The effect of unbalancing team size on the physical and technical demands of small-sided games using elite reserve team soccer players.

Shane Seeley

BSc (Hons)

Submitted in the fulfilment of the requirements of the degree of:

MSc (Research) Sports Science

School of Life Sciences

College of Medical, Veterinary and Life Sciences

University of Glasgow

Supervisors

Mr Nairn Scobie

Prof Niall MacFarlane

September 2021

Abstract

At professional soccer clubs, players within the same club often require a different training stimulus on a given day based on different preceding training/match exposure and different responses to the same training stimulus. Despite large amounts of research into small-sided games (SSGs), there has be no previous research investigating whether unbalancing team size in SSGs results in differential physical and technical demands between teams. The aim of this study, therefore, is to investigate the physical and technical demands of different team sizes within unbalanced SSGs. 20 elite male soccer players (age: 19 ± 1 yr; height: 179.1 ± 5.6 cm; body mass: 71.4 ± 12.4 kg) from the reserve team of a Scottish Premier League club took part in the study during the in-season phase of the 2019/2020 season. Physical demands were measured using GPSports EVO 10-Hz GPS units along with polar H1 heart rate sensors (5 kHz). SSGs were recorded using a GoPro HERO7 4K video camera and technical demands (and possession) were recorded retrospectively by analysing the footage using Nacsport Scout PLUS video analysis software. The game formats used were 5 vs 5 (control group), 6 vs 4 and 7 vs 3, plus the goal keepers. There was 6 testing days throughout the season with 2 testing days per format (12 games total). Game format order was randomised every 3 testing days. SSGs were performed in a 2 x 4 minute fashion with 90 seconds rest between with only one format (e.g. 6 vs 4) measured per testing day. In addition to the above study protocol, 2 seasons of second day recovery data from the first team was compiled to put any "lower-intensity" data into context of the clubs periodisation strategy. The results show no significant differences between any individual physical or technical variables of the smaller, disadvantaged teams and the control. In contrast, the larger teams had significantly lower physical demands. Compared with the control group, the team of 7 had significantly lower mean total distance (284 vs 407 m), heart rate (73 vs 85 $\%HR_{max}$), maximum velocity (18 vs 21 $km.h^{-1}$), high-intensity running distance (0.1 vs 6.3 m) and decelerations (0.7 vs 1.6) per game. The results of the team of 7 showed great compatibility with the second day recovery data. The team of 3 and 4 had significantly lower possession compared with their opposition team of 7 and 6 respectively (35-37 vs 63-65 %). As a team, the team of 7 took significantly more shots than the control group (12 vs 7). The significantly lower demands of the advantaged teams and the control combined with the lack of differences between the disadvantaged teams and the control suggest that different periodisation targets can be hit within the same SSG. This means that recovery groups can be combined with regular training groups. This can lead to increased team cohesion, training enjoyment, and technical/technical development. It could also help younger athletes receive an optimal physical stimulus (in relation to the next match) when training with older teams for one-off sessions, thus allowing them to perform more matches throughout the season. Finally, the technical and tactical differences can be used to develop these skills e.g. how do 4 defenders deal with 6 attacking players and also reduce overtraining in select players.

Contents

List of Tables

Lists of Figures

Acknowledgements

I would like to thank my supervisor, Mr Nairn Scobie, for his optimistic outlook and personable attitude. He gave me an effective balance encouragement/support and independence that promoted my development. I would also like to thank my other supervisor, Professor Niall MacFarlane. He provided the idea that sparked my research topic and constantly challenged the scientific rigour of my research and analysis to ensure it was as impactful as possible. In combination, both my supervisors went above and beyond their responsibilities to facilitate my success.

I would also like to thank the reserve team players for their cooperation during my study and I sincerely hope they have a fruitful career. A special mention to all of the staff at Celtic Football club, Jack Nayler, William Currie, Scott Breddy, Kirsty Miller, Oliver Morgan and John Currie. These staff members invested in me far more than I deserve and I am very thankful.

I would also like to show gratitude for being lucky enough to be born in the United Kingdom. Despite coming from a family without the means to pay for my tuition, I was able to study at a prestigious university and work towards a better future. I recognise that the values that have led to this prosperous country are not free, and have been fought for by previous generations of Britons. To these brave men and women I am forever indebted.

Finally, I would like to thank my partner Katie and my family for all the support they have offered. This thesis is dedicated to my grandparents, Valerie and Patricia, for embodying admirable and important values.

