However, the continued evolution of sport wheelchair devices moved the category of 'sport wheelchair' to the basic level of organisation, in which subordinate categories of different equipment can be conceptualised: basketball wheelchairs, tennis wheelchairs, rugby wheelchairs and racing wheelchairs, amongst others. From the 1990s, elite-level sport wheelchair devices can be split into distinct categories. For each sport, athletes worked to solve specific problems, creating new periods of innovation and stabilisation. This section considers these developments in the case of tennis, racing and rugby wheelchair technology. This section is split into three sub-sections, for each variety of sport wheelchair.

6.3.2.1 – Tennis wheelchairs

Wheelchair tennis began in California, United States in 1976, when Jeff Minnebraker and Brad Parks experimented with a modified version of the sport using Minnebraker's home-made rigid wheelchairs (detailed in Chapter 6.2.2) (Bunting, 2001). Akin to basketball, wheelchair tennis greatly benefited from lightweight equipment which could quickly manoeuvre around the court. Unlike basketball or rugby, however, tennis athletes did not need to consider impact from other players, allowing tennis wheelchairs to focus on speed, manoeuvrability, and responsiveness. Seeking to advance these qualities, tennis athletes and wheelchair designers deviated from the four-wheel design used in basketball in the early 1990s.

According to British wheelchair tennis player Peter Norfolk OBE (60), Robbie Box, an American wheelchair user and tennis player who owned the wheelchair manufacturer Colours, first introduced a three-wheeled frame that allowed for enhanced responsiveness and quicker turning speeds:

> “Robbie Box came [to the US Open in LA Irvine] and he bought this revolutionary new chair he designed, the three-wheeler. And that was the first time we ever saw a three-wheeler tennis chair. And it took off for a while, everyone then moved to the chair.”

The top half of Figure 14 showcases this style of wheelchair, which copied the general frame and shape of the wheelchairs used in basketball, but replaced the caster bar on the front of the chair. Instead of two caster wheels, the three-wheel design featured a thin stem protruding from the centre of the chair, with a single caster wheel on the end. This chair had wide camber in the rear wheels, and no anti-tip wheel. Australian wheelchair tennis athlete David Hall (51) described his process of acclimatizing to the new design:

> “At first you think, '[…] that feels weird.' … but- it's like anything, the more you do it, the more I hit balls in it, the more I could feel like, 'Oh, I can reach that ball as before I couldn't, in the old chair.' […] the old chair might be […] more comfortable than the new chair, [...] but all of a sudden, I can reach a shot that I couldn't reach before, or I could get myself into a position that I was struggling with before, because this […] three-wheeler, made me get into position quicker than what the four-wheeler could.”

Figure 14: Images of three-wheeled (above) and four-wheeled (below) tennis wheelchairs. Bunting, S. (2001), p.47.

In some regard, the three wheeled design addressed problems around speed and manoeuvrability found in the existing four-wheel design, and enhanced athletes' abilities. Yet, this innovation created new problems, particularly around stability. Attempts to address these issues led to the addition of a rear anti-tip wheel – an effective return to a four wheeled design. British wheelchair tennis coach Martyn Whait (51) explained this technological shift:

> "The thought [about the three-wheeled design] was kind of minimal […] rolling friction. […] realised quite quickly that actually, to make it stable enough, that single wheel needs to project quite a long way out in front, which you […] hit your racket on when a ball was hit straight at you. So quite quickly, it then divided from one wheel back into two wheels. [And] when players were leaning out to the side to pick up the ball, they didn't [have the stability]."

Peter Norfolk (60) made similar comments, highlighting the eventual rejection of this design by tennis athletes:

> "And then [Robbie Box] realised he had to put a fourth wheel on the back to stop it tipping out so much. […] they made […] the front stem longer to give you more stability. But then that got in the way of the racket when you were hitting. You know, that was that. That was around for about four or five years, and then everyone went back [to] four wheelers."

Testimony indicated that the majority of athletes and coaches adopted the new design, briefly stabilising that version of the equipment. Whilst athletes were quick to adopt the three-wheel design, the move to the new four-wheel design was also swift, as David Hall (51) recalled:

> "Once [anti-tip wheels] became the norm- […]It was rare that players were either using a three-wheeler or even the two casters on the front, there still were a few players that were doing that, but the majority, vast majority had that- that one caster at the front and the one at the back."

Innovation within the specific context of tennis allowed athletes and wheelchair designers to experiment with new approaches to design not viable for a multi-purpose chair. Whilst the three-wheel design did stabilise briefly, this innovation facilitated the development of further tennis chair designs. Figure 14 highlights both the three-wheeler (two large rear wheels and one small front caster wheel on a stem) and four-wheel design (two large rear wheels, one small front caster wheel on a stem, and one rear anti-tip wheel) designs, which differed in their functionality. The four-wheel design developed into a five wheel or 'Matchpoint' design. The wheelchair used by Peter Norfolk in the 2008 Beijing Paralympic Games (Figure 15) featured two large rear wheels with a high degree of camber, two small front caster wheels, and one rear anti-tip wheel. This latter design has stabilised for the majority of tennis players in the twenty-first century, following a decade of experimentation on tennis wheelchair designs.

Figure 15 – Peter Norfolk in 5-wheel or 'Matchpoint' style tennis wheelchair, at the 2008 Beijing Paralympic Games. ©WheelPower Stoke Mandeville Stadium Archive.

6.3.2.2 – Racing Wheelchairs

By the 1980s, racing wheelchair athletes advocated for a three-wheel design. Unlike tennis, the three-wheel design stabilized as the most effective approach to racing technology. Racing wheelchairs developed in their own technological niche beginning in the early 1970s. Indeed, Cooper (1990, p.296) comments that by 1985 racing wheelchairs were completely distinct from everyday wheelchairs.

Wheelchair racing events began in the United States as early as 1957 (Labanowich, 1987) and were introduced at the 1964 Paralympic Games in Tokyo, Japan, consisting of track, dash, relay, and slalom events (Brittain, 2012, p.70; Guttmann, 1976, p.91). Wheelchair racing road races and marathons were also established external to the Paralympic movement (Brandmeyer and McBee, 1986). The popularity of wheelchair marathon and road races began when former wheelchair athlete and wheelchair designer Bob Hall entered the Boston Marathon as an unofficial entrant in 1975 (Brandmeyer and McBee, 1986, p.182; Williamson, 2019, p.192; Mastandrea, 2006, pp.59-60). Racing wheelchair design aims to balance rigidity and weight akin to other wheelchair models (Cooper, 1990, p.300) but is primarily focused on speed (Cooper et al., 2018). For 800- and 1500-meter track events, road races, and marathons, wheelchair racing athletes prioritised features such as weight reduction and pushing technique for long racing events. Retired wheelchair racer and former Paralympian for New Zealand Evan Clulee (49) explained:

> "Wheelchair racing, it started with hospital wheelchairs and then putting lighter wheels on, putting [on] push rims, different push rims and then changing the front wheels out, later on going to dropping the metal foot plates, to plastic foot plates, to being a solid bar."

A four-wheeled design began to specialise for racing, distinct from court-style wheelchairs. The Shadow wheelchair shown in Figure 16 highlights the shift from a 'normal' four-wheel wheelchair to the elongated three-wheeled racing devices found in the modern sport. These designs allowed for new seating positions, extended wheelbases, and larger front wheels. Racers also experimented with unique features such as steering systems, or adding smaller push rims to the rear wheels, which further differentiated racing chairs from other wheelchair models. For instance, former American wheelchair racer and coach Martin Morse (66) described the first dedicated racing chair he used:

> “{In late 1978 I got started} in wheelchair racing, my first wheelchair was a modified Everest and Jennings everyday wheelchair with 24-inch rear wheels, 16-inch hand rings, and 8-inch pneumatic front caster wheels. We had little, five-inch bolts that are attached to the outside of the front forks. That was how you steered.”

Figure 16: Four-wheeled racing chair, made by Magic in Motion under their ‘Shadow’ product line. 1984. Shared with the permission of Jim Martinson.

Interviewees also outlined specific adaptations racing athletes made to their chairs to address specific performance issues within racing. A key example was the issue of wheel flutter and wheel tracking in the smaller front wheels when racing at high speeds. Athletes devised methods of keeping the front wheels aligned. Clulee (49) outlined the "rudimentary system to keep the front wheels tracking straight" in the late 1970s:

> "[We] had sort of rubber bands- big car tyre bands – pulling them back in, so that you didn't get flutter at high speed."

Additionally, former Canadian wheelchair racer Paul Clark (63) outlined the use of a metal bar to link the two front wheels:

> "[There was] the bar between the front two casters […] It was to do a couple of things. First of all, it was the beginning of having those front forks tilt toward the corner (easing turning). But it also helped to eliminate flutter. […] so by having the two tied together, the flutter was eliminated."

Clark also commented that he drew on techniques used by other racers to further reduce flutter:

> "But [what] I did learn from some of the other athletes, is... a way to stop my front wheel from fluttering, there was a way to tighten down the front wheels and to actually put a different bearing in would help the front wheels not flutter as you went fast."

Racing athletes thus prioritised different designs to court sports. Whilst court sports needed manoeuvrable front wheels to ensure turning in a circle, wheelchair racers were accelerating forward, thus making 'spinny' front wheels a performance and safety liability. Racing technology quickly specialized into a distinct category, separate from wheelchairs used in everyday life or other sports. By the 1980s, the categorisation of distinct racing technology can be found in the pages of *SPORTS 'n' SPOKES*. The survey had separated the distinct categories of sport and everyday by the late 1980s. However, chairs in the sport category were marketed as multi-purpose, using words such as ‘court’ to describe devices that could be used in tennis, basketball, rugby, and racquetball. In contrast, manufacturers pointed out the difference between ‘sport’ and ‘racer’ wheelchairs from the inception of the survey, listing models and images of racers separate to other sport chairs. Similarly, the name of the company ‘British Sports & Racing Wheelchair Co. Ltd’, who only appeared in the 1984 survey (Crase, 1984), implies that racing chairs were technologically different from other sporting wheelchairs, and categorised accordingly by athletes, manufacturers, and other actors, much earlier than wheelchairs intended for rugby or tennis specifically.

Racing wheelchairs became more specialised over time, as athletes experimented with lighter and larger rear wheels, longer wheelbases (the distance between the front and rear wheels), new steering systems, and alternative seating positions. This culminated in the introduction of the three-wheel design. Through testing, athletes found that a longer front end and single, large front wheel greatly benefited performance. Testing by American wheelchair athlete and academic Rory Cooper (60) found that the move to a three-wheel design eliminated many problems with existing racing chairs, from wheel flutter of the front caster wheels to stability and wheel scrubbing:

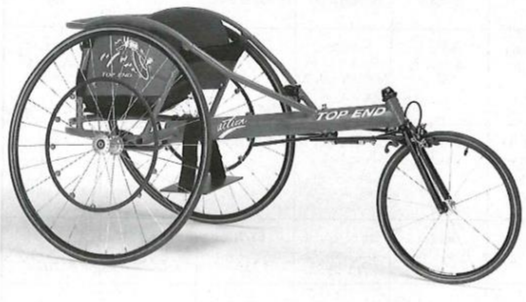
> “Three [wheels] eliminated the scrubbing […], because with four wheels, all four wheels must be aligned perfectly. And not only in the straights of the track, but in the turns, which was virtually impossible. Not without adding a lot of weight and complexity. And thus three wheelers. The other problem is when you make a four-wheeler, it takes a lot of precision work to make all four wheels sit flat on the ground. Three-wheels make a plane, they always sit flat on the ground. With three wheels, you only have to worry about the two rear wheels scrubbing. Because the front wheel can always line up correctly. Then of course, you can make the chair lighter. … I created and published a mathematical model that showed that a three-wheeler and a four-wheeler are equivalent if you have infinite length. It turns out they are 99% equivalent if only a little bit longer.”

Athletes and administrators clashed over rule changes regarding the three-wheel design, which are explored in Chapter 7.1. Once accepted into the rules, however, the three-wheel design quickly became accepted by athletes. Martin Morse recalled, for instance, that at the 1988 Paralympic Games in Seoul, South Korea, there were mainly four-wheeled chairs, but that by the following 1992 Games in Barcelona, Spain, all racing athletes used three-wheel chairs. Figure 17 from *SPORTS 'n' SPOKES'* 13th Annual survey of the lightweights shows that racing wheelchair manufacturers all embraced this new design (Axelson, 1995). The radically different shape and function of the three-wheel racing wheelchair design solved many of the problems athletes had combated since the introduction of the sport, leading to the stabilisation of this design in modern wheelchair racing.

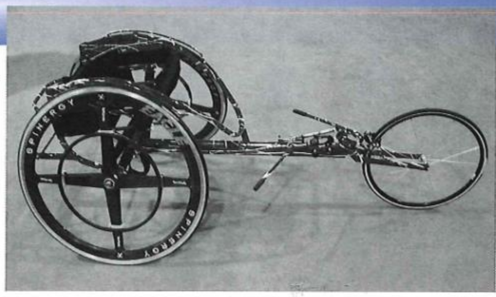
Figure 17: Images of three-wheeled racing wheelchairs. Axelson, p. (1995), p.58.

13th Annual Survey of the Lightweights

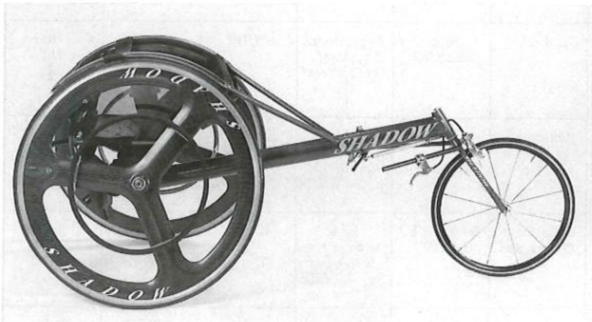
RACING CHAIRS



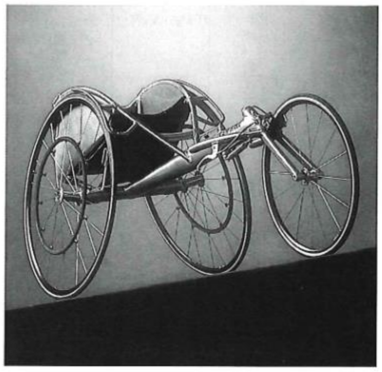
Action Technology's Top End Racer



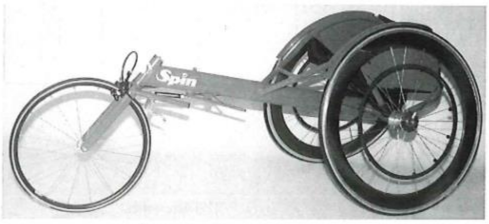
Eagle Sportschairs' Soaring Eagle



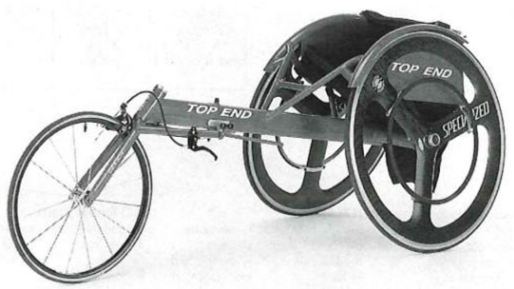
Quickie Designs' Shadow Racer



Hall's Wheels' Leader



Spin Technology's Spin Racer



Top End by Action's Eliminator

6.3.2.3 – Rugby wheelchairs

Wheelchair rugby originated in Canada in 1977, developed by wheelchair athletes as an alternative to basketball for quadriplegic athletes with greater upper body impairments who struggled to shoot and dribble the ball (Cooper et al., 2018; IWASF, 2012; Irwin et al., 2018). Wheelchair rugby shares many similarities with basketball, which allowed rugby wheelchair technology to draw heavily from basketball or generic court-style chairs. However, the increased contact of the sport and early prominence of athletes of limited upper body mobility resulted in specific technological differences. For instance, rugby wheelchairs feature bumpers to receive impact, and an extreme degree of camber to minimise injury to players hands, whilst also increasing agility and stability (Cooper et al., 2018). Specialised rugby wheelchairs also feature a bucket seat akin to wheelchair racing models, providing the user with greater stability and access to the rear-wheel push rims (Cooper et al., 2018; Bulldog News, 1998) Likewise, rugby athletes implemented different versions of existing features such as stronger anti-tip wheels, as explained by former player Robin Tarr (56):

> "I know some of the basketball and tennis chairs now have anti-tip bars, but ours are... much stronger, because we're [being hit] from the front which would take you over the back very easily. […] we have to have very strong anti-tip bars at the back. Our anti-tip bars also have a casing around them, [to protect it] if you get hit from the back of the chair…"

However, more significant variations in rugby wheelchair models emerged as athletes of different mobility levels came to the sport. This necessitated design changes, as players with more upper body mobility were able to transfer more force into their chairs. Speaking about the history of wheelchair rugby, Tarr (56) highlighted the inclusion of higher classification athletes and differences in performance:

> "… when I first started playing, it was predominantly spinal injury players. And we just haven't got that much function. And as the sports develop, you know, you've got

people with a lot more function coming in now, we have disabilities ranging from amputees to meningitis... […] with a lot more function and […] power. […] When they're hitting you, they're not just hitting you with the strength of their arms, they're putting the whole weight of the body through [their wheelchair]. The chairs that we [used] when I first started […] they'd break in half, you know, […] the chairs that are having to be made now need to be able to take that sort of impact…"

Wheelchair rugby technology accordingly evolved as athletes with more mobility came to the sport. Tarr, alongside British wheelchair rugby athlete Aaron Phipps, highlight that different versions of rugby chairs were designed to accommodate different levels of classification. Importantly, new roles within teams were also developed alongside these wheelchairs, altering the play of the sport. Phipps (38) explained:

> "The high point players generally have - like, it looks a bit like a basketball chair, so it's round in front. And the low point players, so people who are more disabled, they tend to have that basket on the front, so they can block the high point players, so it's a bit more tactical."

Two distinct types of rugby chairs developed as these roles were iterated upon (Irwin et al., 2018). Low-point athletes' chairs (known as defence wheelchairs) incorporated a longer front bumper to protect the athletes' body. The wheelchair in Figure 18 also illustrates the pick bar, which is used to hook an opponent's wheels and impede their movement. Accordingly, high-point athletes' chairs (known as offence wheelchairs) incorporated wings around the front of the rear wheels to limit hooking, which can be seen in the bright yellow round wings RGK's Quattro Rugby wheelchair depicted in Figure 19. Tarr (56) expanded on this development, implying that a technological arms race began as athletes of higher and lower classifications strategically implemented new modifications:

> "You've got players with less function, who want as many protrusions from the chair as possible, so they can get a piece of somebody and hold them. […] you've got the high

function players that want chairs as rounded as possible to stop the low point chairs getting hooked. […] it was two chairs that was happening at the time. […] every time they made a chair for low pointers that could […] get a hooking device, they would do an adaption on the high pointer's chair, to stop that hooking device getting into the chair."

Figure 18: Defence rugby wheelchair, unidentified athlete and event. C. Early 2000s. ©WheelPower Stoke Mandeville Stadium Archive.

Figure 19: 'Quattro' rugby wheelchair, produced by RGK Wheelchairs. (Bulldog News, 1998). ©WheelPower Stoke Mandeville Stadium Archive.

The purpose and function of a rugby chair therefore evolved based on the nature of the sport and the role played by the athlete in the team, creating new interpretations of these sport wheelchairs. Interpretative flexibility opened, closed, and stabilised as athletes and designers refined these designs and created optimised models for both types of players.

6.3.2.4 – Sub-section conclusion

Building off lightweight wheelchair innovations for basketball and active everyday use, branching paths of interpretative flexibility allowed for athletes to experiment with specific modifications for different wheelchair sports. This process allowed athletes to solve problems associated with individual sports, providing new opportunities for athletes of different abilities and transforming how these sports were played. From the 2000s, sport wheelchair designs outlined in this chapter underwent a process of stabilisation, as athletes and other social groups settled on key designs for tennis, rugby, and racing wheelchairs. This was marked not only by wider adoption and use of these devices, but the linguistic and psychological ways in which these wheelchairs were categorised as sporting equipment. Importantly, as general approaches to sport wheelchair design stabilised, athletes had their individual device modified to suit their individual bodies and abilities.

6.3.3 – Wheelchair customisation

By the twenty-first century, wheelchair technology for racing, tennis, basketball, and rugby had significantly stabilised, as athletes identified the optimum shape of these devices, and refined versions of these designs had become accepted by other social groups, such as sport administrators, engineers, and coaches. This form of stabilisation accommodates a continued process of modification as athletes customised their wheelchairs to their individual bodies and abilities. As outlined in Chapter 6.2.1, end user customisation was an important part of athletes' tinkering from the beginning of wheelchair sport modifications. However, the competitive importance of customisation grew for elite athletes that could afford to do so, as other aspects of sport wheelchair design technologically stabilised. This section explores customisation within the evolution of sport wheelchair technology and athlete performance, and questions if this process obfuscates the technological stability of these sport wheelchair models.

Previously explored modifications for sport, including lightweight rigid frames, cambered wheels, steering devices, and anti-tip wheels, stabilised in the 1990s and 2000s, improving athletic performance as disability sport became professionalised under the IPC (Bailey, 2008). For elite athletes, personalisation and minuscule adjustments became of increasing importance to performance. Initially athletes involved with wheelchair design created their own customisations, allowing the design to fit their equipment to their own bodies. User-established wheelchair manufacturers began to offer methods of custom building to a wider audience, such as specification forms which listed a set range of measurements a wheelchair could be fitted to, or direct measuring of the athletes' bodies using tape measures. These methods allowed non-disabled engineers to create customised wheelchair devices, working with the athletes to fit the equipment to their bodies. For example, former wheelchair engineer for Draft wheelchairs, Dan Chambers (53), built approximately 650 customised wheelchairs over a career of 21 years. During the interview, he discussed how he collaborated with elite wheelchair athletes including elite British wheelchair racer David Weir, commenting that for wheelchair sport in the twenty-first century;

> "…the fit of the product is […] 70% plus of the advantage that you can get in a particular chair. The technology, you know, the material you make it out of - the wheels you've got on it, the aerodynamics of it, that sort of thing - are the other bit."

Elite modern wheelchair sport necessitates customised wheelchair devices, which present issues of cost and accessibility for new wheelchair athletes or those from Global South nations (Pearlman et al., 2008; Authier et al., 2007; Cooper et al., 2002). However, end user customisation was also an important part of initial wheelchair modifications in the 1970s, as some users could make chairs lighter and more manoeuvrable by the removal of unnecessary features. Athletes with more upper body balance and movement could cut down tall backrests and remove high armrests, making the device more functional for their individual mobility. Accordingly, basketball athletes in the 1970s and 1980s who had less upper-body mobility found these modifications did not work for them, expressed in previous testimony by Sir Phillip Craven and Jalle Jungnell in Chapter 6.2.1. These athletes needed to find alternative designs for their bodies. When describing the modifications made to his early racing wheelchairs in the late 1970s, Canadian wheelchair athlete Paul Clark (63) highlighted personalised aspects of his equipment:

> "Nobody else in any of the other categories [was] worried about falling against the wheels on either side like me. […] just the simple thing of taking a one-inch-wide piece of metal and putting it basically at the side of my chair to brace my chest area […] was like a miracle to help me stay centred in the chair, especially going around corners. So this was a modification that I had that nobody else found useful, but it was only for my body."

Speaking about her experiences of trying out other athletes' wheelchairs in the 2010s, British wheelchair basketball athlete Judith Hamer (29) similarly highlighted how customisation was personalised to the users' impairment, meaning that adjustments could not be universally tested:

> "[For] amputees, it's really hard for us to try different people's chairs out, because our chairs are designed for a person with one leg. ...So a lot of people have asked in the past [if] they can try my chair, I'm like, 'Well, I would love to let you, but it's designed for one leg... it's designed for my legs. And if you've got two legs, you won't fit in it.' And it's not that like I'm narrower than them in the hips or anything, it's that the frame is designed for one leg to fit in it, and you... won't get a good representation of what you're gonna feel like in this chair because […] it's not fitted for you."

Personalised modifications afford athletes of many different impairment classifications and functionalities the opportunity to compete to their best ability. Customisation can accordingly be understood as a form of hybridity between user and device (Winance, 2006), invoking the concept of the cyborg, as divisions between the human and the technological are eroded to create a form of hybridity (Kafer, 2013; Haraway, 2016). A customised wheelchair may correspondingly represent an extended body which affords certain performance abilities (Winance, 2006, p.67). Indeed, Sparkes et al. (2018, p.12) explore the 'cyborgification' of disabled athletes, highlighting testimony from wheelchair athletes who refer to their customised wheelchairs as an extension of the self. For these athletes, successful athletic performance is associated with the connection between athlete and technology.

Across the development of sport wheelchair technologies, wheelchair athletes and designers have engaged in processes of adjustment to find the right fit for their equipment. Focusing on everyday wheelchair selection, Winance (2006) frames the selection of a wheelchair as a negotiation between human actor and technological actant. Likewise, customisation is an act of negotiation, as the athlete experiments to find the best functionality possible with their equipment. The importance of this negotiation could be observed historically in adjustable active wheelchair designs considered briefly in Chapter 6.2.2. Wheelchair users and designers created devices with customisable features to allow athletes to participate in this negotiation. Adjustment and customisation could therefore be considered to be part of the process of technological flexibility, as athletes identified individual problems with their equipment, and altered their design to match their needs. These alterations may occur as the athletes' body or abilities change, or as the sport evolves. British wheelchair basketball athlete Judith Hamer (29) outlined how the customisation of her elite-level basketball wheelchair was an ongoing, gradual process:

> "It's massive trial and error, like I still don't really have it right and I've played for thirteen years now. […] you're always developing, you're always changing and you're always learning. So you might have a chair that really suits you for a couple of years but then you grow out [of] it, especially at the level we play at, like the sport is changing and developing, especially on the women's side, it's a completely different sport to how... I played it when I was growing up."

Tennis athlete Peter Norfolk OBE similarly reflected on the need for constant adjustment, drawing on his own experiences of functionality change, as he lost strength in his right arm, elbow shoulder and wrist following a spinal complication in 2000 (Tennis Foundation, 2010). Norfolk (60) observed that wheelchair design had to evolve with the athlete, commenting on the limitation of fixed sport wheelchair models for early career athletes:

> "As you get better, as your ability improves, you adjust the chair. […] beginners, starters, or even intermediate players […] now, they get a fully fixed chair. Well, that's fine, for potentially a year or a short period of time. But your ability changes. And if you've got no possibility [of] adapting the chair, you then can't really adapt and improve your ability…"

Athletes therefore use adjustment and customisation to enhance and expand their athletic abilities, in accordance with the competitive interpretation of sport wheelchair devices. However, the concepts of technological flexibility and stabilisation in SCOT refers to the broader social-cultural status of artefacts, as opposed to individual instances of adjustment. Alterations for athletes' body do not impact the fundamental design or meaning of the device. The shape, function, or affordances of a sport wheelchair remain the same, retaining the socio-technical stability of the device. This concept was reported by athletes within the data. Design or customisation variations across sport wheelchair models did not diminish the technical closure these objects had reached for athletes. Speaking about the variations of wheelchair racing devices at the Seoul 1988 Paralympics Games, for example, wheelchair racer Ray Carpenter explained that racing wheelchair models were "the same in principle but designs may vary from one to other" (Seoul Paralympic Organizing Committee, 1988c, p.4). Interviewee comments concerning the future development of sport wheelchair technology reinforce this perspective, as a narrative emerged from athletes and wheelchair designers that any advancements in the modern age are incremental. Considering what aspects of a modern sport wheelchair could be customised, British wheelchair rugby athlete and Paralympian for Team GB

Aaron Phipps (38) commented:

> "…you can change the seating, the upholstery […] there's little tweaks that you can do, but... there's only [a] certain [length] you can go with it, how much lighter they [can] go […] if you go too light it gets detrimental […] at our level, it's just marginal gains, […] minor little things that you can do […] the tiniest little change might be the difference between you winning a medal and not winning a medal."

Moreover, the stabilisation of sport wheelchair devices may be observed in the idea that minute adjustments to equipment in the twenty-first century are not as technologically radical as the designs introduced between the 1960s and 1990s discussed previously. This is linked to changes in the sport wheelchair manufacturing industry, as observed by Norfolk (60):

> "But really... no one's reinventing the wheel. They're all just copies of each other, really. It's [up to] major manufacturers to put the investment into the research and invention."

Customisation therefore provided athletes with performance advantages as sport wheelchair equipment broadly stabilised, and major technical transformations ceased. Sport wheelchairs can be distinct in design for the individual athlete, but stable based on their generalised design features, function, and purpose. Adjustment and customisation were a vital part of the evolution of sporting wheelchair models, creating unique wheelchair equipment for each athlete. Customisation allowed sport wheelchairs to better solve problems athletes had with their wheelchairs, acting as a form of technological flexibility on the individual level. End-user customisation is accordingly one design technique employed to address the interpretation of sport wheelchair devices as elite sporting equipment, not impacting the overall processes of closure and stabilisation these artefacts underwent.

6.3.4 – Conclusion

Sport specific innovations and designs led to the creation of many new varieties of manual wheelchair, each of which stabilised following a period of interpretative flexibility and technological experimentation. These new varieties of sport wheelchairs exist distinctly from each other, and non-sporting active manual wheelchairs, to serve a specific function and purpose. The stabilisation of these designs was not impacted by continued adjustment and customisation to athletes' specific bodies. Sport-specific designs, and athlete customisation, were the end result of athletes' initial desire for sport-focused wheelchair devices and the progression of competitive wheelchair sport. Nevertheless, the closure and stabilisation of sport wheelchair devices is necessarily connected to wheelchair manufacturers, who distinguished between sport and everyday models, and offered wheelchair customisation to elite athletes and consumers. Wheelchair stabilisation facilitated changes within the market, and the market in turn reinforced the stabilisation of sport wheelchair design.

6.4 – Chapter conclusion

Wheelchair devices underwent a significant period of technological flexibility across the latter half of the twentieth century, resulting in the creation of specific wheelchair varieties intended for sporting use. Due to the inadequacies of existing wheelchairs for both sport and everyday use, athletes - predominately men with access to engineering skills and equipment - from the 1970s onwards tinkered with and modified their devices to enable better performance, and eventually created new wheelchair designs better suited to their competitive interpretation of wheelchair sport (Stewart and Watson, 2019). Wheelchair designs for sport underwent a non-linear process of acceptance by athletes, as new modifications were trialled across sports and countries. Sport modifications and designs closed as these innovations were adopted by other athletes, and stabilised as they were accepted by other social groups. Further seeking to advance athletic performance, everyday and sport wheelchair models were placed in distinct categories, allowing sport-specific wheelchair models for tennis, rugby and racing to continue to specialise in the 1980s and 1990s. These sub-categories of wheelchairs underwent their own processes of closure and stabilisation, combined with the growth in importance for customised wheelchair designs for elite athletes. In the twenty-first century, sport wheelchair technology is culturally and technologically stable.

The creation and stabilisation of wheelchair modifications, and sport-specific wheelchair models, however, developed alongside broader changes in wheelchair sport regulations and commercial production. Changes in sport and industry altered the degree of agency athletes had in the creation of new sport wheelchair technology and represented wider struggles facing disabled people. The following chapter contextualises the evolution of sport wheelchair technology within these two key contexts.

Chapter 7 – Athlete self-determination in sport administration and industry

Between the 1940s and 1960s, a lack of wheelchair user presence within the ISMGF or major wheelchair manufacturers limited the extent to which wheelchair athletes could assert their substantive or experiential expertise as users of sport wheelchair technology. As shown in Chapter 5, medical professionals controlled the international organisation of wheelchair sport prior to the establishment of the IPC, and held significant influenced wheelchair design. In response, wheelchair athletes had to assert their interpretation of wheelchair technology to legitimise and manifest their competitive ambition in disability sport. Building on the previous exploration of sport modifications, this chapter considers commercial and institutional changes enacted by athletes which establishes their role a critical social group within the history of sport wheelchair technology.

This chapter draws on ideas of user-expertise established in Chapter 3.3.3, including Hamraie and Fritsch's (2019, p.7) identification of disabled people as 'knowers and makers' of technological artefacts such as wheelchairs. From this attribution of expertise, wheelchair athletes' actions within sport administration and wheelchair manufacturing can be understood as forms of self-determination and autonomy. Within disability activism, these concepts are linked to power, as disabled people fought against authoritative institutions and rejected policies that did not include them or value their lived experience (Hunt, 2019; Wehmeyer, 2004; Hamraie, 2017; Williamson, 2019). Disabled activists in the British independent living movement of the 1980s, for instance, fought to improve social support which enabled disabled people to live outside of institutions, and afford disabled people greater control and responsibility over their lives (Hunt, 2019, p.318; Rogovsky, 1997). Disabled people's self-determination and autonomy are therefore politically contingent, shaped by institutions and systems which remove disabled people's control over their own lives. This chapter uses this approach to consider athletes' authority to determine the development of disability sport and sport wheelchair technology. Commercial and administrative changes enacted by athletes within wheelchair sports are accordingly interpreted in this chapter as a political assertion of autonomy and self-determination.

In order to address both sport administration and the wheelchair industry, this chapter is split into two subchapters. The first explores how regulations surrounding wheelchair equipment acted as a site of conflict between wheelchair athletes and sport administrators. Wheelchair equipment regulations initially represented a medicalised interpretation of wheelchair sport and technology, but athletes challenged these by using equipment which was banned by ISMGF regulations, or directly protesting administrative bodies. The second chapter is concerned with the development of the sport wheelchair industry. Athletes asserted their self-determination by founding their own sport wheelchair manufacturers, providing their community with economic and athletic opportunities and establishing a new market for sport devices. However, the later acquisition of these manufactures restricted the amount of autonomy and self-determination athletes had in the market. Overall, this chapter argues that both sport administration and the sport wheelchair manufacturing industry acted as sites of athlete self-determination at distinct points in the history of sport wheelchair technology.

7.1 – Rules and athlete resistance

Previous chapters have drawn on regulations around wheelchairs used in sport to underscore the relationship between athletes, sport administrators and technology. Chapters 5.1.2 and 5.1.3, for instance, considered how differences in administration and interpretations of sport between the ISMGF and the NWBA created different approaches to wheelchair regulations for basketball. Internationally enforced ISMGF regulations retained a medicalised interpretation of wheelchair sport, failing to match the technological advancements developed by athletes in the 1970s and 1980s. Ultimately, athletes entered ISMGF sanctioned events in modified wheelchairs as a form of protest against rules which restricted their interpretation of wheelchair technology. This subchapter highlights changes to equipment rules, demonstrating how regulations acted to facilitate and constrain athlete self-determination over sport wheelchair technology.

This subchapter is split into four parts. The first section considers the shift from standardisation rules to specific wheelchair measurements in basketball, to make the sport more competitive and fairer. The second section interprets the implementation of wheelchair measurements as an enforcement of practitioners' interpretation of wheelchair sport and technology. The third section outlines international differences in wheelchair racing regulations, explaining athlete frustration with ISMGF restrictions, and outlining impetus for protest. Section four, accordingly, details examples of athlete protest to ISMGF rules in order to assert their interpretation of sport wheelchair technology. Using the example of racing wheelchair technology, this subchapter ultimately argues that resistance to equipment rules acted as a significance source of autonomy for wheelchair athletes, as restrictions to technology represented the division between athlete and practitioners. Alongside interviewee testimony, data in these sections has also been drawn from ISMGF rulebooks, found within the NPHT's archival collection.

7.1.1 – Implementation of wheelchair measurement regulations

Player resistance to standardisation rules in basketball led to the adoption of new regulations. This new approach outlined specific regulations an athletes' wheelchair needed to meet in order to be used under ISMGF rules. This section explores this initial rule change from the suspension of standardisation rules to new basketball regulations outlined following the 1964 Paralympic Games in Tokyo, Japan. I argue that these changes to wheelchair basketball rules emerged as a way to regulate athlete modification, whilst also satisfying medical concerns regarding player safety, and the desire for fair sport held by both social groups.

The standardisation rules established by the NWBA were originally proposed by athletes, in order to limit technological advantage (see Chapter 5.1.3) and international differences between wheelchair models (explored in Chapters 5.1.2 and 6.1.1). Athlete objection to standardisation rules grew as the limitations on athletes' abilities became apparent. The ISMGF, in comparison, did not implement standardisation rules, instead aiming to limit athlete modification. According to former British wheelchair athlete and designer Vincent Ross, restrictions to athlete modifications were implemented due to medical practitioners' concerns around patient safety:

> "Everybody used to play in a very, very standard basic chair that was given to them by the NHS with virtually no modifications. In fact, if you modified the chair the NHS gave you, quite often they'd take it off you, give you back a standard one, with the attitude that if you modified the chair, it wasn't to a prescription that the prescriber had issued it to you [and] you were at risk. [But] people used to just modify them anyway. Or get another chair from somewhere, and modify that one."

Athlete use of modified wheelchairs reduced the perception of alternative wheelchair models as dangerous, affording changes in rules to accommodate new wheelchair designs. Simultaneously, athletes experimented with a wide variety of modifications in order to determine what best benefitted their performance. In sports such as racing, basketball, and rugby, athletes seemingly brought modified wheelchairs to smaller events in order to test them. Retired athlete Robin Tarr (56) commented on the early days of British wheelchair rugby in the early 1980s:

> "…the referees had to step in and regulate it, because - I remember one of the tournaments I went to, I literally just had two bars sticking out my chair that I could use […] it was like Ben-Hurs' chariot! Just smash this hook into somebody's chair […] it was taking the spokes out. And I remember some of the guys looking at me in the line-up in horror, saying 'You're gonna play in that thing?' And the referees would actually come across it and they put some strapping on it […] you could literally […] turn up to the tournament with anything. And it was obviously a conversation between the players and the referees that we've started to put some regulations and rules on what you could and couldn't have."

The ISMGF's measurement regulations limited wild variations in wheelchair design, limiting unfair or dangerous modifications, whilst allowing for a small amount of athlete adjustment. Sir Phillip Craven (70) highlighted that the shift to measurement regulations only targeted certain aspects of the wheelchair:

> "…you just had the limits on what you could do with seat height, cushion depth, there was no limit to the width of the chair, most players wanted it as narrow as possible, you know, so you could get through gaps. […] And so then it wasn't [a] free for all, because you had the control of the measurements […]."

In these regulations, athletes were able to customise their wheelchair as long as that conformed to specific dimensions for certain parts of the chair (see Chapter 5.1.2). The establishment of these regulations could be perceived as the process in which athletes and sport administrators negotiated their differing interpretations of wheelchair technology. For practitioners, these regulations helped wheelchair devices conform to medical guidance, whilst affording a small amount of athlete adjustment, balancing safety concerns with athletic ability and fairness. Simultaneously, these regulations matched the competitive interpretation of wheelchair sport held by players, as technological regulations worked to emphasise the physical abilities of the individual. For example, these rules assisted in regulating differences between impairment groups, as commented on by former wheelchair athlete and designer Jalle Jungnell (67):

> "In basketball, […] there were regulations, for example, [that] the height [of] the wheelchair should be (no more than) 53 centimetres. That's obviously good because otherwise, you [could] have these really, really tall players, with good balance and they will fit- I mean, there would be like two different teams on court. […] I think it's good when development could decrease the difference between different handicaps."

A further example of measurement regulations can be found within a rule book compiled for the 1964 Paralympic Games in Tokyo, Japan (International Stoke Mandeville Games Federation, 1960a). Regulations for sports are listed, including archery, throwing events, table tennis and basketball - although no specific wheelchair rules are outlined across these sports. Wheelchair fencing, however, permitted wheelchair alterations to ensure fair competition between athletes. Section 5.1 of the fencing regulations reads:

> “Wheel-chairs must be of such design that no parts thereof obscure any part of the target as seen from the position of the opponent, except that Arm rests, either fixed or removable, are allowed, as long as no part of the arm rest on the side of the sword-arm extends higher than the anterior superior iliac spine on that side, when the fencer is sitting upright in the centre of the width of the chair. Arm rests and chair backs may be removed.”

Wheelchair design was adjustable in fencing based on the needs of the athlete and desire for equal competition. This flexibility existed for the purposes of sport when wheelchair design was otherwise fixed within a medical paradigm. This may be an early example of wheelchairs being interpreted as athletic devices, or as sport administrators accepting athletes’ competitive interpretation of wheelchair sport. New directions in wheelchair basketball regulations quickly followed suit, but administrators instead introduced specific wheelchair measurements to ensure fairness. An amendment was introduced following the 1964 Games to match the International Basketball Rules Handbook issued by the International Basketball Federation (International Stoke Mandeville Games Federation, 1960b). These new regulations worked primarily to limit the advantage of player height:

> “1 – A strap no less than 4 cms. in with must be attached firmly and drawn taut to the telescope bar of the foot rest platform.
> 2 - Cushions in chairs must not measure more than 10 cms. in height.
> 3 - Foot platforms must be not more than 11 cms. from the ground at highest point.”