Abbreviations

$\%HR_{max}$	Heart rate as a percentage of maximum
ES	Effect size
GKs	Goal keepers
GPS	Global positioning system
HIIT	High-intensity interval training
HIR	High-intensity running
HR	Heart rate
HR_{max}	Maximum heart rate
HRZ	Heart rate zone
M	Mean
MD +1	One day after the next match
MD +2	Two days after the next match
MD -1	One day before the next match
MD -2	Two days before the next match
MD -3	Three days before the next match
MD -4	Four days before the next match
R2	Second day recovery
RPE	Rating of perceived exertion
RZM	Red zone minutes (number of minutes > 85 % maximum heart rate)
SD	Standard deviation
SE	Standard error
SSG	Small-sided game
SSGs	Small-sided games
TD	Total distance
$\dot{V}O_{2max}$	Maximal rate of oxygen uptake
WM	Wide Midfielder

1.0 Literature Review

1.1 Introduction

Association football, or soccer, is the most popular sport in the world with approximately 4 billion fans worldwide. When the first sport scientists began to work in football they were treated with suspicion at best and outright hostility at worst from soccer coaches. Originally sports scientists applied more generalised sports science knowledge to the soccer athlete. Over time, there has been a greater application of the scientific method to more soccer specific scenarios and a systematisation of sports science support into soccer. The popularity and the highly competitive nature of high-level soccer has facilitated the production of many new research questions. In attempting to answer such questions, “soccer science” has developed and this body of knowledge is now increasingly understood by soccer coaches. On the 9th March 2013, Sir Alex Ferguson, widely considered one of the greatest soccer managers of all time delivered the following in the Irish Times "sports science, without question, is the biggest & most important change in my lifetime. It has moved the game onto another level that maybe we never dreamt of all those years ago. Sports science has brought a whole new dimension to the game". Sports science has “moved the game onto another level” by better developing physiological capacities, improving recovery strategies, preventing injury and more effectively peaking performance towards games. In order to make these improvements, sport scientists first needed to understand the determinants of performance.

After better understanding the determinants of performance, the natural progression is to research how we can effectively train these determinants within the context of a busy soccer season. Small-sided games (SSGs) have since attracted a lot of attention in soccer science due their wide use within elite (and amateur) soccer. Much of the sports science literature on SSGs misses the main purpose of the research, namely, how does this improve soccer performance during full-sided matches. This literature review critically analyses the relevant literature in elite soccer with an emphasis on SSGs to put the study into context. This study investigates if unbalancing team size in SSGs gives a differential stimulus between teams and if this stimulus could be used to enhance performance in competitive match play.

1.2 The Determinants of Soccer Performance

Performance in soccer is determined by technical skill, tactical awareness and physiological capacities (Hoff et al., 2002). Contemporary soccer is now played at a higher tempo than ever before, leading to an increased importance of physiological capacities and an optimum training program (Reilly, 2005). Strudwick and Reilly (2001) compared the total distance covered in games by players in the top English league before 1992 with the English Premier League (from 1998-2000) and found a mean increase from around 9.0 km to 10.5 km. Increases in distance covered has been seen across all player positions. More recently, Bangsbo et al., (2006) reported the typical distances covered by a top class team being 10 – 13 km with players towards the higher end usually being midfielders. On the surface, total distance may seem like a low resolution quantification of training load (training duration/volume multiplied by intensity), however the distance covered in matches has been shown to be sensitive enough to differentiate the level of soccer, different styles of play and positional roles (Reilly and Gilbourne, 2003). The improvement of monitoring technology is further progressing our understanding of the demands of match play and training. In particular, wearable GPS-accelerometer units (global positioning system units with built-in accelerometers), which are now worn by practically all professional clubs. This allows us to examine the demands of play with a higher time resolution. This is useful as the mean intensity of match play is approximately 70% $\dot{V}O_{2max}$ (Bangsbo et al., 2006). Average values can be misleading as very little football is played around 70% $\dot{V}O_{2max}$. Players are almost always either involved in a high-intensity activities above the lactate threshold (accumulating lactate) or recovering from these bouts by walking or running at a low intensity (removing lactate) during games (Helgerud et al., 2001). The new wearable GPS units allow us to more accurately measure the most demanding aspects of match play. It is these most demanding aspects of match play (e.g. the ability to sprint repeatedly) that can act as a bottleneck in soccer performance.

Due to the long duration of a soccer match (90 minutes), most energy is released from the aerobic energy system (Bangsbo et al., 2006). $\dot{V}O_{2max}$ is considered the most important factor in determining aerobic fitness, with lactate threshold and running economy being other significant contributing factors. In the top four Hungarian teams, their rank in the league table was found to match the average $\dot{V}O_{2max}$ value of the team (Apor, 1988). Similar findings have been discovered in the elite Norwegian division between $\dot{V}O_{2max}$ and league ranking (Wisloeff et al., 1998). Smaros (1980), found a significant correlation between $\dot{V}O_{2max}$ and the distance covered in games. In order to determine whether the relationship between $\dot{V}O_{2max}$ and performance was a cause and effect relationship, Helgerud et al., (2001) conducted an intervention study. In this study, two elite Norwegian teams were used, one control group and another receiving an aerobic endurance training intervention. This intervention consisted of four separate 4-minute runs at 90 – 95 % of maximum heart rate (%HR_{max}) with 3-minutes jogging between the runs. They completed these runs twice per week for a total of 8-weeks in addition to soccer training. The intervention group had a significant increase in $\dot{V}O_{2max}$ (10.8%), lactate threshold (16%) and running economy (6.7%) and no significant changes were found in the control group after the 8-week period (Helgerud et al., 2001). Although lactate threshold increased in absolute terms, there was no changed when expressed relative to $\dot{V}O_{2max}$. Lactate threshold increased due to the increase in both $\dot{V}O_{2max}$ and running economy. Running economy likely increased due to the higher volume of running. Following the intervention, match data was observed to find the following; average heart rate (HR) as a percentage of maximum increased by 5%, average distance covered increased by 1.7 km and the average number of sprints per player increased by 100%. In the study, the intervention group also increased the number of ball involvements by 24% (Helgerud et al., 2001). This was the first study to provide strong evidence that increasing $\dot{V}O_{2max}$ improves match performance.