The variances between fencing and basketball regulations likely emerged due to the differences between these sports. As a stationary sport, fencing presented less concern around player injury from collisions or falling out of the chair. Adjustments including the removal of arm and backrests thus did not conflict with user safety. Basketball, on the other hand, is a contact heavy sport, so changes to back support and arm rests presented increased risks for users, from a medical perspective. Moreover, the mobile nature of basketball meant that differences in individual player height, ability, and bodily movement impacted fairness in competitions. Limitations to wheelchair technologies worked to equalise player performance, particularly before the introduction of classification systems in wheelchair sport.

I argue that these new regulations initially aimed to balance athlete and administrative interpretations of wheelchair sport and technology. Athlete safety and fair competition were prioritised for those of different impairment groups. However, the implementation of specific measurements for wheelchair devices gave sport administrators increased power in defining wheelchair technology. As a result, practitioners resisted the athletic reinterpretation of sport technology and limited athlete self-determination within wheelchair sport.

7.1.2 – ISMGF rules constraining sport wheelchair technology

Sport regulations constrained and defined wheelchair technology. Measurement rules can be understood as a way for sport administrators – who were primarily non-disabled medical professionals (see Chapter 5.1) – to define wheelchair devices and limit athletes' interpretation of sport wheelchair technology. Between the 1960s and 1980s, ISMGF rules surrounding wheelchair regulations thus inhibited athlete autonomy over the use of sport modifications at Paralympics and other sanctioned events. This section suggests that wheelchair regulations enforced by the ISMGF worked to constrain the use of sport-specific wheelchair developments, in-line with a medical interpretation of these devices.

The ISMGF regulations initially only listed equipment checks in reference to sports such as basketball. This indicates that prior to the introduction of wheelchair measurements, ISMGF competitions were solely reliant on the judgement of their adjudicators. In the regulations for the basketball events at the 1964 Games, rule 2, section 13 outlines that the duties of officials included inspecting equipment (International Stoke Mandeville

Games Federation, 1960a):

> "The Referee shall inspect and approve all equipment including, Court, Baskets, Ball, Backboards Timekeepers and Scorers' signals. 'He shall designate the official Timepiece and its operator. He shall not permit any appliances to be worn or on chairs which he considers dangerous to other players or which give a physical advantage to the player."

Following the 1964 Games, the role of the referee was more strictly defined. Rule 2, section 15, which outlined the powers of the referee to make decisions if not covered in the rulebook, was amended to include the line: "Referee shall inspect and approve all wheelchairs" (International Stoke Mandeville Games Federation, 1960b). These amendments included the introduction of specific wheelchair measurements outlined previously, ensuring that all players were competing in equal devices to ensure fairness. However, this also gave officials more power to define which wheelchair models or designs were acceptable to use. In other words, athletes' wheelchairs had to fit in a specific form defined by the ISMGF, and corroborated by their officials. Speaking about changes to wheelchair rules over his time as an athlete, retired wheelchair rugby player and former British Paralympian Robin Tarr (56) explained:

> "So as the chair companies [were] adapting wheelchairs, and athletes were coming up with ideas, the referees were having to monitor these ideas, to make sure that it was actually safe for everybody to play with. So that's when they started, you know, getting the measuring sticks and putting restrictions on what you could and couldn't do."

Paul Clark, (63) A Canadian athlete who previously competed in wheelchair racing events, likewise stated that deviations from these rules resulted in bans from events:

> "Very strict, you would not be allowed to play with... the wrong chair. You would not be allowed to go on a race. In fact, there were several races that I was either not recorded in the results or told to get off the track and go and [revert a modification]."

Strict adherence to these rules suggests that ISMGF administrators thought wheelchair regulations to be of great concern. It is not clear, however, if this importance emerged from the medical concern over prescribed wheelchairs, or the competitive equity of sport – or a combination of the two. Nevertheless, Clark's comment that regulations defined some wheelchair models as 'wrong' reinforces the idea that the ISMGF sought to demarcate acceptable wheelchair technology. This view may become more apparent as wheelchair regulations developed. In amendments to the 1972-1976 ISMGF rulebook, for instance, wheelchair regulations became more specified (International Stoke Mandeville Games Federation, 1973). Rules for wheelchair racing equipment were listed, for example, which specified the maximum rear wheel diameter (65 cm or 25 inches), outlined dimensions for cushion and foot straps, and allowed athletes to remove detachable sides before the start of an event. Moreover, a significant amendment for basketball stated: "No chairs will be allowed with additional wheels or rollers." This rule limited the introduction of developments such as anti-tip wheels, which greatly benefitted athlete stability and control, and prevented injuries (discussed in Chapter 6.3.1). These rules also restricted the rigid-frame Rumple chair, which incorporated a form of anti-tip wheels and had been used by athletes in the United States since the 1960s (see Chapter 6.2.2).

By 1980, general measurement regulations were introduced for all sports. These regulations are drawn from the rulebook for the 1980 Olympic Games for the Disabled, hosted in Arnhem, the Netherlands, and are outlined in Table 2 below (International Stoke Mandeville Games Federation, 1980b). Many of the 1980 rules mirror the 1964 or 1972-1976 rules concerning technological advantage. Rules C13, D14, and E15 retain the regulations concerning footrests, seat cushions, and leg strapping, whereas rule A3 limited mechanical gearing to wheelchairs, as these modifications could grant distinct performance advantages. Rules such as A1, A5, B6, and B8, however, limited the shape and functionality of wheelchairs in specific ways. These regulations restricted alterations to wheel size, use of steering and the introduction of camber, which basketball and racing athletes tinkered with in order to maximise their athletic abilities. Rule A1 further defined the four-wheel limitation, only permitting chairs with four wheels (limiting both additional anti-tip wheels in court sports and three-wheeled racing designs) specifically stating wheelchairs should have "two large wheels and two small wheels." These rules therefore constrained athlete reinterpretation of wheelchairs for sport, limiting modifications that altered the shape or function of the device.

Table 2 – "Rules governing the Wheelchairs in the 1980 Olympics" (Adapted from International Stoke Mandeville Games Federation, 1980b).

A - Wheels	1. The wheelchair shall have four wheels - i.e. two large wheels and two small wheels. No additional wheels or rollers will be permitted. 2. The maximum diameter of the large wheels including the inflated tyre shall be 66.04 cm. 3. No mechanical gears will be allowed for the wheels. 4. One hand rim only will be allowed on each of the large wheels, but these must be one on each wheel. This rule may be waived for persons requiring a single arm drive chair if stated on their medical card by the International Medical Panel. 5. No steering devices will be allowed.
B - Chair	6. The measurement from the bottom of the large wheels to the bottom of the castor (wheel base) shall not exceed 55 cm with the castors in forward pushing position. 7. The maximum height allowed for the seat from the floor to the sides to be 53 cm and a slope not greater than 8 cm. The height of the backseat, measured from seat-rail to the top of the backseat, must be a minimum of 20 cm. The middle of the backseat must be the same as the seat. Deviations in measures on medical grounds must be registered on the medical identity card. 8. Crossbars may not be removed or adjusted. Cambering restricted to 2°.
C - Footplates	9. The back edge of the footplates must be in front of the seat. 10. The footplates must be in position at all times during the competition. 11. Footplates may not be rotated in or out to permit of abnormal placings of one or both feet. 12. Blocks on the footplates are permitted for competitors with short legs provided, they do not extend over the front of the footplates and are made in the form of a solid block. Feet may not be placed on the strap […] between the telescopic bars of the footrest platforms. 13. A strap drawn tight between the telescopic bars of the footrest platform is allowed so that the bottom of the strap is resting as near to the plates as possible.
D – Cushion	14. Only one cushion of uniform thickness and texture is permitted on the seat of the chair. The thickness may not be more as 10 cm and sufficiently pliable to allow both ends to touch when filled. The cushion must be as large as the seat of the chair. No boards or hand material are allowed in addition to the cushion.
E – Basketball and Slalom	15. The footplates must be 11 cm from the floor. Wheelchairs with crash bars around the front of the footplates must ensure that these are exactly 11 cm from the ground and fit right up to the footplates and are not more than 2 cm thick.
F - Basketball	16. The length of the seat upholstery or position of the footplates must be such that there is an angle of 90° and no more for the knees.

Significantly, limitations over certain design features restricted the creation of sport-specific wheelchair models. This may have been a deliberate goal for ISMGF rule makers, who were influenced by medical interpretations of wheelchair sport (detailed in Chapter 5.1.1) and resisted demands from athletes to move disability sport away from hospitals and rehabilitation wards (see Chapter 5.2.4). Sport-specific wheelchairs limited the rehabilitative benefits of sport activities, and thus, regulations restricted modifications or wheelchair designs which deviated from the ISMGF interpretation of wheelchair technology. The 1980 rules specifically restricted numerous specific modifications used by elite racing athletes in the late 1970s and early 1980s (see Chapter 6.3.2.2), and were only gradually permitted between 1984 and 1992 (International Stoke Mandeville Games Federation, 1984a**;** 1984b**;** 1988). Wheelchair racer Craig Blanchette (52) suggested that restrictions over racing technology represented the ISMGF's aim to define wheelchair sport and technology (also outlined throughout Chapter 5.1):

> "For a while, you had to have four wheels. [...] three wheels were actually more stable, when you have most of the weight on the back of the chair and the front wheels further out in front, it was actually more stable than a four-wheeler. But the rules still stated you needed four wheels. […] the sport was outgrowing the rules and the rules were... [...] I guess they were trying to define the sport as they saw it. And wheelchairs had four wheels, so they were trying to set up some guidelines as to what a wheelchair is."

ISMGF regulations aimed to constrain wheelchair technology as athletes advanced sport functionality. Whilst athletes were able to make slight modifications to improve their performance within the confines of ISMGF rules, administrators' interpretation of wheelchair technology constrained significant developments which greatly altered athletes' performances, particularly in sports such as racing. Medical administrators within the ISMGF thus asserted their authority and assumed expertise over wheelchair design, gradually allowing changes which allowed the sport to become more competitive. Athlete self-determination became more pronounced as organisations outside of the

ISMGF followed athletes' expertise and adopted alternative rules, particularly within wheelchair racing.

7.1.3 – Influence of road racing and international rules

From the first International Stoke Mandeville Games in 1950 to the formation of the IPC in 1989, the regulations for wheelchair sport outlined by the ISMGF were utilised in major wheelchair sport events internationally, including the Paralympic Games (Labanowich and Thiboutot, 2011; Bailey, 2008). The Oita wheelchair marathon, for instance, was established as part of the 1981 International Year of Disabled Persons and was jointly organised by the ISMGF (FESPIC, 1985**;** Oita International Wheelchair Marathon, 1983). Regulations concerning racing wheelchair devices followed ISMGF regulations. In 1983, rules for the marathon specifically stated that wheelchair must have four wheels, and only allowed one hand rim on each rear wheel, matching the ISMGF rules of the time (Oita International Wheelchair Marathon, 1983). However, not all wheelchair sports organisations and events followed the ISMGF's regulations. In the field of wheelchair racing, the NWAA deviated from the regulations of the ISMGF at National competitions. In America, wheelchair racers were therefore able to advance racing wheelchair technology, using new modifications in road races which were restricted by the ISMGF. This section considers international differences in wheelchair racing technology and rules, which sparked athlete rejection and protest of ISMGF regulations.

Established in 1958, the NWAA oversaw the organisation of many wheelchair sports in the United States (Savitz, 2006). The NWAA became affiliated with the ISMGF in 1960, requiring the American body to adhere to the ISMGF's rules which at the time only allowed spinally injured participants to compete at international games (Labanowich, 1987). At international events, American athletes had to abide by ISMGF rules for both track and road racing events. However, the NWAA took a more progressive stance on technological development at national events, adopting athletes' interpretation of wheelchair modification. Retired wheelchair racing athlete and previous head wheelchair racing coach at the University of Illinois Martin Morse (66) highlighted that the NWAA banned modified wheelchairs at national track events, but altered this stance based on athlete expertise:

> "By 1977 athletes had started to really modify their chairs. And those chairs were illegal at Nationals with the [NWAA]. So, they would go to road races in modified [wheelchairs] but they couldn't use those chairs on the track at Nationals. And so, in 1979, (wheelchair athlete) George Murray […] showed up at Nationals with a chair that he went road racing in, and he presented it to the NWAA and said, 'This is the future of racing.' And they listen to him. So they allowed athletes to modify their chairs in Nationals in 1980. […] that was my first National. It was amazing, you wouldn't believe all the different contraptions people had invented and tried for wheelchair racing."

Unlike the ISMGF, this account implies the progressive nature of American wheelchair sport, as administrative bodies including the NWAA and the NWBA (see Chapter 5.1.3) centred the opinions and expertise of wheelchair athletes. However, Morse also highlights the role of unofficial sports events for athletes to explore their competitive ambitions. Road racing was popularised in America by athletes such as Bob Hall and Sharon Hedrick, who competed in the Boston Marathon in the mid 1970s (Mastandrea, 2006; pp.107-108). Integrated road races allowed wheelchair racers to compete across classifications and with non-disabled athletes, asserting the view that those who competed in wheelchair sport were legitimate athletes (explored in Chapter 5.2.4) (Mastandrea, 2006, p.108; Brandmeyer and McBee, 1986). Road races also afforded athletes the ability to test new technologies in high-speed environments. Throughout the 1970s and 1980s, athletes introduced a wide range of modifications which significantly altered racing wheelchair technology, such as changes to wheelbase length or the introduction of steering (see Chapter 6.3.2.2).

Interviewees who competed in wheelchair racing during the 1980s outlined the benefit of new racing modifications. Commenting on the benefits of three-wheeled wheelchair frames, former wheelchair racer for Sweden and wheelchair designer Bosse Lindqvist (62) stated:

> "[… in] the early ‘80s [...] we were [averaging] maybe twenty eight, twenty nine minutes on a 10K and like, seven-eight years later, we [were] running twenty one minutes - we were going from an average speed of about 20 kilometres on average, to about 30 kilometres [...] I mean, the safety […] if you take track racing, on 800 meters in the beginning of [the] ‘80s, you would hit a corner and be going [twelve] miles an hour. And suddenly, seven, eight years later, you were hitting the same corner […] at twenty, twenty-two miles an hour […] you needed the good steering to be able to keep [stable], because when we started to go fast, we had tons of crashes. […] we figured out [what] we need[ed] to do, [certain adaptions] to make the chair - to get the racing - a little bit safer [and] still to be able to ...do this high-speed racing, which we want[ed] to do."

Retired British wheelchair racer Ian Thompson (66) likewise outlined the benefits of steering systems for track racing, indicating that ISMGF rules actively reduced athletes’ performance and competitive abilities:

> “The (ISMGF) officials deemed [steering systems] to be outside of the rules. So people weren't able to use those, […] that was the easiest way of actually getting around the corners. Something which actually holds the chair in a steering position whilst going around the bend. And you can then actually put power in equally on both arms to get around the bend, which you [were not] previously able to, you'd have to be pushing one arm more than the other to get around and having to be hopping the front of the chair around the bend.”

The reason behind ISMGF banning of new racing technologies could have been due to safety concerns. Technological improvements allowed athletes to reach higher speeds, leading to multiple crashes, as noted in Lindqvist’s above testimony. One notable incident occurred during the 1987 Boston Marathon, in which a crash impacted 14 of the 46 competitors (Kirby, 1990). Analysis of the event by rehabilitation researcher R. Lee Kirby (1990, p.66) highlights that the incident was partly due to the faster speeds possible as a result of technological progress. However, the improved fitness of athletes was also identified as a reason behind increased performance. Moreover, other factors such as the gradient of the hill, wetness of the road, and formation of the racers were also identified as causes of the crash (Kirby, 1990). Therefore, the danger of new racing technology was not outwardly apparent during this incident. Indeed, Kirby (1990, p.67) notes that serious head and neck injuries 'could' have been possible, if not for other equipment and the "athleticism of those involved," and in actuality, any injuries were minor. Nevertheless, the 1987 Boston Marathon crash and other similar incidents appear to have been the justification for limiting racing wheelchair design. Former British wheelchair racer and politician Baroness Tanni Grey-Thompson (51) highlighted athletes' feelings towards this choice by the ISMGF:

> "And the rules at the time were that you weren't allowed any steering on the chair or brakes, because that would encourage us to go too quickly. Not patronizing at all. [...] [In the rules,] it was felt the three wheeled chairs weren't safe."

Elite-athletes objected to this reasoning, as it clashed with their desire for high-speed wheelchair racing. Whilst the NWAA recognised wheelchair athletes' interpretation of wheelchair racing technology, the ISMGF continued to reject their arguments. Racing athletes accordingly worked to mitigate safety-based objections, by debating the issue at ISMGF technical committee meetings, refining racing innovations, and increasing testing. Ultimately, tests conducted by athletes and sports scientists found that these modifications actually made wheelchair racing safer than before. Academic and former wheelchair racer Rory Cooper performed such tests on technological developments including rear wheel alignment (Cooper, 1989a; Cooper, 1990), road crown compensators (Cooper, 1989b), and steering systems (Cooper, 1989c). Referring to these tests, in interview Cooper (60) commented on the improved safety of these racing modifications:

> "So steering gear, that came about because it protected athletes' wrists and shoulders from undue injury and was safer. First people thought steering gear would be unsafe because you would be locked in a path on the corners. There is no real basis for that

> assertion. Steering gear, which is basically an extension of crown compensators, was not going to go away, it was much faster, and much safer. Because you could push with both hands around the turns.”

Due to these tests, athlete acceptance of new designs in the United States and other countries, and wider dissatisfaction with administrators at Stoke Mandeville, ISMGF regulations regarding racing wheelchairs were seen as outdated. To athletes, the ISMGF was falling behind the international growth of wheelchair racing technology and sport, and therefore out of step with athletes. Former wheelchair racer and coach Martin Morse (66) remarked:

> "We (American athletes) were about {two} years ahead of the rest of the world. Internationally people were stuck with the ISMGF rules, which meant no steering, no compensators. They also had a limit on the length of the chair, and the NWAA allowed a longer chair, {which was} more stable on down hills. I don't think... [the] ISMGF saw what was happening on the roads in the US. They didn't realise that all of a sudden, people were in racing wheelchairs..."

Morse’s comments exemplify the divide between athletes and medically based administrations explored throughout chapter 5. Likewise, retired British wheelchair racer Ian Thompson (66), voiced the opinions of athletes at this time:

> “…there was quite a strong push from the athletes around [the world] you know, the sport needs to keep pace with what technology is and what we're doing."

As a result, racing athletes from the United Sates and other countries became uninterested in track competitions under ISMGF regulations, including the Paralympics. Former American wheelchair racer Martin Morse (66) commented that American athletes had little reason to participate under rules which restricted their competitive abilities:

> "The rules were backwards and there was no incentive for us to go other than for National pride. We had to miss a few lucrative road events to compete at the 1988 Paralympics."

At ISMGF events, American athletes had to use four-wheeled devices which lacked steering and other advances. Former British Paralympian Baroness Tanni Grey-Thompson (51) commented on her time at the 1988 Paralympics in Seoul, recalling that “American athletes having the steering sawn off the chairs because they weren't allowed it." Additionally, Morse (66) stated:

> “…when we went to Stoke every year, we had to turn the technology back in time, to an archaic form of racing, with no steering, short chairs. And as a coach and the athletes that I had, just constantly were working on the official[s] saying, 'You're missing the boat here, this is what racing is like in the United States!' And the Canadians started to adopt our rules, the Mexicans did the same thing. And they would race {our type of chairs} when they came to the US and chairs are highly modified. But when they went to Stoke or to the Paralympics, they had to take all the technology off their chairs.”

The language used by Morse highlights competitive athletes’ attitudes towards these regulations, and the ISMGF as an administrative body. This approach to technology was seen as archaic by athletes, who had access to devices that would dramatically improve their performance. However, they were not allowed to use them at the Paralympics, one of the most significant international disability sport events.

Divisions between ISMGF and NWAA rules created two strands of wheelchair racing, separated by geography and the technologies they were able to use. Protest emerged as athletes from America and other countries resisted and rejected ISMGF regulations. To athletes, these regulations were seen as backwards and arbitrary, and ultimately incompatible with their interpretation of wheelchair sport. Protest to these rules was therefore a site of athlete self-determination within the development of wheelchair sport and technology.

<u>7.1.4 – Modification as a site of protest</u>

Athlete protest to wheelchair sport regulations existed as a significant assertion of athlete self-determination and agency. Protest events organised by and for disabled people can be traced back to the early twentieth century (Hunt, 2019; Greater Manchester Coalition of Disabled People, 2010), increasing significantly in the United States by the mid-1980s and in other countries by 1989 (Barnartt, 2010; Barnartt and Scotch, 2001). Disabled people fought for access, citizenship, and fair representation in organised protests such as the 1977 Section 504 Sit-in (Osorio, 2022; Williamson, 2019, pp.131-132) and the 1990 and 1992 Block Telethon protests (Stage, 2023). Athlete protest against the ISMGF links to wider disability rights protests, which emphasised the self-determination of disabled people. Analysis of disability protests between 1970 and 2005 by Barnartt (2010, p.236), however, highlights that disabled people's political action generally targeted entities within countries (private companies, local and state governments, public services, transportation) as opposed to trans-national organisations. In this instance, individual but linked acts of protest by athletes against the ISMGF worked to alter wheelchair sport regulations for all disabled athletes internationally.

Protest was achieved as athletes found loopholes in ISMGF rules and used modified sport wheelchairs at sanctioned events. These modifications needed to operate within the technical confines set by the ISMGF, whilst undermining their purpose. Examples of this form of resistance are common within wheelchair racing, due to the rapid evolution of racing technology and the comparatively slow evolution of ISMGF rules. Athletes also challenged these rules off the track, as they argued against regulations in administrative settings. By doing so, athletes tested the boundaries and logic of these regulations. This section explores examples of athlete technological and administrative protest to demonstrate how athletes asserted their interpretation of wheelchair sport and technology.

One example of this can be seen in the development of push-rim placement. In the 1970s, the rear wheels of manual chairs featured a large push-rim, placed toward the edge of the wheel for easier access. Swedish athlete Lars Löfström modified his racing wheelchair to have two push-rims on each rear wheel. The additional push-rim was smaller, around 12 or 13 inches, placed closer to the centre of the wheel (Brady, 2023). The placement of the additional push-rim allowed Löfström to accelerate quicker than other competitors at the 1976 Paralympics in Toronto, Canada, allowing him to win the event. Officials reasoned this constituted an unfair advantage, and amendments to the 1972-1976 regulations show that only one push-rim would be allowed in future competitions to negate this benefit (International Stoke Mandeville Games Federation, 1972b). In the 1970s, many athletes still used the same wheelchair in sport and everyday life, and the lower placement of the smaller hand-rim on the rear wheel was of less benefit in everyday use of the wheelchair. It could be speculated that the restriction to one hand-rim was put in place to discourage this form of modification. Wheelchair racers responded by maintaining Löfström's smaller push-rim modification (Brady, 2023).

This decision symbolised athlete desire for specialised sport wheelchairs, and rejection of ISMGF interpretation of wheelchair technology. Indeed, as racing wheelchair technology continued to specialise, and ISMGF rules restricted these advancements, athlete protest became more creative. A significant source of protest was the rule against three-wheeled chairs, as this design presented significant advantages in racing (see Chapter 6.3.2.2). As indicated in Table 2, ISMGF rules nevertheless required all wheelchairs used at sanctioned events to have four wheels until 1984 (International Stoke Mandeville Games Federation, 1980b**;** 1984a). Creative racing athletes therefore protested this ruling by using wheelchairs that had four wheels, but functioned as three-wheelers. This was achieved by diverse methods highlighted by interviewee testimony. For example, American wheelchair designer Rory Cooper (60) recalled using a toy wheel as the fourth wheel of his racing chair, in order to maintain the advantages of the three-wheel design. He commented: "That's where the letter of the rule versus your engineering knowledge comes in…". Likewise, retired wheelchair racer Baroness Tanni Grey-Thompson similarly recollected how Swedish wheelchair athlete and designer Bosse Lindqvist undermined the wording of the rules:

> "[Bosse] turned up at a race with a three wheeled chair with an eight-inch caster duct taped to the back. Because the rules said, 'You have to have four wheels.' The rules didn't say four wheels on the ground. [As well,] Eagle [Sportschairs] had a chair with four wheels. But the two front wheels were very close together, so in fact, it was a three wheel[ed] chair."

Other interviewee comments outlined other ways in which athletes subverted regulations to have wheelchairs that were functionally three-wheelers. Ian Thompson, retired wheelchair racer and coach, recalled one instance where an athlete competed in a four-wheel wheelchair, but let out the air of one wheel as the race began, meaning the device functioned as a three-wheeled wheelchair. Figure 20 shows a wheelchair of similar functionality, using two front wheels of different sizes. This wheelchair was used by former Canadian wheelchair athlete Paul Clark used a similar device in the 1986 Oita wheelchair race. During interview, Clark (63) outlined how this wheelchair flaunted the ISMGF rules:

> ‘”I had a twelve-inch front wheel […] And then I had one of the eight-inch regular hospital [caster wheels] that I mounted as well beside it. And of course, it had to be looking like it would almost touch the ground […] it was really more for decoration. That got me into trouble in some races, because in a couple of races […] I just decided, 'Well, I'm not going to bolt my fourth wheel on this time, I'll just leave it off' and then I took a dinky toy wheel and […] I taped it to my chair. So when the refs would say, 'Well, where's your fourth wheel? I'd say, 'Well, right here.”

Figure 20: Paul Clark's 'four-wheeled' racing chair. 1985. Taken from the poster for the 6th Oita International Wheelchair Marathon, 1986. Shared with permission of Rudi Van den Abbeele.

Modifications and the use of 'three-wheeled' chairs therefore represented athlete protest to ISMGF rules. By using these wheelchairs, athletes simultaneously reinforced their own autonomy concerning wheelchair technology, whilst undermining the letter and intention of the established ISMGF regulations. The use of modifications therefore constituted a site of agency for athletes, as they found creative ways around restrictions to enforce their interpretation of wheelchair technology.

Rule-maker reception to these challenges often resulted in the banning of the offending athlete from events. During his interview, Paul Clark (63) made several comments around being removed from races due to illegal wheelchairs, or being allowed to compete but not having his results recorded. Clark's testimony implies that other athletes did what they could to protest his removal from a competition:

> "[…] other athletes were very supportive of me having three wheels, because they knew that I was a good athlete. And they would just come around me at the starting line so that the police couldn't take me off the course. […] And then, of course, I was not included in the results for that race anyway, because I had three wheels instead of four."

Modification therefore also acted as a site of communal resistance, as athletes reportedly objected to the removal of other players for using wheelchair designs. It could be speculated that this type of protest occurred due to international frustration surrounding ISMGF racing wheelchair regulations highlighted in the last section, or wider divisions between athletes and the ISMGF (see Chapter 5.2.4). However, it is unclear if such occurrences were common at sport events, or if other athletes saw the use of three-wheeled devices at ISMGF competition as an unfair advantage. Indeed, other examples of this form of support we not found within other interviews or primary data. Nevertheless, Clark's testimony may suggest that these designs were perceived as a form of protest against rules which restricted the evolution of wheelchair racing.

Athletes also protested these regulations from within sport administrative bodies. Previously noted in Chapter 5.2.4, wheelchair athletes were better represented in wheelchair sport organisations outside of the ISMGF, such as NWBA (Bailey, 2008, p.20; Labanowich, 1987). In American disability sport, this created a culture in which athletes felt empowered to change their sport. Former American wheelchair racer and coach Martin Morse (66) recalled his involvement in the evolution of the NWAA's regulations:

"I guess with Brad Hedrick (wheelchair athlete, coach, academic, and director of the Disability Resources and Educational Services at University of Illinois between 1977 and 2014), sometimes I'd be complaining about some of the rules or regulations that existed in wheelchair racing. And he always said the same thing to me, 'If you have a problem […] then step up and […] push for changes.’ So I did that. In 1984, '85, I wrote the NWAA Wheelchair Road racing rules. I modified the rules that (wheelchair athlete) Phil Carpenter had developed for {The International Wheelchair Road Racing Club in 1980.} The rules that I developed in '84, '85 - that's in the National Wheelchair Athletic Association rulebook, which were eventually adopted by [the] ISMGF and the IPC."

Accustomed to athlete autonomy within American wheelchair sports organisations, American athletes including Morse and Cooper directly challenged ISMGF regulations surrounding the use of racing wheelchair modifications within the Paralympics (Brady, 2023). Cooper (60) recalled:

“I was the one of the US representatives and I made the argument for three wheels starting in about 1986. I think we finally finished in 1994. We took an incremental approach to get several rules changed, we had to get rid of 120-centimetre overall length requirement. So, we worked on it, once we finally got rid of that, it made three wheelers practical."

The gradual changes referred to by Cooper may be viewed in ISMGF regulations for track events. In the 1980-1984 rule book, wheelchairs had to have two small front wheels and two larger rear wheels (International Stoke Mandeville Games Federation, 1984a). In the 1984-1988, this regulation changed, now stating that “the wheelchair shall have at least two large wheels and one small wheel.” This was also reflected in rules for other events which followed the ISMGF regulations, such as the 1989 Oita wheelchair marathon (Oita International Wheelchair Marathon, 1989). However, Cooper stated that athletes continued to fight to remove the restriction on length, as three-wheeled devices needed to be longer to maximise their performance enhancements. As a result, many athletes in the 1988 Paralympic Games in Seoul, South Korea, still used four wheeled wheelchairs, despite the rule around three-wheeled designs being lifted in 1984 (Seoul Paralympic Organizing Committee, 1988c, p.3). This can be observed in images from racing events at the 1988 Games, such as Figure 21, taken from the newspaper published at each day of the Games by the organising committee. Seemingly, other rule changes were necessary for the entire performance benefits of three-wheeled racing models, akin to the number of modifications needed to benefit the rigid frame design outlined in Chapter 6.2. Moreover, steering devices were not allowed outside of road races (as seen in the 1984-1988 handbook (International Stoke Mandeville Games Federation, 1984b) until the restriction was altered in the 1988-1992 rulebook, now stating: "Only hand operated mechanical steering devices will be allowed" (International Stoke Mandeville Games Federation, 1988). These incremental changes highlight the potency of athlete involvement in wheelchair administration, particularly as wider changes such as the establishment of the IPC in 1989 allowed the competitive interpretation of wheelchair sport and technology to take hold. Morse (66) reflected on the impact of these changes:

> "[…] between the 1988 games and the 1992 games. That was a moment of technological leaps for disabled {men and women}, because we went from chairs that had no steering and no compensators in 1988, to 1992 where the chairs did have steering and compensators. That was a huge, huge moment in racing technology. […] And that all came about because of the rule that (Rory) Cooper and I wrote on steering and compensators."

Figure 21: Line up of female Paralympians for a track racing event at the 1988 Paralympic Games in Seoul, South Korea (Seoul Paralympic Organizing Committee, 1988b, p.1).

Athlete protest to technical rules were potent both on and off the track, as athletes asserted their interpretation of racing technologies. Following the 1988 Games in Seoul, South Korea, ISMGF regulations concerning wheelchair technology were altered, allowing three-wheeled racing wheelchairs to be used in sanctioned events. As three-wheeled designs, use of steering, and extended wheelbases became universally accepted in international rules, racing wheelchair technology began to stabilise. This stabilisation would not have been possible without athlete protest. Resistance to wheelchair technology regulations were therefore a potent site of agency autonomy and self-determination within wheelchair sport.

<u>7.1.5 – Conclusion</u>

Regulations surrounding wheelchair technology evolved alongside of the introduction sport-focused wheelchair modifications and models. In this process, regulations both affirmed and resisted athletes' interpretation of wheelchair sport and technology. Initially, restrictions ensured fairness between competitors, emphasising athletes' physical abilities over technological advantages. Regulations also maintained medical control over wheelchair technology, which ultimately restricted athletes' self-determination in the development of wheelchair technology. As political protests led by disabled people occurred in the later decades of the twentieth century, wheelchair athletes rejected ISMGF regulations which hindered their self-determination and competitive interpretation of wheelchair sport. Accordingly, athletes protest of ISMGF rules was an expression of user expertise and autonomy, as wheelchair users campaigned for their interpretation of sport and technology to be reflected in equipment regulations.

7.2 – Industry and lead user autonomy

The industry which designed and distributed sport wheelchair technology grew to be another significant source of autonomy and self-determination for wheelchair athletes by the mid-1980s. Following the breakdown of a monopoly over manual wheelchairs, and manufacturer's disinterest in user-led design, some wheelchair users founded manufacturing companies to serve the athletic community. These actors can be defined as 'lead users', due to their personal interest in innovation and need for innovation ahead of the target market (Shah, 2000, p.12). Moreover, lead users can be identified as entrepreneurs, as they often established small businesses, facilitated significant change in equipment, and established new markets (Vamplew, 2018; Maritz and Laferriere, 2016; Parker Harris et al., 2014). By the 1990s acquisition of these companies by larger conglomerates resulted in a loss of athlete autonomy, primarily due to the lack of wheelchair users in positions of power within the modern industry. Accordingly, this subchapter argues that these later changes in the sport wheelchair industry constituted a loss of autonomy and self-determination for athletes.

The first section of this subchapter highlights the importance of innovation to athlete autonomy. Stagnation and manufacturer indifference in the wheelchair market created a space in which athletes could assert their interpretation of wheelchair devices and establish manufacturing firms. The second section expands on these ideas, exploring the different ways lead users' companies contributed towards athletes' economic and social agency. The third section follows, outlining the economic reality of the sport market, and the trend of acquisition which removed lead users from positions of influence in the industry.

7.2.1 – Innovation, business, and athlete autonomy

Athlete reinterpretation of manual wheelchairs resulted in a period of intense innovation between the late 1970s and 1990s that radically transformed this industry. This section argues that innovation was an important source of autonomy for athletes, as new designs presented a direct challenge to existing wheelchair manufacturers. Innovation in wheelchair design was uncommon in the mid-twentieth century due to medical practitioners' guidance and a monopoly over the manual wheelchair market by E&J. Moreover, these companies rejected users' feedback and design suggestions. As a result, the development of user-led wheelchair design and creation of sport wheelchair manufacturers emphasises multiple forms of athlete self-determination. Socially and politically, innovation represented athlete rejection of existing manufacturers, and the assertion of lead users' substantive expertise.

By the middle of the twentieth century, the industry which made wheelchair technology had stagnated. According to C.E. Brubaker (1986; 1988), a medical researcher specialising in rehabilitative engineering, standard wheelchair designs had not changed significantly between the 1930s and 1980s. Manufacturers failed to innovate, only prescribing wheelchairs of a generic design to all users. One explanation for the stagnation of wheelchair technology was economic. Brubaker (1986) hypothesised that a lack of innovation emerged from the desire to keep production simple and cost effective (Stewart and Watson, 2019). As he later observed, the acquisition of wheelchairs from government agencies or insurance companies in the United Sates required manufacturers to stick to set price points and design specifications set by medical professionals (Brubaker, 1988). As shown in Chapter 5.1, practitioners' interpretations of wheelchair sport and independent living did not require significant innovations toward wheelchair technology. Indeed, creating devices separate to those used in everyday life was antithetical to the physical and social rehabilitation of sport (detailed in Chapters 5.1.1 and 6.3.1). Fearing product rejection from medical professionals, manufacturers did not invest in research or development around manual wheelchair design.

Alternatively, a lack of innovation may have been sustained due to the monopolistic control of the wheelchair market by E&J. Borisoff (2010) estimates that by 1978, E&J controlled 90% of the manual wheelchair market in America and internationally. As a result of this control, E&J executives may not have seen a need to innovate, as they ran a monopoly and lacked competitors. Innovations for sport did occur as other companies tried to create their own space in the market. For example, a smaller competitor of E&J, Stainless Medical Products Inc, collaborated with rehabilitation staff at the University of Illinois in 1967 to create a sport-focused wheelchair model (Labanowich and LaMere, 1984). Despite retaining the folding functionality, Stainless' resulting design was lighter and more adjustable than E&J's products, offering features such as removable armrests (Labanowich and Thiboutot, 2011, p.248). Stainless' wheelchairs became popular with athletes, used by notable wheelchair basketball teams in the US including the University of Illinois Gizz Kids (Labanowich and LaMere, 1984) although wheelchair athlete and coach Armand Thiboutot noted the rigid Rumple wheelchair was still more manoeuvrable on the court in the same era (Labanowich and Thiboutot, 2011, p.248). Figure 22 shows that Stainless marketed their wheelchairs to athletes as sport models, utilising language of 'Champions' and dubbing one model the 'Super-Sport.' E&J, nevertheless, was able to copy the Stainless design rather than conduct their own research and development. Labanowich and LaMere (1984) note that shortly following the introduction of Stainless' product, E&J began producing a similarly designed sport wheelchair. As a result, Stainless ceased wheelchair production shortly after this time (Labanowich and Thiboutot, 2011, p.248). The market was accordingly discouraged from innovation.

Figure 22: Stainless advertisement. Approximately late 1970s. Shared with permission of John Brewer.

Wheelchair technology stagnated as innovation slowed, and athletes, in turn, interpreted a lack of innovation as a marker of manufacturer arrogance or power. According to Cliffe Crase, wheelchair athlete and editor of wheelchair sport magazine *SPORTS 'n' SPOKES*, E&J "became smug" and "stopped listing to users" (Shapiro, 1993). Historically, wheelchair manufacturers and medical professionals had dismissed user feedback or proposals (Williamson, 2019). Woods and Watson (2004), for instance, detail that in the 1950s and 1960s, user suggestions on NHS-provided wheelchair designs were largely disregarded by engineers and medical professionals. In this instance, a lack of innovation was not financially driven, but by the perceived authority and expertise of these professional groups over the users of the devices. E&J similarly rejected the innovative designs of the Quadra wheelchair (Labanowich and LaMere, 1984; Labanowich and Thiboutot, 2011). Initially created by wheelchair athlete Jeff Minnebraker in 1972 and supported by a team of other athletes – Brad Parks, Mary Boegel and Eric Walls – the

Quadra was one of the first rigid frame lightweight adjustable wheelchair made of aluminium (see Chapter 6.2.2) (Vogel, 2012; Labanowich and LaMere, 1984). Subsequently, the chair became popular with active wheelchair users in the United States, and the Quadra team struggled to keep up with demand (Vogel, 2012). Seeking more resources to manufacturer their designs, Boegel recalled pitching the Quadra to E&J executives in the late 1970s (Vogel, 2012). E&J executives reportedly dismissed their proposal on the grounds of their perceived authority and expertise:

> "We are the biggest wheelchair company in the world. We know wheelchairs, you don't. This type of chair will only work for, at best, one percent of the market. And it will be a dangerous liability for higher level injuries."

Athletes' innovative actions in wheelchair technology may therefore be understood as a form of political advocacy or self-determination. Athletes resisted economic and structural inequalities which limited positions of influence they had over wheelchair design. By taking innovation into their own hands, any athlete or wheelchair user could reject the stagnant designs which the industry proliferated, and refute the embedded narrative that these actors 'knew' wheelchairs more than users.

To assert their agency in wheelchair design, many early innovations were implemented with simple equipment and materials available to athletes. In context of inclusion and the use of digital technologies, Zidjaly (2015, p.187) defines disabled peoples' agency as "what people with disability actually do with the resources available to them." Extrapolating from this definition, wheelchair users engaged in acts of modifications based on the tools and knowledge at their disposal. Early modifications such as removing push handles and arm rests, or cutting down backrests could be achieved with a hack saw or similar tool, and required no other technical knowledge, as reported by Martin Morse and Phillip Craven in Chapter 6.2.1. Similarly, Gary Davidson (56), retired wheelchair basketball athlete and Scottish representative for manufacturer Max Wheelchairs, recalled the resourcefulness of Ian Rae, a fellow wheelchair athlete who modified Davidson's wheelchair:

"… (Ian) went and got an Asda trolley, and took the front casters off it. Because then, money was tight, you know? *Laughs* So he went and stole an Asda trolley. And he went and took the casters off it […] he found that the thinner the tyre, the better it was, because there's less […] friction and it went faster. [He] took the 26-inch wheels off this bike that he got, and put pushing rims on it [...] And that's the way it was set up, there was nothing technical about it."

Early instances of modification and customisation constituted an initial form of agency – a way for athletes to assert their reinterpretation of wheelchair technology in simple ways, using the resources available to them (Zidjaly, 2015).

Major advancements in sporting wheelchair technology occurred as athletes who possessed professional skills and equipment began to modify wheelchairs. Many wheelchair users involved in wheelchair modification had pre-existing interest or knowledge in engineering, having professional experiences in metal or woodworking, or having gained engineering degrees. Many were involved with motorcycle or bicycle sports before possessing a spinal cord injury, as highlighted in Chapter 5.2.4. These wheelchair users therefore had the skills, technical knowledge, and equipment to make more advanced modifications or begin to design their own wheelchair frames. This trend therefore represents a different form of user self-determination, reflecting experiences of wheelchair use and desire for improved athletic performance, but utilising the resources, knowledge and expertise of professional engineering or craftsmanship.

Twelve interviewees in this research fit this categorisation, who will subsequently be referred to as 'lead users'. Prior to his injury, British wheelchair user and retired athlete Vincent Ross worked as a draughtsman, and built and raced road, dirt, and motor bikes. He referenced making wheelchair modifications in his garage workshop, modifying wheelchairs for himself and some others. Rory Cooper (60), American academic and retired wheelchair racer, similarly benefitted from a familial background in car repair and an educational background in engineering:

> "I was lucky, my parents had an automotive machine shop and my grandparents, my mother, my father were all auto mechanics and auto machinists. I learned a lot of those skills by working in the family business growing up, [...] and then when I studied engineering [at] University I learned about other processes and materials that are better for the job."