In his book "Science and Application of High-Intensity Interval Training" (Laursen and Buchheit, 2019), high-intensity interval training (HIIT) is defined as "Exercise consisting of repeated bouts of high-intensity work performed above the lactate threshold (a perceived effort of "hard" or greater) or critical speed/power, interspersed by periods of low-intensity exercise or complete rest". HIIT, therefore, is a popular training format in elite soccer as soccer itself is a form of HIIT. Sports scientist agree that accumulating several minutes in your 'red zone' (90 %HRmax or above) like in the above study by Helgerud et al., (2001) provides an optimal stimulus to for maximal cardiovascular and peripheral adaptions (Buchheit and Laursen, 2013). These red zones minutes can be accumulated using different work/relief intensities, durations and exercise modalities. Manipulating these variables are important as they provide a different acute response which must be aligned with weekly periodisation strategies, and should contribute to beneficial long-term physiological adaptations.

Training increases energy demands of target cells which stresses metabolic systems. These include the ATP/PCr system, anaerobic glycolytic energy production and oxidative energy production (aerobic system). Buchheit and Laursen, (2013), classified HIIT based on the respective contributions of these three energy systems combined with the neuromuscular/muscoskeletal load. The aim of HIIT is to stress (overload) specific physiological systems to a greater (or equal) level that is required during competition so that the systems better tolerate the same stress in the future. There are 3 general physiological targets of HIIT: (1) the aerobic oxidative system, made up of oxidative (mitochondrial) energy production and the oxygen delivery system i.e. cardiac output which is influenced by stroke volume, (2) the short-term anaerobic energy glycolytic system and (3) the various aspects affecting the neuromuscular and muscoskeletal system. In soccer training SSGs are typically performed as “long intervals” (>2 minutes work periods) with the goal being to integrate the cardiovascular and mitochondrial energy production over glycolytic energy production (Buchheit and Laursen, 2013). If successfully achieved, the aerobic system is overloaded while players develop the technical/tactical aspects of match play which is considered a larger part of soccer performance, leading to performance gains (Laursen and Buchheit, 2019).

1.3 SSGs as a Training Tool

In professional soccer, a $\dot{V}O_{2max}$ of 65 ml/kg/min is common, and this value typically increases slightly throughout the season (Reilly and Gilbourne, 2003). A high aerobic fitness has been linked to better recovery between high-intensity bouts (Impellizzeri et al., 2006) and an overall greater aerobic energy production resulting in higher glycogen sparing and less fatigue during matches (Reilly, 1997). The 2001 study by Helgerud shows the effectiveness of using interval training to improve aerobic fitness and match performance. A 2006 study by Impellizzeri and colleagues investigated whether the same improvements seen from generic fitness training could be gained using soccer-specific aerobic training in the form of small-sided games (SSGs). One group of junior soccer players followed the protocol of Helgerud (4 x 4 min runs at 90 – 95 %HR_{max} with a 3 minute jog in-between) and the other group played SSGs in the same format. This study found that aerobic fitness was enhanced equally for general fitness training and SSGs and that these improvements were significant (Impellizzeri et al., 2006). These improvements were lower than that seen in the Helgerud 2001 study with improvements in $\dot{V}O_{2max}$, lactate threshold and running economy reaching 7%, 10% and 2% respectively despite the training period being 6-weeks longer. It was also found that mean match-intensity increased from 83 $\%HR_{max}$ to 85 $\%HR_{max}$ from pre to post training (Impellizzeri et al., 2006) following the trend of the study by Helgerud. In the 2006 study by Impellizzeri and colleagues, the total distance (TD) covered in matches increased by 571 m, again lower than the increase found by Helgerud. Despite this there was a greater increase found in high-intensity running (HIR) of 18%. HIR has been reported to be more effective at distinguishing top-class soccer players from lower level soccer players. Mohr et al., (2003) found that top-class players covered significantly more HIR distance (a 28% increase) whereas they only covered 5% more TD in matches. This suggest that an aerobic endurance program may significantly improve match performance in elite soccer players.