Lead users such as Ross and Cooper utilised their personal and professional knowledge and experiences when modifying and re-designing wheelchair devices. Technological innovation became a way for athletes to resist a stigma of incapability, which assumed devices including wheelchairs should be made *for* disabled people, and not *by* them. In dismissing ideas and feedback, manufacturers and professionals invalidated the expertise and autonomy of many wheelchair users, which developed from their lived experiences of wheelchair use, and professional or personal skills as engineers, designers, and athletes (Hamraie and Fritsch, 2019).

Lead users also recognised a gap in the wheelchair market, and established manufacturing companies. The founding of manufacturers represents a third form of self-determination, as these athletes directly challenged manufacturers such as E&J who operated within the sports market, and proliferated wheelchair users' reinterpretation of sport technology. Wheelchair users' designs were more visible (via advertisements) and available (to be purchased, as opposed to made by the user or those they knew) than before. Furthermore, lead users were able to shape a new market for sports wheelchairs following the 1978 anti-trust suit against E&J, which created space for other manual wheelchair companies on the market (Shepherd and Karen, 1983; Borisoff, 2010). Lead users continued to innovate throughout the 1980s and 1990s, developing new approaches to sport-specific wheelchair models as demonstrated throughout chapters 6.2 and 6.3. Innovation in the context of the wider wheelchair industry represented the continued assertion of lead user agency. Athletes established a small market for sports wheelchair technology, and continued to iterate on sport-specific wheelchair models.

Nevertheless, lead user Vincent Ross (69) observed that his personal interest in the technology led to business difficulties:

> "So for me, the fun was coming up with innovations and making new things.[…] I was more interested in making something new, and basically a new toy for myself, to be perfectly [honest]... than driving the business forward as a business if you like. We manged to keep going all this time, so […] I wasn't that bad at it, I suppose. But the fun part for me is doing new stuff and still is, you know."

Innovation served multiple potent roles within the development of sport wheelchair technology and industry. Manufacturers such as E&J resisted innovation, due to the economic consequence of product rejection from medical institutions, and a lack of competition. For athletes, innovation represented the assertion of their reinterpretation of wheelchair technology, declaration of agency, and rejection of existing companies. As wheelchair users had been ignored by manufacturers for decades, lead users work modifying wheelchairs and establishing manufacturing companies represent an assertion of their own autonomy and expertise. Indeed, as the sport wheelchair market developed, user-owned wheelchair manufacturers became a source of economic autonomy and support for wheelchair athletes.

7.2.2 – Lead users as manufacturers

This section considers the impact of lead users' businesses on the wheelchair market, and other athletes. Based on Vamplew's (2018) definition, lead users can be defined as entrepreneurs as they created equipment, establish new markets, and increased the supply or quality of innovative products. Lead users can also be defined as entrepreneurs in a traditional sense, as they established their own businesses. Literature concerning disability and employment has highlighted the role of individualised self-employment and entrepreneurship for creating job opportunities for disabled people. Rates of self-employment are higher amongst disabled populations, linked to factors such as employer discrimination in traditional workplaces, or the increased accessibility, independence, and flexibility of self-employment for disabled people (Callahan et al., 2002; Jones and Latreille, 2011; Maritz and Laferriere, 2016). In light of the discrimination against users from within the wheelchair industry in this era, it is argued that user-led manufacturers were a key source of economic, social, and communal agency for wheelchair athletes. These ideas can be perceived in the types of products manufacturers offered, the value of user-led design, and the economic and athletic support they offered to other wheelchair users. In creating these enterprises, lead users engaged in worldmaking, producing material conditions that allowed disabled people "to thrive" (Hamraie and Fritsch, 2019, p.7) – here interpreted as fulfilling the competitive ambitions of athletes.

These ideas are split into three subsections. Initially, lead users' abilities to identify gaps in the market are highlighted, as their position as both manufacturer and athlete gave them increased knowledge of consumer interests. Secondly, the use of lead users' identity in advertising is analysed. The third section considers how lead users used their companies to create opportunities for other wheelchair users. This section explores a range of manufacturers and lead users, but focuses on the testimony of Jim Martinson, a retired wheelchair racer and founder of the American wheelchair manufacturer Magic in Motion, which produced the Shadow brand of sport wheelchairs between 1980 and 1992.

7.2.2.1 – Gap in market

Lead users engaged with entrepreneurial activities in order to address the gap they identified in the market (Shah, 2000; Maritz and Laferriere, 2016; Parker Harris et al., 2014). Lead users such as Loral 'Bud' Rumple and Jeff Minnebraker created sport-focused designs in the 1960s and 1970s as they were frustrated with existing technologies (see Chapter 6.2.2). Martinson's career creating sport-focused wheelchairs, likewise, came about due to manufacturers inability or unwillingness to address demand. Establishing a company presented an opportunity for Martinson, and other lead users, to direct the development of wheelchair technologies, whilst serving their own interests in creating sporting devices. Martinson (73) explained that advancements in other technologies created an opportunity for lightweight equipment, which existing large scale manufacturers such as E&J were not pursuing:

> “I realized that people needed to have lightweight wheelchairs. I lived less than 45 minutes [away from] Boeing airplanes, where they make them. We have aluminium, we have titanium. And we were building wheelchairs out of steel. […] So I go, 'This is stupid. Why can’t people with disabilities have lightweight equipment?' And... I sat down with my wife, and some other people in the house, and said 'I'm going to step out and start manufacturing wheelchairs.'”

The actions of lead users embody a form of activism which asserts the expertise and abilities of disabled people. Hamraie and Fritsch (2019, p.7) write that disabled people engage in epistemic worldmaking practices due to ‘misfitting' in the existing world. Lead users, who possessed substantive expertise, were able to materialise new approaches to wheelchair design (see Chapter 6) and proliferate new products via their own businesses.

As athletes and wheelchair users, these business owners understood their market and could address audience needs. During his athletic career as a wheelchair racer, Canadian wheelchair Paul Clark set up a company with his non-disabled friend, Dale Williams, which operated between 1979 and 1984. Williams, who was not disabled, had helped Clark make a customised wheelchair for racing. Clark (63) explained:

> “We started to realise that the chairs that we built might be good for me, because I was only about 120 pounds. And some of the [adult athletes] that we built it for, they were just bigger and beefier, and they bent the frames. And one guy was really rough on the chair that we sold him. So we decided that we should make it a youth racing wheelchair company. So we built all of our chairs rather small. And they were made for young developing athletes, because they were always the most challenged to get into racing in the first place, because none of the wheelchairs would ever fit these young people. So we then, over about three years, I think we stopped in about [‘84], we produced about 30 chairs.”

The economic success of manufacturers such as Motion Designs, the manufacturer of the everyday Quickie lightweight wheelchair, further demonstrate that user-founded manufacturers understood users as consumers, as opposed to patients. The Quickie was created by wheelchair user Marylin Hamilton and her non-disabled engineering friends Jim Okamoto and Don Helman. Following a hang-gliding accident, Hamilton wanted a lightweight wheelchair to replace her medically provided wheelchair so she could perform better in tennis (Shapiro, 1993). The three created lightweight and sleek devices, and came in a range of colours – creating a stark contrast to hospital provided, chrome or steel-coloured wheelchairs. Marylin Hamilton spoke about her team's approach to lightweight wheelchair products (Hamilton, 2021, p.11):

> "We really thought a lot about, not a wheelchair for me, but how do we take that (Hamilton's wheelchair) and […] commercialize that for everyone, and how do we take that chair and really create creature features in it with adjustability so you don't have to buy a whole new chair when you may be different or want to do something different […]."

As the sales and marketing representative for the Quickie brand, Hamilton focused on the athlete market, who found performance benefit in their product's lighter materials. According to Hamilton, this strategy resulted in a lack of interest from major wheelchair manufacturers of the era. The industry at large was not receptive to the idea of a lightweight everyday wheelchair, allowing Quickie to develop their products, audience, and marketing. Hamilton (2021, p.12) stated:

> "The dealers out there were not willing to purchase from us in the beginning because we weren't giving as much margin, they were more expensive and […] they didn't know if we were going to be around in five years. And so, they weren't taking that risk with us. But the therapists got it and the consumers got it."

Quickie reached financial success by advertising wheelchair products in new ways. Hamilton described that marketing materials for other wheelchairs products as “drab, it was sick, everything was black and white and only showed products, they never used people in a wheelchair” (Hamilton, 2021, pp.18-19). In comparison, Quickie’s wheelchairs were colourful, distinguishing them from chrome-coloured medical devices and redefining their user as active (Williamson, 2019, p.193). Quickie advertisements shared this vision. Figure 23 is an example of one of many full-page advertisements that could be found in issues of *SPORTS ‘n’ SPOKES*, showcase Hamilton and fellow tennis athlete Randy Snow, smiling and confident in their Quickie Wheelchairs. Moreover, Hamilton stated that name Quickie itself made the devices more fun (Hamilton, 2021, pp.19-20), whilst advertisement that featured Hamilton and other wheelchair users using these devices reinforced ideas of activity and independence. Shapiro (1993) accordingly argues that the colourful and sporty nature of these wheelchair models appealed to the growing disability politics movement of the era. Quickie wheelchairs not only brought sport technology to the market, but notions of mobility and independence. Reportedly, Quickie grew into a $40 million-a-year business by the late 1980s (Shapiro, 1993; Cooper et al., 2002). Shapiro (1993) also argues that the establishment of Quickie and other user-established manufacturers captured a growing generation of independent, employed wheelchair users, who constituted a new consumer group – but one that was being ignored by traditional manufacturers as they sold wheelchairs largely through medical institutions. User-established wheelchair manufacturers thus captured the economic self-determination of wheelchair users of this era – both as business leaders and as consumers.

Figure 23: Motion Designs advertisement for Quickie, featuring Marilyn Hamiliton (right) and Randy Snow (left) (Motion Designs, 1983, p.3).

7.2.2.2 – Marketing to consumers

User-directed wheelchair design subsequently possessed distinct value for some athletes. Interviewees commented that lived experience of wheelchair use was an important factor in the design process, as the designer understood how the product would be used both on and off the court. Swedish wheelchair user, former basketball player, and wheelchair designer Jalle Jungnell (67) outlined why his company, Panthera, stopped making sport wheelchairs by the 1990s following his retirement from wheelchair basketball:

> "I think if you're gonna do very high-end products, you have to understand them. Otherwise you can't do it. […] that's when I stopped (producing basketball wheelchairs), because I [didn't] understand, really, any longer what is needed, because it's fine tuning. […] You have to really have a feeling […] an understanding, and I think it's difficult if you don't do it yourself. So I think many, many users, many, many examples, [like] Bob Hall […] they've been in sport themselves, they understand. The fact is [they are] behind the chair, why it's good and why it's not good. That's why they can develop new things."

This sentiment also applied in partnerships between athletes and non-disabled engineers. Commenting on his previous work with non-disabled wheelchair designers, retired wheelchair rugby player Robin Tarr (56) said:

> "It's much better if you've experienced it, you know, I've experienced sitting in chairs, I know how a chair moves, […] I've got a good feeling about how a chair should be. So working with somebody who [has] that engineering mind, the two together can put something together, you know, and it works well."

Retired British wheelchair basketball athlete Maurice Hammerton (59) likewise expressed the idea that wheelchair users closely understood wheelchair technology and the needs of users. However, he commented that during his athletic career he purchased devices from lead users as they provided the type of equipment he wanted, not because they were also wheelchair users:

> "I didn't buy... from them just because they were players, but it just happened to be that they knew what I wanted, and they could provide the best equipment for me. The chairs that I bought in the early days, […] they were made by Swedish basketball players…"

Nevertheless, manufacturers in the 1980s appeared to use the lived experience of disabled designers as a marketing tool. For instance, *SPORTS 'n' SPOKES* annual wheelchair surveys aimed to showcase a range of wheelchair models on the market, using information submitted by manufacturers. These listings often highlighted user involvement. Ortho-Kinetics Inc, for example, distributed the Swede 24 model of wheelchair in the United States, and drew on its designer's athletic success as a marketing point. In the 1986 annual survey (Crase, 1986), product manager Melody Dill states: "Unique to the Swede 24 Champ is an oval hand-rim. The chair was designed by Bosse [Lindqvist], record holder in the 400-meter distance, who found the larger ovalhand-rim gives him better grip." Lindqvist's contributions as a wheelchair user also appeared in Swede 24 advertisements outside of *SPORTS 'n' SPOKES*, implying that this was a larger part of the company's wider marketing strategy in the mid-1980s (Simonds, 1985). Other companies such as Hall's Wheels, Bair Enterprises, Sports Chairs, X-L Enterprises, Spinner International and Magic in Motion referenced the involvement of wheelchair athletes as a strength of their product design in the *SPORTS 'n' SPOKES* annual surveys across the early 1980s.

Print advertisements were enhanced by other forms of community-based advertising. Exploring innovations in skateboarding, snowboarding, and windsurfing, Shah (2000, pp.20-21) outlines that innovative athletes benefitted from being known by their peers when aiming to sell their products. The athletic experience of these entrepreneurs and their position within communities of athletes legitimised their innovations and expertise over technology. Likewise, word-of-mouth, and the use of their equipment around other athletes, were an effective source of passive advertisement (Shah, 2000). For example, Jim Martinson (73) outlined how he used sport events as an opportunity to advertise products, using his athletic success to sell the chairs he produced:

> "I was winning races, and people are hearing about it (Martinson's sport wheelchairs) - and everything's done in the newspapers […] - or in *SPORTS 'n' SPOKES*. So I put a little ad in there… […] I won that Seawall marathon[…] They had taken a picture and it was the first time they [used] colour […] in that magazine. So that was my biggest source. Word of mouth. Huge. Anywhere I could advertise, [I] would advertise. So, different magazines, [and] especially [going] to Junior, Nationals (racing events) [or going] to basketball tournaments."

This later form of advertising reinforces that lead users' lived experiences and role as 'knowers and makers' (Hamraie and Fritsch, 2019) informed their businesses. In context of athlete rejection of medical control over wheelchair sport and technology, and the growth of disability politics internationally in the 1980s – including the disability rights movement in the United States (Shapiro, 1993) or independent living movement in the United Kingdom (Hunt, 2019) – athlete-led businesses worked to provide alternative consumer options which recognised the expertise of disabled people over wheelchair technology. Indeed, the rapid growth of the sport and active wheelchair industry demonstrates the demand for new wheelchair products, and lead users' abilities to recognise and serve this growing market. For instance, thirteen sports manufacturers were listed in the 1983 *SPORT 'n' SPOKES* annual survey, which increased to twenty-two by 1987's survey (Crase, 1983; Crase et al., 1987). The number of active and sport wheelchair manufacturers featured peaked at thirty-one in 1994 (Axelson, 1994). Wheelchair users were accordingly able to make a significant impact, following wider trends after the breakup of E&J's monopoly over the manual wheelchair market in the late 1970s (Shepherd and Karen, 1984; Borisoff, 2010).

7.2.2.3 – Providing opportunities for other athletes

Entrepreneurship differs from self-employment, as the former can create opportunities to establish larger businesses which have wider socio-economic benefits, such as creating other jobs (Maritz and Laferriere, 2016; Parker Harris et al., 2014). As their market grew, lead users were able to provide a range of opportunities for other wheelchair athletes via their own businesses. Some company owners, for example, employed other athletes or disabled people. British wheelchair user and manufacturer Vincent Ross (69), for instance, made brief reference to hiring friends to weld for him. Martinson's wheelchair manufacturer Magic in Motion similarly hired wheelchair users as workers, which was remarked upon in their 1988 *SPORTS 'n' SPOKES* annual survey marketing (Crase, 1988, p.19):

> "The main reason Magic in Motion products are better is because the employees are users of the Shadow wheel-chairs. These same employees give feedback to management for new and better design. This information, plus customers' input, keeps us ahead of the competition."

The hiring of disabled workers thus constituted an advantage for product design, but also a business edge. Martinson (73) outlined a financial incentive to employing disabled workers:

> "I hired some of the guys that were participating in sports, [they] were good athletes and they were in this area. Tim O'Connell, I hired him as […] my wheel builder […] Tim is paraplegic and a wheelchair racer. I [also] needed a welder. So I hired Bart out of Alaska, he's paraplegic, he bought my racing chair, […] And the other thing was that (in) the state of Washington, if you hire a person with a disability to get them back into the workforce, they pay half of their wages. […] I'm still struggling […] we're not making millions or anything. […] But because [Bart was] paralysed - you have to use your foot (for mainstream welding machines) […] so the state paid for a handheld device that would take the place of using your foot so you could weld. So I tried to hire

as many persons with disabilities, because first of all, they're good people, they're good employees, and they liked what we were doing."

Nevertheless, lead users used their position as business owners to support other wheelchair users, such as providing means of employment. This can be interpreted as an extension of self-determination. In creating new sport wheelchair devices, lead users were able to direct their resources back to their community, and employ other disabled people. Unlike traditional manufacturers, who had rejected wheelchair user involvement and feedback, these companies actively sought employees with this lived experience.

Another form of community support was the sponsorship of wheelchair sport events and athletes. Retired wheelchair tennis athlete and businesswoman Marylin Hamilton commented that her company Motion Designs "sponsored not only sports people and events, but we also sponsored businesspeople as role models" (Hamilton, 2021, p.17). This is similarly demonstrated by Jim Martinson as he sponsored and encouraged new wheelchair racers. American athletes Craig Blanchette (Wheelchair racer) and Chris Waddell (Wheelchair racing and mono skiing) were both sponsored by Magic in Motion. Both benefited from extensive training sessions with Martinson, who was an elite wheelchair racer and mono ski enthusiast at the time. Waddell (52) recalled:

> "I was affiliated with Shadow, and Jim not only was the manufacturer, but he became a friend, and a hero in a lot of ways. […] Tim O'Connell worked with him, who had seen Jim compete at the 1984 Olympics at the demonstration event […] and ended up going, 'Okay, that's what I want to do.' […] Jim, in some ways, was a Pied Piper. And so, I got to meet with him, got to ski with him. Which seeing him ski for the first time, I went, 'Oh, phew.' Like, 'You can actually do this.' Like, I can't do it right now. But I can see that somebody can, and so that's good."

Comments by Waddell and Hamilton conjure the idea of role models discussed in Chapter 5.2.2. Akin to Abu Yilla's prior testimony, Waddell drew significant inspiration from older wheelchair athletes such as Martinson. Martinson was similarly a role model and source of economic support for Blanchette (52), who highlighted that Martinson provided new athletes with equipment and the means to attend competitions:

> "Jim came down on a weekend and brought a couple of the athletes, and we did a track day, basically, we just showed up - it was almost like, when I look back on it now, it was like a scouting session… after [the race], Jim Martinson said, 'I'd like to sponsor you.' […] he said, 'Let's get your equipment updated. Let's measure you for a new chair. And let's get you racing in the state of the art, best chairs.' And then he said that he would purchase my airline ticket and pay for my hotel for the next race. I didn't have any money [at the time]."

Moreover, Blanchette (52) described working closely with Martinson on the engineering of his wheelchairs, due to his interest in racing technology.

> "…we would […] constantly talked about wheelchair design, and camber and hand rim size and steering and front wheel size."

The support given by Martinson assisted in the early development of Blanchette's and Waddell's athletic careers. As a lead user, Martinson was able to support young athletes and could provide a small few with financial support and cutting-edge equipment. Athletes such as Blanchette were also able to collaborate with lead users testing new designs and modifications. Significantly, the involvement of wheelchair users with these companies was stressed in interviews with lead users, including Martinson and Hamilton, as athletes acted as role models for other wheelchair users. For lead users, therefore, inspiring and supporting other athletes appeared to be an important role that wheelchair manufacturers could play in the sport and the industry.

7.2.2.4 – Sub-section conclusion

Self-employment and entrepreneurship by wheelchair athletes represented an important source of socio-economic autonomy. The establishment of these companies reinforced the expertise of disabled athletes over sport and active wheelchair technology, challenging the existing wheelchair market which excluded wheelchair users. These companies allowed lead users to create the products desired by athletes similar to themselves, whilst supporting their community by employing disabled workers and new athletes. For the wider wheelchair athlete community, these manufacturers had a better understanding of customer desires due to their lived experience of wheelchair use and athletic success. However, the autonomy and self-determination afforded to wheelchair athletes transformed as the industry expanded.

7.2.3 – Acquisition and lead user agency

Sports wheelchair manufacturers were a significant source of economic and technological autonomy for wheelchair athletes. However, the sports and wider wheelchair market continued to evolve throughout the late 1980s and 1990s, marked by the acquisition of user-owned businesses by larger corporations. As a result, wheelchair users lost significant influence over the industry and sport wheelchair technology. Literature concerning the acquisition of entrepreneurial firms has focused on the buyer's reasons for purchases (Ali-Yrkkö, 2002; Ahammad et al., 2017; Puranam, 2001) or the seller's reason for selling (Graebner and Eisenhardt, 2004). This section considers these factors but is more concerned about the impact of acquisition on wheelchair athletes' self-determination. If technological innovation and entrepreneurship were a source of agency against medical control over sport, or disablism within the wheelchair industry, why did lead users relinquish control of their businesses?

This section is split into two subsections. First, the market scope of sport wheelchair manufacturers is explored, outlining the economic realities of these businesses. The remaining section then focuses on the impact of manufacturer acquisition on athlete agency. Topics explored in this sub-section include lead user interest in selling their businesses, the dissolution of wheelchair brands made by lead users, and the lack of wheelchair-users within modern sport wheelchair manufacturers. This section again draws on Jim Martinson's testimony, concerning the acquisition of Magic in Motion.

7.2.3.1 - Realities of the market

Whilst athlete-founded manufacturers can be seen as a source of autonomy and self-determination for wheelchair users, the economic realities of the market limited their success. Interview testimony reported that the vast majority of athlete-owned sports wheelchair manufacturers were not financially successful, despite the impact they had on athletes and active everyday wheelchair design. Wheelchair designer and founder of Da Vinci Mobility Vincent Ross (69) outlined that the market for sport wheelchair shrank once lightweight everyday wheelchairs were sold as their own products:

> “We started to get orders for more everyday chairs where people weren't going to really use them for basketball. That market had to grow because we couldn't make a living making basketball chairs.”

Sport wheelchair devices were a niche within the wider wheelchair market. British wheelchair tennis coach Martyn Whait (51) commented that in the modern wheelchair industry, active everyday models are “the biggest market for the wheelchair manufacturers, and sport is kind of a bit of a side-line.” This may indicate the stabilisation of sport and everyday wheelchair devices had a large financial impact on lead users who made sport wheelchair devices. However, testimony from engineer and academic Rory Cooper (60) suggests that sport wheelchair equipment itself was never financially successful:

> “They were all small businesses or all of them basically just living hand to mouth. All the companies were all basically driven by athletes and their friends trying to grow the sport, create an opportunity for other people, maybe make a little bit of money, I don't think - frankly, anybody made a lot of money off of sports [equipment].”

Sport wheelchair manufacturers in the late 1970s and early 1980s found their largest consumer base in everyday wheelchair users, who wanted the technological advantages sport chairs offered. Accordingly, the delineation between sport and active everyday wheelchairs detailed in Chapter 6.3 had dual purpose. Athletes wanted specialised sports chairs to advance their sport, but a larger group of consumers wanted new everyday devices which incorporated the technological advantages of sport wheelchairs. This partly accounts for the economic success of Motion Designs, highlighted in Chapter 7.2.2.1, as the Quickie employed lightweight design and aesthetics found in sports wheelchairs, but was focused on the larger consumer base of everyday wheelchair users (Shapiro, 1993; Williamson, 2019). When these wheelchair models specialised and stabilised, consumers had little reason to purchase a basketball or sports wheelchair. Indeed, Ross (69) later commented on the comparative size of the athlete market, explaining the business choices he made:

> “I realised reasonably quickly that wheelchair sport was not where we were going to make any- make a business out of it. Making better everyday chairs, there's a bigger market for, you know, everybody from eight to eighty can benefit from a better everyday chair. There's- about 2% of the disabled population [that] play wheelchair sports.”

The relative size of the sport wheelchair market indicates that the economic impact of athlete-owned businesses was relatively minor. On one hand, lead users experienced some entrepreneurial independence and autonomy via their businesses, particularly due to the social and political impetus behind these manufacturers. On the other hand, the sports market was niche, and became smaller as everyday wheelchair technology improved, limiting economic success for sport devices alone. Lead users’ self-determination was constricted by market demand, as sport wheelchair technology was simply not as profitable or demanded as lightweight everyday models. Indeed, by the early 2000s, the number of sport-focused wheelchair manufacturers on the market had shrunk, partly as a result of the limited financial return of specialised sport equipment.

7.2.3.2 – Manufacturer acquisition

Another important factor in the economic autonomy of lead users and reduction of user-owned manufactures on the market was the acquisition of many athlete-owned companies throughout the 1980s and 1990s. Sport-focused brands were acquired by assistive technology companies, such as Sunrise Medical or Invacare, who were part of larger healthcare conglomerates. Interviewee testimony and data from *SPORTS 'n' SPOKES* indicate that larger companies recognised the commercial potential of active wheelchair devices, and purchased sport wheelchair manufacturers to enter the market. The business choice to purchase these companies was strategic, either due to the manufacturing similarities between sport wheelchairs and commercially successful active everyday wheelchair models, or as user-owned companies were purchased for their brand name or geographic reach. Table 3 outlines various wheelchair manufacturers encountered in the research, showcasing the dominance of certain corporations over the modern sport market as a result of acquisition.

Table 3 – Active status of acquired sport wheelchair brands

Corporation	Subsidiary brands	Year acquired (approx)	Production focus	Brand active (in 2023)?	Sport wheelchair producer (in 2023)?
Sunrise Medical	Cooper Engineering	1985 (by Quickie)	Racing	No	No
	Quickie	1986	Basketball, tennis, multi-sport, everyday.	Yes	No
	Magic in Motion / Shadow	1992	Racing, basketball, everyday, mono ski	No	No
	SOPUR	1992	Everyday, sport, racing	Only in Austria and Germany	Only in Austria and Germany
	RGK	2015	Basketball, tennis, rugby, multi-sport, racing, everyday.	Yes	Yes
	Oracing	2020	Racing	Under RGK	Yes
Invacare	Action	1991	Basketball, tennis, rugby, multi-sport, racing, everyday	No	No
	Top End	1995	Basketball, racing, tennis	Yes	Yes
	Küschall	1995	Basketball, multi-sport, racing, everyday	Yes	No
	Poirier	Unclear	Sport, everyday	No	No
Permobile	Colours 'n' Motion	Between 1994 and 2001	Sport, everyday	Purchased again by DO Medical 2008 and Nissin in 2022	Yes
	TiLite	2014	Sport, everyday	Yes	No
	Panthera	2021	Sport, everyday	Yes	No
ETAC	Marathin Produkter / Spinner	1984	Sport, everyday	No	No
Ortho-Kinetics	Quadra	1986	Sport, everyday	No	No

Interviewee testimony expressed a range of reasons surrounding the choice for users to sell their businesses. One reason may have been economic, as acquisition presented an opportunity to make a profit or reduce individual liability. Retired wheelchair athlete Jim Martinson, for instance, sold Magic in Motion in 1992 to Sunrise Medical due to personal and financial struggles. As indicated in the previous section, sport wheelchair manufacturing was not highly profitable itself, so lead users' choice to sell their companies likely had distinct financial weight. Rory Cooper, on the other hand, stated that he sold his company Cooper Engineering to Quickie in the early 1980s as he wished to focus on his academic and athletic pursuits. Similarly, Dan Chambers, a non-wheelchair user who created custom racing chairs for British wheelchair company Draft, speculated that athletes who were involved in wheelchair design generally had little interest in running businesses. Chambers (53) explained that he became involved in the industry following his collaboration with wheelchair racer Barry Norman:

> "Neither me nor Barry actually, really, got into it to run a business. I've got into it as I was interested in sports engineering, and ended up running a 1.2-million-pound turnover company with seven staff, was not what I planned really. And I think it's the same for a lot of people. ...Chris Peterson, from Top End […] I mean, he was an engineering graduate, met up with George Murray, who was a wheelchair racer, and they set up Top End. And then 10 years later, they sold it to Action, and they sold it to Invacare, who now own it. [...] he started out as the engineering side and ended up [designing] and running the fabrication of the factory. And again, I think he just got burnt out eventually."

Chambers' example notably focuses on those athletes who collaborated with non-disabled engineers. Data from other sports may indicate that wheelchair athletes lacked interest in running businesses in the long run. Shah (2000, pp.20-21) outlines that small scale manufacturing presented low additional costs for lead users, who often already modified or created sport equipment for their own use. Athlete disinterest in business may be associated with the scale of industry as products became popularised and costs increased. In the development of ultralightweight hiking backpacks, Gross (2022, p.34) states that innovative hikers were largely uninterested in pursuing commercial efforts to sell ultralightweight backpacks as they had developed new equipment for their own efficiency and comfort on the trail. In sport wheelchair technology, lead users likewise became involved due to their own athletic interests, and the wider competitive reinterpretation of wheelchair sport and technology. The impetus to start businesses emerged following the acceptance of modifications by other athletes - for example, the difference in success between the Rumple chair and Quadra discussed in Chapter 6.2.2. Athletes were inclined to sell their businesses, as they did not ultimately enter the industry in order to run large businesses, or saw little financial reason to continue.

Irrespective of reasoning, the acquisition of user-owned sport wheelchair brands altered the presence of lead users in the industry. Company acquisition generally resulted in previous owners departing their companies. This reduced the number of wheelchair users involved in the design, production, or marketing of sport wheelchair devices, and invalidated the appeal of user-designed equipment. As well, employment opportunities for disabled people in user-owned companies were threatened by acquisition. Martinson (73) commented that when Magic in Motion was acquired by Quickie in 1992, he was told that the manufacturing company could remain where it was, and that existing employees' jobs would be preserved. However, once the purchase was made, plans changed:

> "The President of Quickie was Tom O'Donnell, and he said, […] 'we'll run this sports division out of Kent, Washington,' where we had all these welding machines - [we were] doing everything but painting at that time... in house. And then [later Tom] says, 'No, we're going to move it to Fresno (California, where Quickie was based). […] why (would) you take a company that was building... […] customised wheelchairs to a place in Fresno that didn't know how to do it. All my employees but one of them quit. They didn't want [to go to] Fresno."

Martinson's experiences further highlight other infringements on the brands wheelchair users built. Once acquired, parent companies were able to absorb brands and concepts into their wider company portfolio. Akin to wider examples of corporate acquisitions

(Öberg, 2014), medical conglomerates used sport wheelchair brands to appeal to certain international markets, whilst lowering costs by standardising wheelchair designs across manufacturing centres. This can be seen in Sunrise Medical's use of the SOPUR brand, founded by wheelchair athlete Errol Marklein, only in German and Austrian markets, or Invacare's use of the Poirier brand only in the French market (see Table 3). Martinson, however, found that Magic in Motion was absorbed into Quickie, which had itself been acquired by Sunrise Medical in 1986. Racing wheelchair designer Dan Chambers (53) highlighted that the Magic in Motion and Shadow branding disappeared by the mid-1990s:

> "Shadow were bought up by Sunrise Medical, who took all their designs and put them into their Quickie product. So Shadow... completely disappeared as a brand. But a lot of their ideas were used and adopted."

During interview, Martinson (73) reflected on this as the result of selling his brand:

> "They took it away. They dumped Shadow and put it... [on] Quickie. Quickie racer, Quickie basketball chair, Quickie tennis chair. But you know, when you sell a company, you know, you get what you get."

The companies and brands that wheelchair athletes built, which once represented user autonomy and self-determination, became part of a wider, commercialised industry in the 1990s and 2000s. Wheelchair athletes or users were largely removed from wheelchair design as a result of acquisition, which also occurred as sport and non-sport manual wheelchair designs began to stabilise. Accordingly, many interviewees expressed negative sentiment towards the acquisition of lead user owned companies. Peter Norfolk OBE (60), who founded British wheelchair supplier EPC Wheelchairs in 1989 (EPC Wheelchairs, Undated) commented:

> "…you'd be lucky to find someone in a chair now in some of these companies. I don't agree with it. […] A lot of the bigger companies […] they did have people in chairs. And

> they made quite a big difference to the design, the input. But it's all about money now, it's all about finance. If you look at how the big companies operate, they are owned by finance houses or investment companies […] the end user is just the by-product now... I think quite a lot [is] lost (as a result of acquisition). I think you can look at lots of ranges of chairs and styles. And you know full well that there's no user involved in it."

Akin to scholarship about other instances of consumer reaction to corporate attainment of entrepreneurial firms (Biraglia et al., 2023; Gaustad et al., 2019), Norfolk's testimony suggests that acquisition impacted the authenticity of these brands. Ultimately, this altered the relationship between end user and designer, the latter of which were generally not wheelchair users themselves. British wheelchair rugby player and Paralympian Aaron Phipps (38) expressed a similar sentiment, implying that international acquisition had a negative impact on the technology:

> "It's a shame, you've got companies like RGK who've been bought out by Sunrise (Medical), which is a massive American company. That was a little privately owned British company, you know, largely the best wheelchair basketball chair in the world. Now owned by Sunrise, which is a shame. Bought out. But everything, you know, it's got a price."

Significantly, these comments indicate that athletes objected to the commercialisation of the sport wheelchair industry. Interviewees such as Phipps, Craven, and Martinson expressed the narrative that wheelchair athletes' motivations in manufacturing sports equipment was not economic. Rather, they were concerned with the technology itself, and athletes' control over its evolution. Speaking about his own perspective as a wheelchair designer, Jalle Jungnell (67), wheelchair user and founder of the wheelchair manufacturer Panthera, commented:

> "I, as a user, have control over how our wheelchairs should look in the future. And that was kind of what happened in the 80s. That people in wheelchairs took control over the situation themselves, if not totally controlled, but suddenly they get involved and,

> in some cases, they took control over it. Because there are other interests, as we talked about, from investors, they want to make money. I mean, look at Invacare and even Sunrise [Medical…]. [The] equity company that owns Sunrise, they want to make money, they want to buy them, make the best of them […] I don't want to do that, and I don't think it's good for us [as] users either. I think it's good if we, instead of taking the money out of the company, we invest them in development and getting better."

Similar comments emerged regarding changes to production which were motivated by cost reduction, such as changes to custom building commented on by non-disabled racing wheelchair designer Dan Chambers (53):

> "What was lost was the close connection between the designer builder and the customer. Because in the middle there's a healthcare company going, 'what's the bottom line? How can we reduce our costs? What is that product? What is that single product costing us?'"

Reflecting on the acquisition of his company, Magic in Motion, Jim Martinson (73) similarly expressed disappointment over the streamlining of sport product diversity as a way to reduce costs:

> "My complaint is not that they didn't pay me, the complaint was that I feel like we could have done so much more for persons with disabilit[ies]. […] There's a few companies doing [Snow skis, Mono skis,] water ski[s] - tennis chairs [are] big, basketball chairs [are] big. […] I hate it because I see so many people that benefited so much from our little company..."

This narrative appears to be consistent with athletes' motivations to advance wheelchair sport and technology outlined in previous chapters. Athlete-established companies provided opportunities to provide new equipment for a range of disability sports (detailed in Chapter 6) and advance the competitive interpretation of disability sport outlined in Chapter 5.2.4. Lead users were also interested in addressing market gaps and creating employment opportunities, as explored in Chapters 7.2.1 and 7.2.2. Accordingly, athlete objection to the commercialisation of sport wheelchair technology may not only refer to the loss of athlete involvement with sport wheelchair technology, but the related loss of individual autonomy and communal self-determination within the industry, which originally motivated the creation of user-owned manufacturers.

7.2.3.3 – Sub-section conclusion

Changes in the sport wheelchair market resulted in the loss of power and autonomy that lead users found in the creation of new sport wheelchair technologies. The small scale of the sport market limited economic success, and a trend of manufacturer acquisition removed wheelchair users from positions of influence within the industry. User-own companies transformed once acquired, as athletes' brands were amalgamated into wider corporate structures, and product diversity shrank in line with cost saving measures. Accordingly, interviewees identified factors such as commercialisation, cost-cutting measures, and a lack of product diversity as major impacts of corporate acquisition.

7.2.4 – Conclusion

The evolution of the sport wheelchair industry developed athlete autonomy and self-determination over sport wheelchair technology. The establishment of sport wheelchair manufacturers afforded lead users the opportunity to distribute their interpretation of sport wheelchairs to a wider audience and assert their expertise as wheelchair athletes. Athlete-created wheelchair designs accordingly became accepted by consumers and corporate actors. However, the stabilisation of sport wheelchair technologies, the small size of the sport market, and lead users' lack of interest in running businesses allowed large companies to acquire athlete-owned manufacturers. Whilst sport wheelchair technology had stabilised according to wheelchair athletes' competitive interpretation of sport, other opportunities afforded by user-owned companies, such as employment opportunities or user involvement in wheelchair design, were ultimately diminished.

7.3 – Chapter conclusion

The substantive expertise of athletes manifested in two different ways as explored in this chapter. In the first subchapter, elite athletes asserted their self-determination by undermining and defying the rules of the ISMGF which resisted the implementation of competitive sport wheelchair technology, particularly in wheelchair racing. In doing so, athletes asserted their interpretation of wheelchair equipment, and helped to legitimise the use of sport-specific wheelchairs in competitions internationally. In this case, athlete activism existed as a rejection of administrative control over wheelchair sport and technology. However, athlete autonomy only emerged in resistance to rules which restricted their interpretation of wheelchair equipment. Following changes to these rules, it is unclear if athlete communities retained power or influence within administrative structures of the IPC or other sports organisations.

In the second subchapter, lead users – entrepreneurial athletes with knowledge of engineering and the ability to make and sell products - expressed their self-determination by establishing their own manufacturing companies due to existing manufacturer's lack of interest in sport or user-directed wheelchair designs. The user-created sport wheelchair market centred athletes' expertise of consumer's desires and values, whilst creating opportunities for other disabled people. However, any social or economic autonomy gained in this arena disappeared as user-owned manufacturers were purchased by medical equipment conglomerates, and sport wheelchair technology became more commercialised.

In the assertion of their expertise, wheelchair athletes successfully orientated their manifestation of sport wheelchair technologies as legitimate pieces of sport equipment, accepted at major competitions and sold to a new market of active consumers. However, the latter of these developments reconstructed sport manufacturers as attractive purchases for large corporations, who added athletes' creations to a wider portfolio of assistive technology products. Nevertheless, athletes role in shaping the form, use, and commercial viability of active wheelchair devices was key in the evolution sport wheelchair technology. Entrepreneurialism and athlete involvement in sport administration therefore provided disabled people a high degree of autonomy within the development of sport wheelchair technology.

Chapter 8 – Thesis Conclusion

This thesis has explored the socio-technical history of manual sport wheelchair devices, informed by the following research aims:

- Identify how attitudes towards disabled people and wheelchair sport both informed and were a result of wheelchair design.
- Explore the evolution of manual wheelchair technology, focusing on the creation of wheelchair modifications and devices made for the purpose of sport.
- Consider the role of wider social and political factors that exist between users and designer, and the consequences of innovation on wheelchair sport and wheelchair athletes.

Based on these research aims, I sought to answer the following research questions:

1. In what ways did different interpretations of wheelchair sport held by medical professionals and athletes influence the development of wheelchair technology?
2. How did manual wheelchair design evolve and stabilise to create different varieties of sport wheelchair technologies?
3. What was the socio-political and economic context and impact of technological change, and what consequence did this have on the autonomy and self-determination of wheelchair users?

In exploring these questions, the development of sport wheelchair technology emerged as a battleground in which disabled athletes asserted their agency, expertise, and capabilities. Medical professionals, who controlled the administration and regulations of disability sport, alongside wheelchair design, restricted wheelchair sport to be physical and social rehabilitation and recreational activities. Their interactional expertise with sport led to regulations which inhibited athletes' competitive desires, and sanctioned the stagnation of wheelchair design. In response, athletes modified their wheelchairs, wishing to assert their competitive interpretation of sport and better optimise their devices for sport and everyday living. Later, lead users introduced entirely new lightweight wheelchair models which provided significant performance benefits. In the 1980s, the concept of dedicated sport wheelchair models emerged, stabilising following athlete protests to ISMGF regulations and entrepreneurial firms specialising in sports equipment. In this arena, athletes resisted the classifications and perceptions of medical professionals, successfully vying for control and redefining wheelchair as active devices used for competitive sport.

Concepts from the field of STS have framed the relationship between athletes and medical professionals within this thesis as those between user and designer. As users, wheelchair athletes reinterpreted wheelchair sport and technology, and inscribed new social and political meaning into sport technology and competition. Building upon recent historical and sociological literature, this thesis reinforces the significant work of disabled people as 'knowers and makers' of sport wheelchair technology (Hamraie and Fritsch, 2019, p.7). In recognising user-led modification and design, this thesis establishes technological innovation as a space in which disabled people exercised their expertise and agency. The development of sport wheelchair technology therefore tells an important historic narrative about disabled people's advocacy and self-determination. Accordingly, this thesis suggests that disability studies research may look to historic methodology and the field of STS to enhance emancipatory research This concluding chapter will summarise chapters 5, 6 and 7, outline the key themes and contributions of this thesis, and consider the limitations and opportunities for future research.