SSGs have a higher specificity of training and allow for simultaneous development of tactical and technical skill in addition to physiological capacities. If training involving SSGs can offer an equal development of physiological capacitates, the question arises to whether more general training should be made redundant in soccer training. Hoff et al., (2002) compared the HR and $\dot{V}O_{2max}$ response of 2 x 4 min of a dribbling track and a 5 vs 5 SSGs (with goal keepers) using elite male Norwegian soccer players. Both training methods fulfilled the criteria for effective aerobic interval training reaching a mean HR of 91.0 and 93.5 $\%HR_{max}$ for SSGs and dribbling track respectively (Hoff et al., 2002). In terms of $\dot{V}O_{2max}$, the dribbling track and SSGs average were 84.5 % $\dot{V}O_{2max}$ and 91.7 % $\dot{V}O_{2max}$ respectively. These HR and $\dot{V}O_{2max}$ values do not differ significantly between one another in this present study. An important finding from this study is that, using SSGs the individual athletes with the highest $\dot{V}O_{2max}$ played at the lowest percentage of this $\dot{V}O_{2max}$ (Hoff et al., 2002). This is likely because the pace of the game is set based on the two teams. This pace will elicit a smaller percentage of maximal effort for the players with greater aerobic fitness. Unlike in running, where the purpose is to run at a given intensity (speed), it is possible to conserve energy in a competitive game situation. Conserving energy could even be tactically advantages in game situations. Furthermore, the peak velocities reached in SSGs are not as high as in game situations or in straight line running due to the smaller spaces used. In SSGs, in order to give the fitter players a similar stimulus to the less fit athletes and expose all soccer players to the peak velocities they perform in games, I would suggest combining general training (i.e. running) and more specific training.

1.4 Manipulating the Training Stimulus in SSGs

A fundamental training principle known as "the specificity of training" is present in SSGs. As the movement types and patterns in SSGs is almost identical to match play there may be greater transfer into games and an increased efficiency of movement (Little, 2009). The combination of high training specificity and the ability to develop different skills and capacities simultaneously leads to an efficient method of training players, making SSGs popular among soccer coaches and sport scientists alike. As SSGs are used frequently in almost any soccer training schedule, many researchers have attempted to better understand what variables effect the training stimulus provided by SSGs. General fitness training has the advantage of being able to closely control the training stimulus for each player. The development of relatively cheap GPS and HR technology means recording and analysing soccer training has never been easier. Pitch dimensions, player number, coach motivation, rule alteration and the presence of goal keepers (GKs) have all been shown to significantly affect the intensity of play during SSGs (Little, 2009). To more effectively utilise SSGs as part of soccer training, it is important we have a good understanding of both the physical and technical demands of different variations of SSGs. The physiological effect of altering pitch size in SSGs was investigated in 2004. It was found that increasing the pitch size resulted in an increased mean and maximum HR, however the significance of these changes were not stated (Owen et al., 2004). Nonetheless this suggests that larger pitch sizes in SSGs increases the intensity of play. Other researchers found no significant difference in mean HR when changing the pitch dimensions in SSGs (Kelly and Drust 2009). A disadvantage with HR data is that it is not just a measure of exercise intensity, HR can also be increased by excitement or anxiety. Because of such contradictory findings and the limitations of relying solely on HR data, the effect of pitch size on soccer athletes in SSGs needed to be more closely examined.

In 2010 Casamichana and Castellano examined the physical, physiological and motor responses (technical actions) of different pitch dimensions during 5 vs 5 SSGs with GKs. 10 male youth soccer players were used with 3 different playing areas (large, medium and small was 62 x 44 m, 50 x 35 m, and 32 x 23 m respectively). Large was the area per person from playing an 11v11 match on the soccer team's home pitch and the length to width ratio always remained consistent from this pitch (1.4:1) for the 3 different playing areas. During games played on the larger pitch, the players data showed significantly higher mean HR, mean maximum HR (%HR_{max}), RPE, TD, distance of high-, medium- and low-intensity running, m.min^{-1}, max speed, work-rest-ratio and sprint frequency than the small pitch (see table 1). Table 1 also shows the two significant differences found between the large and medium pitch category (TD and distance covered between 13.0-17.9 km/hr). The frequency of most motor variables studied was significantly higher in the smaller pitch than the medium and large pitch (Casamichana and Castellano, 2010). Increased player density likely resulted in opposing players coming into contact more frequently leading to more passes and tackles. A shorter distance between goals encourages more shooting as the proportion of the pitch in which they are likely to shoot on-target is greater leading to a significantly higher "control and shoot" motor variable in the small (5.0) compared with the large (1.8) SSGs. Increased technical actions likely caused the ball to go out of play more often (decreasing effective playing time) which the authors cited as a major factor for reducing physical demands in the small SSGs. Despite this, they did not express their values relative to effective playing time. The mean HR found in this study were 86 and 89 %HR_{max} between the small and large pitch respectively. These values are lower than those seen in other studies which could be related to the relatively long duration of 8 minutes, which is double that used in other studies (Kelly and Drust, 2009) and that commonly used in training. Another criticism of this study is that accelerations, which are very fatiguing actions, were not recorded. Accelerations (and decelerations) are likely present in the smaller pitch despite athletes not having the space to reach higher speeds. It is for this reason that physical load values used in this study are likely an underestimate for the small pitch dimensions.

Table 1: A summary of the difference in physiological, physical and ratings of perceived exertion compared with small, medium and large small-sided games modified from the cited paper (Casamichana and Castellano, 2010). Data presented as mean (± SD). Post-hoc Bonferroni test: [a] $SSG_L > SSG_M$; [b] $SSG_L > SSG_S$; [c] $SSG_M > SSG_S$.

	Small-Sided Game Size		
	SSG_L	**SSG_M**	**SSG_S**
Mean Maximum HR ($\%HR_{max}$)	94.6 (± 4.3)[b]	94.6 (± 3.4) [c]	93.0 (± 5.7)
Mean HR ($\%HR_{max}$)	88.9 (± 3.9)[b]	88.5 (± 4.9) [c]	86.0 (± 5.8)
Total Distance (m)	999.6 (± 50.0)[a,b]	908.9 (± 30.6) [c]	695.8 (± 37.1)
Distance per Minute ($m.min^{-1}$)	125.0 (± 6.2)[a,b]	113.6 (± 3.8) [c]	87.0 (± 4.6)
Max Speed (km/h)	23.1 (± 2.6)[b]	20.4 (± 1.9)	18.05 (± 1.5)
Distance Low-Intensity Running (7.0–12.9 $km.h^{-1}$)	366.3 (± 74.8)[b]	329.3 (± 54.0)	238.9 (± 41.7)
Distance Medium-Intensity Running (13.0–17.9 $km.h^{-1}$)	180.9 (± 42.6)[b]	155.4 (± 41.4)[c]	50.2 (± 21.0)
Distance High-Intensity Running (> 18.0 $km.h^{-1}$)	74.2 (± 58.9)[b]	28.5 (± 33.3)	4.9 (± 5.5)
Work-to-Rest Ratio	1.7 (± 0.3)[b]	1.3 (± 0.2)[c]	0.7 (± 0.2)
Number of Sprints	5.8 (± 3.9)[b]	3.0 (± 2.2)	0.8 (± 0.7)
RPE	6.7 (± 0.8)[b]	6.7 (± 0.8)	5.7 (± 1.0)

Despite greater pitch dimensions in SSGs suggesting a higher load on players (Owen et al., 2004; Casamichana and Castellano, 2010) the length and width are likely to disproportionately affect the physiological, physical and technical demands. To test this hypothesis, researchers investigated four different pitch shapes: short-narrow (25 x 40 m), short-wide (25 x 66 m), long-narrow (50 x 40 m) and long-wide (50 x 66 m). The results of this study showed that pitch length had a greater impact on the physical demands than pitch width (Casamichana et al., 2018). In particular, RPE, total distance and peak speed were higher in the long-narrow (RPE 6.3, total distance 126.6 $m.min^{-1}$ and peak speed 6.1 $m.s^{-1}$) and long-wide pitches (RPE 6.6, total distance 131.4 $m.min^{-1}$ and peak speed 6.2

m.s^{-1}) compared to the short-narrow (RPE 3.8, total distance 101.2 m.min^{-1} and peak speed 4.8 m.s^{-1}) and short-wide pitches (RPE 4.9, total distance 107.7 m.min^{-1} and peak speed 5.2 m.s^{-1}). In a qualitative assessment, all these values for the long pitches were found to be almost certainly different from their short pitch counterparts. This is likely because players must cover a given distance in order to score or defend their goal whereas using the full width of the pitch is optional. This further develops the original hypothesis of as the pitch area per player increases, greater loads are placed on soccer players. The length and width should be considered separately when designing training drills involving SSGs. The effect of the type of SSG, whether a possession game or a game with GKs, on the physiological, physical and technical parameters has also been examined. In 2008, Mallo and Navarro compared a 3 vs 3 SSG whilst changing the presence of a GKs. They found that the intensity of the SSG without GKs were significantly higher during a competitive match than with GKs measure by distance covered (747 vs 638 m) and mean HR (173 vs 166 beats.min^{-1}) and HIR. During games played with GKs heart rates were significantly lower (Mallo and Naverro, 2008). The likely reason for this increased intensity without GKs is that with GKs, players are more tactically organised in relationship to the goals leading to a decreased intensity.

The number of players used in SSGs during training is highly variable during soccer training. It is therefore important that we understand how player number effects the physiological and physical load and the number of different technical actions seen. In 2009, researchers investigated how a 6 vs 6 and a 3 vs 3 SSG with GKs compared in terms of the physiological response and the number of motor variables seen. The SSG with 3 vs 3 had a significantly higher mean HR (87.6 % compared with 82.8 % HR_{max}) despite having smaller pitch dimensions suggesting a higher intensity (Katis and Kellis, 2009). There was also a significantly greater number of short passes, shots on goal and dribbling. Dribbling the ball has been shown to result in a higher energy expenditure (EE), blood lactate and RPE likely due to the increased muscular recruited whilst controlling a ball (Hoff et al., 2002). It must be taken into account that the dribbling was not continuous in the study by Katis and Kellis (2009) however the higher number of technical actions likely increased EE. The authors of this study hypothesised that the players in the smaller team also worked harder off of the ball also contributing to the increased HR response.

Using the reductionist approach of changing only one factor (e.g. pitch size) at a time helps us to better understand the effect this factor has on SSGs. In practice, however, the size of SSGs is often changed with the number of players used. In 2009, researchers investigated how a 6 vs 6 and a 3 vs 3 SSG with GKs compared in terms of the physical and technical demands using youth soccer players. Pitch dimensions for the 6 vs 6 and 3 vs 3 group were 30 x 40 m and 15 x 25 respectively. The SSG with 3 vs 3 had a significantly higher mean HR (87.6 % compared with 82.8 % HRmax) despite having smaller pitch dimensions, suggesting a higher intensity (Katis and Kellis, 2009). There was also a significantly greater number of short passes, shots on goal and dribbling. The authors of this study concluded that the smaller game format provides a greater stimulus for physical conditioning and technical improvement for youth soccer players. I agree that the physical stimulus is greater, however technical development may not be superior, as with less players there is less tactical context. Physical, technical, and tactical performance are not mutually exclusive but amalgamate to influence performance (Bradley and Ade, 2018).