8.1 – Data Chapter Overview

Chapter 5 – Interpretations of wheelchair sport

This chapter utilised the concept of relevant social groups from SCOT to contextualise how attitudes towards wheelchair devices, their users, and their perceived use shaped the technological evolution of these artefacts. The first section of this chapter provided historical context about the development of wheelchair sport, establishing the rehabilitative interpretation of sport held by medical professionals. For this social group, wheelchair devices of the era were suitable for sport, as wheelchair sport itself was primarily interpreted as a method of social and medical rehabilitation. For wheelchair athletes, however, wheelchair sport was associated with additional social and political importance. Notably, many wheelchair users interpreted wheelchair sport as legitimate athletic competition distinct from its rehabilitative benefits. Sport allowed wheelchair users to highlight their physical abilities, and resist paternalistic attitudes which emphasised the participatory, not competitive, aspect of sport events. This chapter establishes that end-users to sought to alter wheelchair devices based on their competitive interpretation of wheelchair sport.

Chapter 6 – Technological evolution of sport wheelchair devices

Chapter 6 outlined technological changes to wheelchair devices made by athletes between the 1950s and 1990s. Athletes' competitive interpretation of sport accentuated the limitations of their existing devices for basketball and other sports, opening interpretative flexibility. Athletes began to modify their existing wheelchairs or create brand new devices, intended for sport and active use. Modifications to existing wheelchairs represented a rejection of the design philosophies embedded within wheelchair devices, whilst the creation of rigid frames or features such as anti-tip wheels represented the new function lead users imbued into wheelchairs as sports equipment. This chapter therefore underscores wheelchair athletes' role as designers and innovators of sport and active wheelchair technology. Furthermore, this chapter considered the benefit of sport modifications for daily use, and the emerging delineation between sport and everyday manual wheelchairs. Sport wheelchair designs became accepted by athletes and active manual wheelchair users based on their improved functionality, but equipment tailored to individual athletes and sports maximised performance capabilities. Sports wheelchairs therefore became their own sub-category of active, lightweight manual wheelchair technology, resulting in specialised wheelchair designs for basketball, tennis, rugby, and racing.

Chapter 7 – Athlete self-determination in sport administration and industry

The closure and stabilisation of athletes' sport focused wheelchair technologies contributed to wider changes within sport administration and the manual wheelchair market. Within these areas, athletes worked to assert their autonomy and expertise over wheelchair technology. Athletes rejected practitioner authority and control within the ISMGF, who restricted the use of sport-specific wheelchair models, particularly within wheelchair racing events. Technological advances and administrative differences in the United States turned the use of sport-focused wheelchairs into a political act of protest. Athletes' competitive interpretation of sport ultimately solidified as gradual rule changes were implemented, and the ISMGF was ultimately succeeded by the IPC. Athletes similarly positioned themselves as lead users and entrepreneurs within the sport wheelchair industry, introducing sport devices to address the market gap for active manual wheelchairs in the late 1970s and early 1980s. Athlete-owned wheelchair manufacturers existed as a significant site of self-determination, particularly as wheelchair users had little influence over wheelchair design previously. However, the acquisition of athlete-led manufacturers altered the nature of this autonomy. This chapter demonstrates the self-determination of lead users of sport wheelchair equipment, as they worked to stabilise their innovations within sport administration and the market.

8.2 – Discussion of key themes and contributions

The following section consolidates key overarching concepts identified across the three data chapters. These themes emerged as disabled people's autonomy and self-determination became a fundamental part of the narrative of sport wheelchair technology. In doing so, concluding thoughts about this research are outlined, and theoretical extensions stemming from these findings are proposed. Themes and the contributions of the research have been grouped into three sections, following on from the research questions set at the beginning of the chapter.

Firstly, the social shaping of disability objects emerged from the utilisation of STS concepts and the focus on the user as a key agent of socio-technical change (Kline and Pinch, 1996). A user orientated approach allows STS research to better locate marginalised groups within the history of technology and conceptualise disability things as part of disabled people's political interaction with the world. Second, in tracing the technological evolution of sporting equipment, this thesis has presented a powerful narrative of user innovation and technological re-categorisation. In the modern era of wheelchair sport, this legacy must be understood by wheelchair designers and athletes. The final contribution of this thesis is the use of a historical methodology to explore instances of disabled people's advocacy in new contexts. Narrow conceptualisations of disability politics may ignore the important political work found within sport and technology. This research has highlighted one example of how a historic approach reveals new insights into disabled people's social and political emancipation.

8.2.1 – The social construction of wheelchair technology

Concepts, debates, and vocabulary from STS have potency for historical and sociological disability research. Scholarship by Galis (2011) and Blume et al. (2014), for instance, have remarked on the power of STS concepts in exploring how disability is enacted simultaneously by the body, technologies, and other semiotic forces. Likewise, this research draws on the potency of STS theories to frame the relationship between wheelchair artefacts and social groups of human actors. Accordingly, a key theme of this research was the ways in which disabled people shape the technologies they use.

Wheelchairs, akin to any technological artefacts, are inscribed with the ideologies and biases of their designers. Medical design philosophies resulted in a disability script (Ravneberg and Söderström, 2017; Olaussen, 2010) - an attitude towards disability and impairment imbued into an object by the designer, which presumed disabled people to be inactive. Wheelchairs such as the armchair-like Travaux wheelchair models imagined all wheelchair users as inactive and stationary, thus prioritising user comfort or safety over mobility (Woods and Watson, 2004; Anderson, 2011). In turn, users reinterpreted wheelchairs as devices which could enable improved athletic activity, and later, elite performance. Armed with a competitive interpretation of wheelchair sport, athletes imagined an active user - themselves - who required lightweight and manoeuvrable equipment for a competitive edge.

SCOT was utilised in this research to capture how disabled people, as users of wheelchair devices, reinterpreted and reshaped these technological objects. In the 1940s and 1950s, wheelchair sport was a tool of medicine and rehabilitation, intended to encourage enthusiasm for physical activity amongst patients with spinal cord injuries and support social reintegration into the workforce (Guttmann, 1973). Wheelchair sport did not require elite athletic performance, as the goal for administrators within the ISMGF and other bodies emphasised participation and rehabilitation. Wheelchair design thus did not need to be altered to meet the goals of wheelchair sport, and the ISMGF sought to restrict wheelchair devices made for the sole purpose of sport via regulations. Active wheelchair users, on the other hand, nurtured alternative interpretations of sport and competitions such as the SMG. Whilst athletes did report the rehabilitative benefits of athletic activities, interviewees who took part in the research generally focused on the socio-political and communal importance of sport, and their individual athletic ambition. Defining themselves as athletes, these wheelchair users wanted wheelchair sports to be recognised as legitimate athletic activities as opposed to recreational events. Amidst dissatisfaction with ISMGF administration, users reinterpreted their wheelchairs as athletic equipment, to improve their sporting performance and highlight their abilities as sportspersons. Innovations in wheelchair technology therefore reflected the interpretation of wheelchair sport which emphasised athletic ability, individual performance, and competition.

Contrary to critiques offered by scholars including Winner (1993) and Clayton (2002), this thesis has indicated that SCOT may account for marginalised groups within the history of technology. This thesis drew on user-focused SCOT literature, examples from feminist STS, and wider STS concepts such as configuration and script theory to consider the influence of the end user on the design, use, and evolution of socio-technical artefacts. In the case of sport wheelchair technology, disabled athletes were a ‘critical social group’ (Orlikowski and Gash, 1993) who significantly shaped future iterations of wheelchair artefacts. Focusing on the users of artefacts afforded this research to place greater emphasis on disabled people, who were often excluded or rejected from environments of design and innovation due to structural and cultural inequalities (Hamraie, 2017; Williamson, 2019; Woods and Watson, 2004). Highlighting the role of users in this narrative allowed for the agency and expertise of wheelchair athletes to be clearly identified. Sport wheelchair technology was shaped by the views and actions of wheelchair users, who sought to improve their athletic performance in spite of medicalised ideologies around wheelchair devices or rehabilitative interpretations of disability sport. When used effectively, this type of STS approach has important use in sociological and historical disability research. The user-focused framework of this thesis worked towards the emancipatory aims of disability studies, providing an account which prioritised the material use of wheelchair devices, whilst centring the autonomy and self-determination in wheelchair users in sport administration, industry, and innovation. This thesis also contributes to recent object-orientated disability history literature by scholars such as Williamson (2019; 2012) and Virdi (2020a; 2020b) by highlighting how disabled people's involvement in design radically changes how the intended user is imagined, and how the resulting object functions.

Further, I suggest that these STS concepts may be successfully employed alongside other theoretic approaches which capture disabled people's relationship with technological artefacts. Williamson and Guffey (2020) suggest that their design model of disability provides agency to material and digital artefacts which enable access and empower disabled people. Likewise, Hamraie and Fritsch's (2019, p.2) term 'crip-technoscience' points to the "messy" and "non-innocent" work undertaken by disabled people as technologists. In this thesis, I suggest that language and concepts from STS may enhance these concepts, by further emphasising the agency and expertise of disabled people who engage with sociotechnical artefacts. This, in turn, may require future STS scholarship to further reflect on the boundaries set by the idea of 'the user', and broaden this category to consider the different emotions and socio-political concepts entangled with 'use'. The everyday use of active lightweight wheelchairs, for example, were associated with political concepts of independence and mobility (Shapiro, 1993) which are distinct from the competitive prowess, physical contact, or masculinity-building embedded in the use of specialised basketball or rugby wheelchairs. These are questions which may be answered by the combination of STS with scholarship from fields of disability, sport, and design.

8.2.2 – The legacy of sport wheelchair innovation

One of the primary aims of this project was to trace the evolution of wheelchair technology used in sport. Since the 1950s, wheelchair technology has evolved to advance users' sporting performance and expand their athletic capabilities. This thesis has outlined many significant innovations, including those that were later adopted for everyday use by wheelchair users who did not require athletic equipment. This change had significant impact on wheelchair technology, altering how these devices were categorised, and subsequently, affording for new varieties of sport wheelchairs to emerge. Outlining this evolution is vital in recognising athletes' contributions to lightweight manual wheelchair technology, and disability sport overall.

The evolution of sport wheelchair technology began with modifications and adjustments made to medically-provided wheelchairs. Users tinkered with armrests, backrests, and push-handles, temporarily or permanently removing unneeded features which added additional weight. Athletes soon identified E&J devices as the best models for basketball and other sports, highlighting initial preference for lightweight and responsive equipment. The emergence of athlete-designed rigid wheelchair frames in the 1960s and 1970s improved upon these performance factors, whilst also introducing features such as camber and anti-tip wheels (Labanowich and Thiboutot, 2011). The adoption of certain modifications or models was not universal, however, and athletes began to customise their devices to their individual bodies and mobilities. Later, designs became specialised for each sport, allowing athletes to further enhance their performance. Racing wheelchairs present the most extreme example of specialisation, as the desired goal of racing events prioritised designs which enhanced acceleration and allowed for better handling around corners. In the modern age, sport wheelchairs have become a distinct category of devices, each specialised for a different activity or level of athlete performance.

The development of sport wheelchair equipment triggered significant changes in wider wheelchair technology and wheelchair sport. For instance, the evolution of wheelchair technology altered the techniques used in basketball and racing. The stabilisation of sport devices enhanced athletes' abilities, and wheelchair sports altered to incorporate athletes' abilities and the creation of new techniques which altered how these sports were played. Additionally, sport modifications which made wheelchairs more responsive and stable, and reduced weight, were of benefit beyond the court or track (Stewart and Watson, 2019). Athletes used modified wheelchairs in their daily lives, and wheelchair users who were not athletes likewise drew on these technological benefits. As wheelchair athletes began to manufacturer their own wheelchairs, entrepreneurial lead users entered the manual wheelchair market and sold these new wheelchair designs to a new generation of active wheelchair users. Figures such as wheelchair user and Quickie co-founder Marylin Hamiliton enabled this technological and cultural shift, as lightweight, sporty wheelchairs non-only improved user mobility, but served as a political rejection of wheelchairs which configured their users as inactive (Shapiro, 1993).

Charting the evolution of sport wheelchair technologies may reveal patterns about modern and future sport developments. In the modern day, sport wheelchair devices are technologically distinct from everyday, medical, or powered wheelchair models. Innovations for sport are therefore marginal and specific to a sporting context, as seen by the rise in bioengineering and precise customisation for elite athletes – a small subset of wheelchair users who require cutting edge technology to facilitate their athletic success. For the majority of wheelchairs, sport wheelchair technology is too specialist to be of external use, and innovations are highly specific to this athletic context. Indeed, the creation of new equipment in the last decade, including specific wheelchair models for badminton, ballroom and latin dancing (known as wheelchair dance sport or para dance sport), and motocross (known as WCMX), demonstrate this emergent shift. This suggests that wheelchair models for active everyday wheelchair use, and those intended for sports such as basketball, racing, tennis, and rugby, are technologically stable for those defined uses. However, wheelchair athletes in newer sports and athletic pursuits have identified problems which would be address by specialised wheelchair models for their sport. The sport wheelchair, as a generic device or subcategory of wheelchair devices, is therefore still open to interpretative flexibility.

In this narrative, emphasis has been placed on athlete contributions to historic wheelchair design. This was a deliberate choice, emerging from the realisation that wheelchair users are comparatively less involved in modern sport wheelchair innovation or manufacturing. This trend can be interpreted as a loss of autonomy and self-determination for disabled people, as argued in Chapter 7. However, this may also reflect the closure and stabilisation of wheelchairs for sports such as basketball, racing, tennis, and rugby. Major innovations for these sports have already been created, primarily by athletes, and the modern industry exists to streamline these ideas for elite performance. It is therefore surprising that wheelchair athletes are largely unrecognised as the key innovators of modern sport wheelchair technologies. The testimony of wheelchair athletes and coaches Ian Thompson and Adam Bleakney, for instance, spoke to this amnesia, as they recalled instances of modern manufactures that essentially 'rediscovered' a design or approach already tested by wheelchair athletes in prior decades. Further, initial investigations into this project revealed that younger athletes knew very little about the history of the technology or sport. Subsequent innovators and athletes should therefore look to the history of sport wheelchair technology, not only to not repeat prior achievements, but to recognise the achievements and contributions of prior wheelchair athletes.

8.2.3 – Historical research in disability studies.

The historical approach of this research demonstrates that re-conceptualisations of the past are a potent way disability studies can contextualise disability politics, technologies, and the value of sport. Blackie and Monicreif (2022, p.793) contend that disability history can be characterised by its political impetus, commitment to a socio-cultural approach to disability, and insistence that disability is a powerful category of analysis. In this thesis I have demonstrated this impact by centring the perspectives of wheelchair athletes, analysing sport and technology as a site of advocacy, and establishing the cultural, political, and economic context in which change occurred. In doing so, this thesis asserts that disability history, alongside topics of sport and technology, are potent research subjects to sociologists who study disabled people's social and political emancipation. It is therefore important that the sociological perspective and emancipatory goals of disability studies are connected to the growing field of disability history literature.

Historical research functions to present narratives about the past, drawing on evidence gathered and interpreted by the researcher situated in the present (Munslow, 2000). Previous histories of disability sport worked to celebrate the revolutionary work of medical professionals or organisational histories of the Paralympic movement. These narratives had an important role in demonstrating the value and impact of disability sport, and capturing the medical and administrative background of the Paralympics. However, these approaches rendered disabled athletes themselves invisible and reinforced the achievements of medical professionals (Peers, 2009). In the last two decades, scholarship by historians including Frost (2020) and Brittain (2011; 2012; 2014), alongside the work of organisations such as the NPHT and non-academic publications by athletes (Labanowich and Thiboutot, 2011) function to re-centre disabled athletes within these histories. This scholarship joins these examples, highlighting how the actions of disabled athletes caused significant changes in wheelchair sport technology, administration, and business. This has been achieved by examining the relationship between practitioners and disabled people, and how each group used their expertise to define wheelchair sport and technology. As a result, this thesis has not only outlined the significant role played by wheelchair athletes, but demonstrated how scholarship about disability sport history may interact with wider disability history, studies, and politics.

This thesis has established that wheelchair athletes were the creators of important innovations in sport technology, from modifications such as the lowering of backrests or removal of armrests, to the creation of the rigid frame wheelchair, or implementation of rear wheel camber or anti-tip wheels. These innovations occurred as a result of experimentation and resistance, prompted by wheelchair users' interpretations of sport and the role it played in their lives. As shown in Chapter 5, sport possessed important socio-political qualities beyond medical recovery and employment-based integration. Sport events provided opportunities for community building and gender construction (Smith and Sparkes, 2002; Sparkes and Smith, 2003). Moreover, sport training and administration allowed disabled people to gain positions of power or authority they were otherwise denied in society. The advancement of wheelchair sport and technology was thus part of emancipatory goals, as athletes wrestled with non-disabled medical practitioners for authority and control.

Technological innovation was one way wheelchair users asserted their experiential knowledge around their equipment and status as experts. Advocating for their interpretation of wheelchair sport, athletes remade the material world (Hamraie and Fritsch, 2019, p.7; Dokumaci, 2023). Changes to wheelchair devices, such as the removal of push handles, weight reduction, and anti-tip wheels altered the physical affordances associated with these devices. Alongside aesthetic changes, sport wheelchairs redefined the users from dependent patients to independent athletes (Shapiro, 1993; Stewart and Watson, 2019). This trend can be showcased in Chapter 7, as athletes protested ISMGF rules by utilising modified wheelchairs, or established entrepreneurial manufacturing firms to challenge the lack of sporting models on the market. The assertion of athlete-created innovations provided a platform from which disabled people advocated for their world-view and status as experts.

Sporting technology therefore represents a vital, yet hereto rarely explored, space of disabled people's power and authority. Literature about disabled people's political movements in the latter half of the twentieth century rarely mentions sport, despite the rapid growth and visibility of international events such as the Paralympics and impact of sport on disabled people's lives. The actions of disabled athletes captured in this thesis are akin to grassroots or community political groups, which can be conceptualised within wider narratives of disabled people's struggles for control over how they lived (Hunt, 2019). Wheelchair sport thus holds historical significance as an arena in which disabled people successfully advocated for their rights and self-determination. By examining the historical evolution of wheelchair devices, narratives about disabled people's expertise and autonomy, which was previously rendered invisible, can be identified. Wheelchair athletes were a critical social group (Orlikowski and Gash, 1993) to the development of wheelchair technology and sport, and in turn, this thesis argues that sport and technology are an important part of disabled people's emancipatory history that are often overlooked by disability scholars.

8.3 – Limitations of thesis and future research

Some key ideas which emerged in the formation of this thesis had to be left unexplored, due to time or lack of space. Additionally, there are limitations of this research approach which may impact the accuracy of the narrative presented. This subchapter will briefly explore the most significant of these ideas. The first subsection captures ideas of language and psychological categorisation, and the process of end user customisation. The second subchapter considers the interviewee subset and other groups that would be significant focuses of future research. Finally, a note is made about my positionality as a researcher.

8.3.1 – Categorisation and customisation

A key topic of interest present in Chapter 6 of this research was the division between sport and lightweight everyday wheelchairs. Future research may explore this categorisation in more detail, by considering the language which delineated between varieties of wheelchair. *SPORTS 'n' SPOKES* annual wheelchair surveys, for instance, highlight terms such as 'court', 'sporty' or 'multi-sport' wheelchairs which served both wheelchair athletes and non-athletic wheelchair users who wanted the technological benefits of a lightweight wheelchair, or wanted to use one sport wheelchair in multiple sports. Whilst the use of language was briefly interrogated in this thesis, a dedicated look at advertisements and other documentary evidence from this era may outline processes of flexibility, closure, and stabilisation in more detail.

Additionally, greater analysis of language used to categorise sport wheelchairs would help to locate non-elite athletes within this history. This thesis focused on elite wheelchair athletes, as these lead users innovated their equipment to be at the top of their field. Those who did not play sport at the highest level (i.e., recreationally) but still used sport-style wheelchairs, are not as present in this thesis. Instances of this had some presence in the data collection, such as British wheelchair basketball coach and former Paralympian AJ Jackson, who commented that old elite-level wheelchairs would often be donated to club athletes, who often had no interest in contemporary elite-level devices. Future research could therefore capture these athletes in greater detail, and explore how changes to wheelchair technology for elite athletes in the 1980s and 1990s effected recreational sport persons.

Future research may also explore the relationship between categorisation, customisation, and stabilisation, and the impact of this on wheelchair sport, in greater detail. User customisation emerged as athletes sought to ensure performance benefits, and became increasingly vital in contemporary elite competitions as sport wheelchair devices have stabilised technologically. However, this thesis was not able to explore issues of cost and access which emerged from this practice. Data from this research suggests that stabilisation made sport wheelchairs more niche within the manual wheelchair market, making the devices more expensive, and thus discouraging new athletes from these sports. In particular, this has impacted wheelchair racing, in which the importance of custom building makes entry into the sport financially prohibitive. The economic realities of sport wheelchair devices as a result of stabilisation and categorisation would therefore be a potent topic for future exploration.