1.5. The Demands of Full-Sided Soccer and Training Specificity

Top class soccer performance is constantly evolving; therefore sports scientists and coaches must be aware of the ever changing end goal. This knowledge can guide both first team and academy training strategies. An informative retrospective study by Barnes (2014), investigated how the physical and technical parameters of the English Premier League has evolved from the 2006/07 season to the 2012/13 season. TD covered has changed little in this period, however the speed at which this distance is covered has changed significantly. HIR distance (distance between 19.8 and 25.1 $km.h^{-1}$) increased from around 890 m to 1151 m and this was increased both in and out of possession. This supports findings that HIR distance is a better measure of total distance for discriminating competitive standards. Sprint distance increased by around 35% moving from 2.1% of total distance in 2006/07 to 3.2%. This higher sprint distance was a result of more frequent (and more explosive) sprints, not from longer/father sprits. Maximum velocity also increased from 32.8 to 34.4 $km.h^{-1}$. The combination of shorter, more explosive sprints, with higher maximum velocity highlights the importance of acceleration ability. This study also found that the number of passes increased by 40% with the number of successful passes increasing by 17%. Unfortunately, this study did not breakdown the different technical and physical requirements of different playing position and did not measure tactical factors.

Although the study conducted by Barnes (2014) was an improvement on previous studies focussing solely on quantifying the physical demands of matches (Castellano, Blanco-Villaseñor & Álvarez 2011; Di Salvo et al., 2009), there was a need for further investigation.

Having physical, technical and tactical data of the most demanding aspects of soccer match play for each position would allow the production of drills that replicate these demands. These drills may better develop soccer players and aid end-stage rehabilitation. A study by Ade, Fitzpatrick and Bradley (2016) completed a detailed analysis of movement patters, technical skills and tactical actions of elite soccer players in matches. The depth of this analysis required a limited portion of the game to be analysed in order to be achievable with current technology. This data was collected before and after high-intensity efforts, defined as efforts above 21 $km.h^{-1}$ lasting ≥ 1 second. Despite large inter-match variability of physical and technical metrics, many patterns emerged for different playing positions (Ade, Fitzpatrick and Bradley 2016). Because of the depth of the study, it is difficult to summarise all of the findings. In order to illustrate the utility of this data, I'll focus on just one player position, wide midfielders (WM). WMs performed significantly more repeated high-intensity efforts than centre backs, centre midfielders and centre forwards and these efforts were both further distance and longer in duration. Whilst in possession, WMs drive towards the centre of the pitch more, perform more crosses after runs, and perform more arc runs compared to full backs. Unlike other positions, out of possession, WMs finished most efforts in wide locations potentially due to tracking the opposition full backs. This breakdown for each position, allows drills to be designed that simulate common match situations for each position, in and out of possession. These drills can be designed to maintain ecological validity and therefore specificity. This data can also be used to validate whether the team is playing in line with the club's philosophy.

Although the work by Ade, Fitzpatrick and Bradley (2016) has given detailed information of match play for training prescription, other research has critiqued training drills performed as closed skills (Davids et al., 2013). Davids et al., (2013) argues that prioritising drills in training is reductionist and ignores the active role of the performance environment in changing decision making and movement behaviour. Drills designed to improve physiological and technical performance isolate the action from the performance context, potentially reducing transfer. It is difficult to overestimate the importance of perceptual, cognitive and decision-making skills in soccer performance. This notion is supported by research showing actions performed in a controlled setting significantly changes the movement pattern compared to the sporting context (Pinder et al., 2011). Training, therefore, should emphasise the unpredictable nature soccer. Ecological dynamics theory is a theoretical rationale for team games preparation that models team sports as complex social systems (Davids et al., 2013). Within this system, self-organisation tendencies emerge in individuals and in interpersonal interactions between players at various sub-phases of play in competitive game formats. Soccer players must learn how to couple effective action with the constantly changing perceptual information they receive. This perceptual information can trigger "opportunities to act" in the athletes. Important perceptual information includes relative distances from teammates, opponents, goals, the ball, and other players. Davids et al., (2013) suggests that training should be set-up to create these opportunities and train players to choose the appropriate behaviour. This may help athlete's discovery different ways of achieving key performance outcomes.

The different trains of thought in the preceding two paragraphs are really an argument of specificity. The work of Ade, Fitzpatrick and Bradley (2016) suggests increasing specificity by analysing physical, technical, tactical data of each position and designing drills to meet these demands. One benefit of breaking down performance into pre-planned drills is that it allows coaches to rationalise the decision-making process before moving to a training game format (i.e. simple to complex). Given that training game formats elicit a smaller percentage of $\dot{V}O_{2max}$ in the fittest players (Hoff et al., 2002), a portion of pitch based physical conditioning must be outside of game formats. This portion, therefore, can use specifically designed drills replicating physical, technical and tactical demands of each possession based on similar match analysis of Ade, Fitzpatrick and Bradley (2016). The downside of using pre-planned drills as it neglects the psychological aspects of soccer performance Davids et al., (2013). Anecdotally, when working with elite youth soccer players and trying to get them prepared to meet the demands of the first team training, even the fittest of the reserve team players struggled to keep up with the first team training game formats. The stress and pressure of training with the first team certainly contributes, however the increased speed of play and therefore faster perceptual, cognitive and decision-making demands may play a significant part. To meet the kind of specificity described by Davids et al., (2013), we need to find a way to overload the technical and tactical demands of SSGs and ideally, keeping the physical training stimulus.

1.6 The Complexity of a Professional Soccer Club

In the high number of competitive soccer matches within a season, different players have a different amount of time on the pitch. Some play the full 90 minutes, other players are subbed on or off and many do not play at all. This means that in the days training following a game, different players require different training prescriptions. In order to manage this, the training group is often split allowing for a lower intensity group (or recovery group) and the regular training group. The recovery group typically take part in the warm up and then do some low-intensity runs and some low-intensity technical work. This is shown in a study quantifying training load from players in the English Premier League. Anderson et al., (2016) found that players covered an average total of 1453 m two days after a game in a typical two games per week schedule. He also found no sprinting (> 25.2 $km.h^{-1}$) and almost no HIR (an average of 8 m) defined as distance above 19.8 $km.h^{-1}$. Splitting up the training group can lead to decreased team cohesion and often producing an “inner circle” of the top players and isolating others. Within a soccer club, players are often called up to play higher within the academy structure or with the first team or reserve team. As these different squads within soccer clubs have games on different days and individuals within the squad can play games on loan also, it can be challenging to combine players who require different acute physical stimuli within the same training group. The common approach is to modify the training group, not including them in the bulk of the session.

1.7 Conclusion

SSGs are clearly an important tool in improving soccer performance for physiological, technical, tactical and psychological reasons. Much is known about how altering different parameters in SSGs can change the physical (and to a lesser extent technical) demands of SSGs. At the time of writing, there was no published papers investigating the effect of unbalancing teams in SSGs following extensive literature searching. The aim of this study is to investigate how unbalancing team size in SSGs may prove useful in better preparing athletes for full sided games by providing differences in physical and technical demands between each team. If the competing teams have significantly different physical and technical demands, there may be scope for providing an alternative training stimulus to different players in the same SSG. This has the potential to combine training groups (e.g. second day recovery with the rest of the squad) who require a different stimulus, strategically reverse overtraining for select players, tactically overload specific players (skill development), and optimise the training of younger players pulled up through the academy system relative to their upcoming game. In summary, the present study is investigating how unbalanced SSGs could be a powerful tool in optimally preparing soccer athletes for match play.

2.0 Methods

2.1 Participants

The data in this study was collected from 20 professional elite male soccer players from the reserve team of an elite Scottish Premier League club (see table 2) who were treated as adults and volunteered to be a part of the study. The data presented in table 2 is typical of professional players at this stage of their soccer careers. Their mean max velocity (measured using GPS) is higher while there 8 site skinfold and 1500 m time trial is lower than what would be observed in the general population. Weekly in-season training for the participants consisted of 5 morning soccer sessions lasting 60-90 minutes each and 3 afternoon gym sessions enduring 60 minutes each, in addition to a soccer game on a Saturday. Data collection commenced on the 25th October and continued until the 8th February 2020. Data collection was prematurely halted due to the COVID19 outbreak and global pandemic.

My supervisor (Prof Niall MacFarlane) provided the hypothesis for the present study which I used to design the study protocol to be implemented within the soccer club. My role at the club was Sports Scientist for both the first team and reserve team throughout the 2019/2020 season with an emphasis on utilising training/match GPS data to enhance performance. The interview process for the Sport Scientist role involved presenting a potential research project. As this study remained unmodified from its proposal, this provided a stronger position for negotiation. While the study was designed independently of the soccer club, the practical limitations of the applied setting resulted in the necessity for some revision to meet the requirements of club management. Initially the head coach of the reserve team refused any research to be conducted on his players and advised I focus on academy level soccer athletes (under 18 years old). He voiced general concerns with player compliance, increased risk of injury, interference with training, and potentially reduced match performance. More specifically, the head coach was concerned that in the teams with fewer player, they would either overexert themselves or not input any effort. After gaining the support of the reserve team players and convincing the head coach of the potential utility of the research, he decided to allow my study to go ahead. We agreed on two, 4-minute games per data collection day with 90 seconds passive rest time in-between to reduce the risk of overexertion. I dealt with the concern of lack of player effort by reinforcing my position as observational, solely measuring the outcomes with no interference.