8.3.2 – Interviewees

Reflecting on the data set of this research, the majority of interviewees were white and male, and generally had key knowledge in wheelchair racing. Whilst this may be reflective of the lead user presented within secondary literature and primary sources, this research should have considered the role of gender and race in more detail. For example, the lack of data from East-Asian countries meant that significant elite racing wheelchair manufacturers in the present, such as Honda or Nissan, were not represented. Future research projects may therefore choose to place more emphasis on different identities, nationalities, and experiences to contrast a more nuanced interpretation of wheelchair sport and technology. Expanding on this point, this thesis ultimately chose to limit the historic exploration of the sport wheelchair industry up to the early 2000s due to scope and for the sake of clarity. As a result, some significant topics raised by interviewees and other primary data could not be adequately explored within the space of the thesis. For instance, the testimony of some interviewees could not be effectively used at all, due to the limited exploration of the twenty-first century in the final thesis. The last two decades therefore present insightful avenues for future research, which may build on the concepts of athlete agency and stabilisation presented in this thesis.

Future extensions of this research may also consider the role of non-disabled actors in more detail. Throughout this period, non-disabled individuals who shared the competitive interpretation of wheelchair sport contributed to the evolution of sport wheelchair technology. Outside of sympathetic medical professionals, such as Nugent or Labanowich, these actors were largely friend or family members with engineering or metalworking skills who became interested in wheelchair technology. Dale Williams, Jim Okamoto, and Don Helman are examples of these non-disabled individuals, but were only briefly mentioned in this thesis (see Chapter 7.2.2.1). These perspectives were present in the interview and research data, but were largely not included in the thesis due to scope and clarity of argument. For example, Australian tennis athlete David Hall, and Kiwi racer Evan Clulee both reported how their non-disabled fathers created homemade wheelchairs as the athletes first began in wheelchair sport. Likewise, British engineers Dan Chambers (Draft Wheelchairs) and Andy Hawtin (Dynolight Racing) were interviewed as non-disabled individuals who worked with athletes to create customised, elite racing wheelchairs. Future research may explore the relationship between non-disabled designers and wheelchair athletes, and if they would be considered a separate social group to wheelchair athletes within the framework of SCOT. Moreover, focusing on non-disabled wheelchair designers would allow for further consideration of the contemporary wheelchair sport industry in more detail.

8.3.3 – Researcher positionality

Another limitation of this project may be found in my interpretation and presentation of this history, as it has been filtered through my experiences as someone who is not a wheelchair user. By utilising oral history testimony, this research has aimed to prioritise and represent the perspectives of athletes, however only a small subsection of athletes could ultimately be interviewed and highlighted within the thesis. This research therefore cannot claim to represent the views or experiences of all wheelchair athletes in the explored time period. This is particularly true of athletes of marginalised genders or racial identities, who had limited representation in the interview dataset, and with whom I do not share lived experiences. Indeed, how I analysed interview testimony and archival data has also been shaped by my racial and gender identity.

Furthermore, my research was invariably impacted by the COVID-19 pandemic and subsequent lockdowns in the United Kingdom, reflected in my initial access to archives and utilisation of remote oral history data collection methods. The research context of the Covid-19 pandemic therefore significantly shaped my thesis, alongside my wellbeing and postgraduate experience (Pyhältö et al., 2023).

8.4 – Conclusion

This thesis has outlined the socio-technical development of manual sport wheelchair technology between the 1950s and 2000s. Building on knowledge produced by wheelchair athletes and previous scholarship, I have presented a narrative which firmly centres wheelchair athletes at the heart of sport wheelchair innovation. First, this thesis sought to understand the motivation behind technological innovation, contextualising the development of wheelchair sport and the status of wheelchair devices by the mid-twentieth century. I then outlined how wheelchair devices were modified and improved by athletes for sports such as basketball, exploring when sport technologies were accepted by other disabled people for alternative uses. After, the thesis contextualised technological change by demonstrating how athletes altered wheelchair sport administration and the manual wheelchair market. In doing so, this thesis underscored the expertise and self-determination of wheelchair athletes within wheelchair sports. Resisting medical authority, wheelchair athletes developed a new interpretation of wheelchair sport, asserting the value of competitive events. New technologies improved users' athletic abilities, and transformed the everyday function of wheelchair devices. Within this narrative, certain wheelchair athletes emerged as lead users, who used their lived experience of sport and wheelchair use, and engineering skill, to build new devices, establish manufacturers, and change sport regulations.

Drawing on previous research into wheelchair technology, and in conversation with contemporary trends within disability studies and histories concerning material culture and technology, this research utilised concepts from STS to frame this narrative. I drew on SCOT and feminist approaches to centre disabled people as users of technological artefacts within this history, and applied the concepts of interpretative flexibility to show how users reframed wheelchair devices for a competitive sporting context. This thesis also considered the relationship between users and designers in the development of technologies for disabled people, including how attitudes toward disabled people are imbued into objects by their designers. STS theories and concepts facilitated the framing of technological change as a form of emancipatory resistance, and subsequently has potency for sociological and historical research into disability things.
Utilising oral history methodology, archival research, and digital sources, I have centred the experiences and perspectives of wheelchair-using athletes and designers in this thesis. I have outlined the technological evolution of sport wheelchair equipment, and argued that athlete-led innovation was a site of autonomy and self-determination for wheelchair users. This research concludes by defining wheelchair athletes as 'knowers and makers' (Hamraie and Fritsch, 2019, p.7) of sport wheelchair technology.

Back matter

Appendices

Appendix A – Participant information sheet

Participant Information Sheet

Title of Project: A socio-political and technical history of the Sports Wheelchair

Name of Researcher: Samuel Brady

You are being invited to take part in a research study. Before you decide to take part, it is important for you to understand why the research is being done and what it will involve. Please read the following information carefully and discuss it with others if you wish. Ask the researcher/s if there is anything that is not clear or if you would like more information. Take some time to decide whether or not you wish to take part.

Thank you for reading this.

I am researching the social, political, and technical history of the sports wheelchair. This is to find out the history of this technologies' development, how it was approached by users, and the impact the sports wheelchair made on disabled people and accessible technologies. I think it is important to identified who developed these wheelchairs, for what purpose and how this was achieved. Furthermore, important social and political questions can be explored through the history of this technology. For instance, was user experience or performance more important when modifying sports wheelchairs, or to what extent did design philosophies link to disability politics? To address these questions, I am working with the National Paralympic Heritage Trust, to interview a number of sport wheelchair users and wheelchair manufacturers to better understand the development and use of this technology. These interviews will help me address my research interests and write my thesis, alongside supporting archival materials that will be used. Most excitingly, these interviews will be preserved, becoming part of an oral history archive owned by the National Paralympic Heritage Trust and held by Buckinghamshire Archives, allowing people's stories to be heard by future generations.

I am looking for a range of participants, irrespective of age, sport played, or level of sport achieved. If you would like to volunteer, an hour-long interview will be conducted over the video-communication platform Zoom, or over telephone. There will be a short (5-15 minute) set up period before interviews, to ensure equipment is working properly. As well, there is an optional debrief after the interview if you wish to discuss anything with me. I can also assist in some technical set up if required. There may also be opportunities for supplementary interviews at a later date.

This is an opportunity for participants to speak about their stories and contribute to the historical record, so future scholars or members of the public can hear about your experiences. However, there is the possibility that this research may touch on sensitive or personal information. As a participant, you have the right to withdraw from the research at any time, without prejudice, and without providing a reason. Furthermore, you have the right to withdraw sections of an interview, or the whole interview entirely, if deemed necessary.

Automatically, all participants will be pseudonymised, wherein any identifiable information such as your name will be reduced to a reversible code, known only to the researcher. This process is put in place to ensure your privacy. However, individuals can opt-in to be made identifiable in the thesis and any other written work by the researcher. Participants have the choice to be made identifiable at three points in the research period; when you first consent to participate, after the interview, and once the audio file and transcript are returned to you for review. Participants will also be sent a separate consent form for the archival of the identifiable testimony. Any concerns about data protection or usage can be discussed with the researcher at any time.

Please note that assurances on confidentiality will be strictly adhered to unless evidence of wrongdoing or potential harm is uncovered. In such cases the University may be obliged to contact relevant statutory bodies/agencies.

Data will be stored on an encrypted hard drive and on secure cloud storage provided by the University of Glasgow. Interviews will be transcribed, organised, and analysed by myself, and will be used in the final written piece. There is a possibility that information from the interviews will be used in other pieces of work, such as articles or presentations. After the project, ownership of the interviews will be transferred to the National Paralympic Heritage Trust and the files will be stored by Buckinghamshire Archives in an oral history archive, which is accessible to the public.

This project is conducted in partnership with the University of Glasgow and the National Paralympic Heritage Trust. It is part of the Arts and Humanities Research Council's Central Doctoral Partnership projects, who also provide the funding for the project.

This project has been considered and approved by the College Research Ethics Committee.

Researcher:

Samuel Brady,

University of Glasgow

s.brady.1@research.gla.ac.uk

Supervisor:

Dr Nicholas Watson,

University of Glasgow,

Nicholas.Watson@glasgow.ac.uk

Supervisor:

Dr Anne Kerr,

University of Glasgow,

Anne.Kerr@glasgow.ac.uk

Supervisor:

Vicky Hope-Walker,

National Paralympic Heritage Trust,

vicky.hopewalker@paralympicheritage.org.uk

To pursue any complaint about the conduct of the research: contact the College of Social Sciences Ethics Officer, Dr Muir Houston, email: Muir.Houston@glasgow.ac.uk

<u>Appendix B – Topic Guide Example: Jim Martinson</u>

- Could you tell me how you began playing wheelchair-based sports?
- Can you tell me about the wheelchair (or wheelchairs) you used? What model of wheelchair was it and how did you come to use it?
- Can you walk me through how your racing wheelchair evolved over the course of its use?
- Could you describe any modifications made to your wheelchair in detail? When did they occur?
- Can you tell me about how sports wheelchair technology has changed since you began playing wheelchair sports?
- Can you tell me about the Ski-chair you invented?
- What led to your interest in engineering / producing sports wheelchairs?
- Can you tell me more about Magic in Motion?
- Could you give me an example of the types of wheelchair Magic in Motion produced?
- How did the designs sold by Magic in Motion evolve over the years?
- Can you tell me more about the materials/design changes involved with the wheelchairs you produced?
- Do you have any examples of user reactions to the sports wheelchairs you designed?
- Can you tell me more about the acquisition process of Magic in Motion by Quickie?
- What costs were associated with your sports wheelchair?
- Do you have any thoughts on the idea that sports wheelchairs have become more commercialised in recent years?
- Based on your experiences, what are your thoughts on the statement: ‘Sports wheelchairs are politically liberating devices?’

Appendix C – Topic Guide Example: AJ Jackson

- Could you tell me how you began playing wheelchair-based sports?
- Can you tell me about the wheelchair (or wheelchairs) you use/used? What model of wheelchair was it and how did you come to use it?
- Could you describe the difference between using a daily wheelchair for sport to using a sports wheelchair?
- How has sports wheelchair technology changed since you began to play?
- What was the process of selecting/accessing an appropriate wheelchair like?
- How has your relationship with your sports wheelchair evolved?
- How involved are you with the technological side of your wheelchair? Can you repair your wheelchair yourself, for instance?
- Has your wheelchair been specialised to you in any way? How was this specialisation carried out, and who did this?
- What costs were associated with your sports wheelchair?
- Can you tell me more about the companies that manufacturer basketball wheelchairs?
- Can you tell me more about the wheelchair basketball community?
- Would you say you have faced any barriers in wheelchair basketball due to your gender?
- Do you have any thoughts on the idea that sports wheelchairs have become more commercialised in recent years?
- Based on your experiences, what are your thoughts on the statement: 'Sports wheelchairs are politically liberating devices?'
- Can you speak to any impact using a sports wheelchair had on your health or rehabilitation?
- How do you feel about media representations of wheelchair athletes/sports?
- What would you consider to be your greatest achievement when using a sports wheelchair?

Appendix D – Topic Guide Example: Dan Chambers

- Which firm/company did you work for? How long did you work there?
- Could you tell me about any experiences that led to your work in this industry?
- Could you give me an example of the type of wheelchair your firm produced?
- Can you walk me through how this wheelchair design evolved over the model's lifespan?
- Can you tell me more about the materials/design changes involved with the wheelchairs you produced?
- Can you tell me about computer software used to design wheelchairs?
- Do you have any specific examples of a wheelchair users' experiences that influenced any design choices in your work?
- Do you have any examples of how users reacted to sports wheelchairs you designed?
- Did you ever work with doctors or physiotherapists when customising wheelchairs for customers?
- Can you tell me about how sports wheelchair technology has changed since you began working in this industry?
- To what extent has the shape of sports wheelchairs stabilised – is this a positive?
- Was there any opposition to your design ideas/company ethos, and if so could you provide an example?
- How did you respond any examples of opposition?
- Did the idea of the sports wheelchair as a liberating device influence your design ideas?
- Did the commercialisation of sports wheelchairs influence your design ideas?

Appendix E – Privacy Notice

Privacy Notice

Privacy Notice for Participation in Research Project: A socio-political and technical history of the Sports Wheelchair

Please note: 'we' refers to the University of Glasgow and myself (Samuel Brady).

Your Personal Data

The University of Glasgow will be what's known as the 'Data Controller' of your personal data processed in relation to your participation in the research project, 'A socio-political and technical history of the Sports Wheelchair'. This privacy notice will explain how The University of Glasgow will process your personal data.

Why we need it

We are collecting basic personal data such as your name and contact details, and, where relevant, limited special categories data (such as disability, or other health data) in order to conduct research for this project. We need your name and contact details to arrange a convenient time for the interviews and to preserve your experiences in an oral history archive. Special limited categories may be recorded as part of participant's personal testimony. We will only collect data that we need in order to provide and oversee this service to you.

We only collect data that we need for the research project. We will de-identify your personal data from the research data by using pseudonyms and replacing identifying information with an '[x]'. You are able to opt-in to be identifiable in the collected data. After the project's completion, the identifiable research data (the interview) is planned to be archived by Buckinghamshire Archives in agreement with the National Paralympic Heritage Trust. This will only be done with your consent.
Please note that your confidentiality may be impossible to guarantee due to the nature of the project and intended use of data. Please see accompanying **Participant Information Sheet**.

Legal basis for processing your data

We must have a legal basis for processing all personal data. As this processing is for academic research and later archival interest, this use of your data is categorised as a **Task in the Public Interest**, allowing processing of the basic personal data that you provide. For any special categories data collected we will be processing this on the basis that it is **necessary for archiving purposes, scientific or historical research purposes or statistical purposes.** Furthermore, we ask for your **Consent** to take part in the study to fulfil ethical guidelines. Please refer to the accompanying **Consent Form**.

What we do with it and who we share it with

All the personal data you submit is processed by staff at the University of Glasgow in the United Kingdom. In addition, various security measures have been taken to ensure that your personal data remains safe, such as pseudonymisation and encrypted, secure digital files and devices. Please consult the accompanying **Consent form** and **Participant Information Sheet.**

We will provide you with a written summary of the research results and access to your individual interview if requested.

How long do we keep it for?

Your data will be retained by the University only for as long as the length of the research project. After this period, the data will be securely transferred to Buckinghamshire Archives for prosperity, under the ownership of the National Paralympic Heritage Trust. At this point, data held by the researcher and university will be securely deleted from servers and devices.

What are your rights?*

Under GDPR guidelines, individuals have rights over their data and involvement in research. If at any point you believe that the information we process relating to you is incorrect, you can request to see this information and may in some instances request to have it restricted, corrected, or erased. You also have the right to object to the processing of data and the right to data portability. Where we have relied upon your consent to process your data, you also have the right to withdraw your consent at any time.

Please note that as we are processing your personal data for research purposes, the ability to exercise these rights may vary as there are potentially applicable research exemptions under the GDPR and the Data Protection Act 2018. For more information on these exemptions, please see UofG Research with personal and special categories of data.

If you wish to exercise any of these rights, please submit your request via the webform or contact dp@gla.ac.uk

Complaints

If you wish to raise a complaint on how we have handled your personal data, you can contact the University Data Protection Officer who will investigate the matter. Our Data Protection Officer can be contacted at dataprotectionofficer@glasgow.ac.uk

If you are not satisfied with our response or believe we are not processing your personal data in accordance with the law, you can complain to the Information Commissioner's Office (ICO) https://ico.org.uk/

☐ I consent to the University processing my personal data for the purposes detailed above.
I have read and understand how my personal data will be used.

Signed: ………

Date: ………]

End of Privacy Notice
____

Appendix F – Consent Form

Consent Form

Title of Project: A socio-political and technical history of the Sports Wheelchair

Name of Researcher: Samuel Brady

Please tick as appropriate

Yes ☐ No ☐ I confirm that I have read and understood the Participant Information Sheet for the above study and have had the opportunity to ask questions.

Yes ☐ No ☐ I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.

Yes ☐ No ☐ I consent to interviews being audio-recorded.

Yes ☐ No ☐ I consent to interviews being video recorded.

Yes ☐ No ☐ I consent to be identified by name in the written thesis and any future publications arising from the research.

I agree that:

Yes ☐ No ☐ All names and other material likely to identify individuals will be pseudonymised, unless specifically requested.

Yes ☐ No ☐ The material will be treated as confidential and kept in secure storage at all times.

Yes ☐ No ☐ The material will be retained in secure storage for use in future academic research.

Yes ☐ No ☐ The material may be used in future publications, both print and online.

Yes ☐ No ☐ I waive my copyright to any data collected as part of this project.

Yes ☐ No ☐ I acknowledge the provision of a Privacy Notice in relation to this research project.

I agree to take part in this research study ☐

I do not agree to take part in this research study ☐

Name of Participant ……………………….. Signature ………………………………………..

Date ………………………………….

Name of Researcher …………………………………Signature …………………………………….

Date ………………………………….

<u>Appendix G – Ethical Approval</u>

21 July 2020

Dear Samuel Brady,
Project Title: A socio-political and technical history of the Sports Wheelchair
Application No: 400190177

The College Research Ethics Committee has reviewed your application and has agreed that there is no objection on ethical grounds to the proposed study. It is happy therefore to approve the project, subject to the following conditions:

- Project end date: _ 01/02/2023
- The data should be held securely for a period of ten years after the completion of the research project, or for longer if specified by the research funder or sponsor, in accordance with the University's Code of Good Practice in Research:

(http://www.gla.ac.uk/media/media_227599_en.pdf)

- The research should be carried out only on the sites, and/or with the groups and using the methods defined in the application.
- Any proposed changes in the protocol should be submitted for reassessment as an amendment to the original application. The *Request for Amendments to an Approved Application* form should be used:

http://www.gla.ac.uk/colleges/socialsciences/students/ethics/forms/staffandpostgraduateresearchstudents/

Yours sincerely,

Dr Muir Houston
College Ethics Officer

Appendix H – Request for Amendments Approval

College Research Ethics Committee

Request for Amendments - Reviewer Feedback

Ethics Committee for Non-Clinical Research Involving Human Subjects

Application Details

Postgraduate Student Research Ethics Application

Student id. Number if applicable: xxxxxxxx

Application Number: 400190216

Applicant's Name: Sam Brady

Project Title: A socio-political and technical history of the Sports Wheelchair

Original **Start** Date of Application Approval: 09/07/2020

Original **End** Date of Application Approval: 01/02/2023

Date of Amendments Approved: 07/09/2020

Outcome: Amendments Approved

Reviewer Comments

Approved.

Appendix I – Coding framework

Table of Codes and sub-codes		
Industry	Designers	Community
• Accessibility and cost • Company purchases • Employment • Marketing • User-led companies • Wheelchair companies • Wheelchair Market, Industry	• Athlete agency • Background in Engineering (Users) • Collaborations • Communal or Social aspect to sport and tech • Competitiveness • Non-disabled designers • Other industries and sports • User involvement, maintenance • User-made innovation and adaptions, and User designers	• Communal or Social aspect to sport and tech • Gender • Geographic spread • Race
Technology	Sport/Rules	Other
• Box or Rigid Frame Chairs • Entry level chairs • Customisation of wheelchairs • Definitions • Early sports chairs • Flexibility and developing specialisation • Look or form • Manufacturing process • Medical wheelchairs • Performance • Stabilisation and specialisation • Technical innovations	• Advancing the sport • Change in sport • Funding • Medical model • Medical reception to new technology • New techniques or skills • Rules • Safety • Sport and rehabilitation • Sports organisations	• History of subject • Media Representation

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