The nature of conducting research in an elite sport presents many challenges with sampling and compliance. For example, it is impossible to use the same players for each and every test or even to standardise the study based on player position. To overcome these factors, the present study was carefully designed to control as many variables as reasonably possible. Data was collected at the same time of day, on the same pitch (AstroTurf) and in the same phase of the weekly periodisation cycle. To remove the order effect, only one SSG format was used per day and the order of these games were randomised. Participants wore GPS units and heart rate sensors from the beginning of pre-season, which began in mid-June and finished in July. The first data collection day did not take place until October. This gave the participants 4 months to familiarise with the equipment used in this study. This time period also allowed participants 3 months of in-season training and game schedule so that they were adapted to in-season conditions for the duration of the study. Finally, ball feeders were used in order to quickly resume play after a ball was kicked out of bounds or into the goal preventing variation in playing time. All of these factors will hopefully contribute to the clarity of results.

A common problem in elite sport research is the inability to collect sufficient high quality data. This is often a result of a lack of compliance from athletes and coaches. Athletes can refuse to engage in the study appropriately and coaches can change their mind on data collection at extremely short notice. In addition, players can become ill/injured, be placed on loan with another club, and can be promoted to play with the first team. All of these factors can change the number of players available at short notice. In order to minimise these effects, a long familiarisation period was used. This allowed a strong rapport to be built with athletes and coaches allowing more effective negotiations of testing days. As the study utilised SSGs, players quickly became immersed in the competition, thus presenting no issue for compliance. These factors allowed large amounts of data to be collected throughout the season (118 data sets).

Ethical approval was granted for this study by the College of Medical, Veterinary & Life Sciences Research Ethics Committee at the University of Glasgow. All participants were given a briefing by the researcher and an information sheet before providing written consent for their data to be included in the study.

Table 2: Physical characteristics of the study participants mean (± SD)

N	Age (years)	Height (cm)	Body Mass (Kg)	8 Site Skinfold (mm)	Max Velocity (km.h^{-1})	1500 m Time Trial (min)
20	19.3 (± 1.1)	179.1 (± 5.6)	71.4 (± 12.4)	46.4 (± 8.5)	33.0 (± 1.2)	5.4 (± 0.4)

2.2 GPS Units

GPSports EVO 10-Hz GPS units (Canberra, Australia) were worn in specially made GPSports vests. The GPS units (63.6 x 43.7x 18.5 mm, 53 g) have integrated tri-axial accelerometers and magnetometers with 100-Hz sampling frequencies. The vests position the GPS unit in the middle of the shoulder blades in the upper thoracic region. These vests also have a compartment for attaching a heart monitor. Polar H1 heart rate sensors (5 kHz) were used in this study and the HR data was stored and downloaded from the GPS units. Each participant had their own GPS unit assigned to them, reducing any potential interunit variability. Before training, GPS units were alarmed to come on, placed in vests and hung on the respective hooks of each of the study participants placed at the exit of the building. Following training GPS data was downloaded and processed via the standard GPSports software. The typical percentage error of these units are as follows: total distance (m) 1.9 %, peak speed (km.h^{-1}) 8.1 %, distance between 0-14 km.h^{-1} (m) 2.0 %, distance between 14-20 km.h^{-1} (m) 7.6 % and the distance above 20 km.h^{-1} (m) 12.1 % (Johnston et al., 2014). This suggests that the slower GPS rate leads to greater error when players are moving at speed.

2.3 Independent Variables

The independent variable for this study is the number of players on each team (not including the GKs). Three different groups were tested including a 5 vs 5 (control group), 6 vs 4 and 7 vs 3. Figures 1, 2 and 3 show the 3 different team imbalances used in this study.

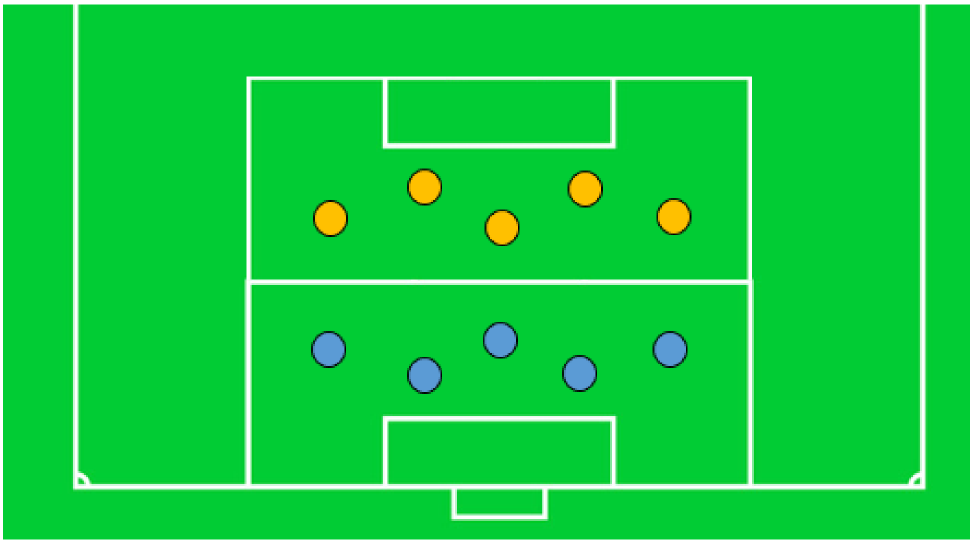

Figure 1: A figure showing the control group (5 vs 5) set-up used in the present study.

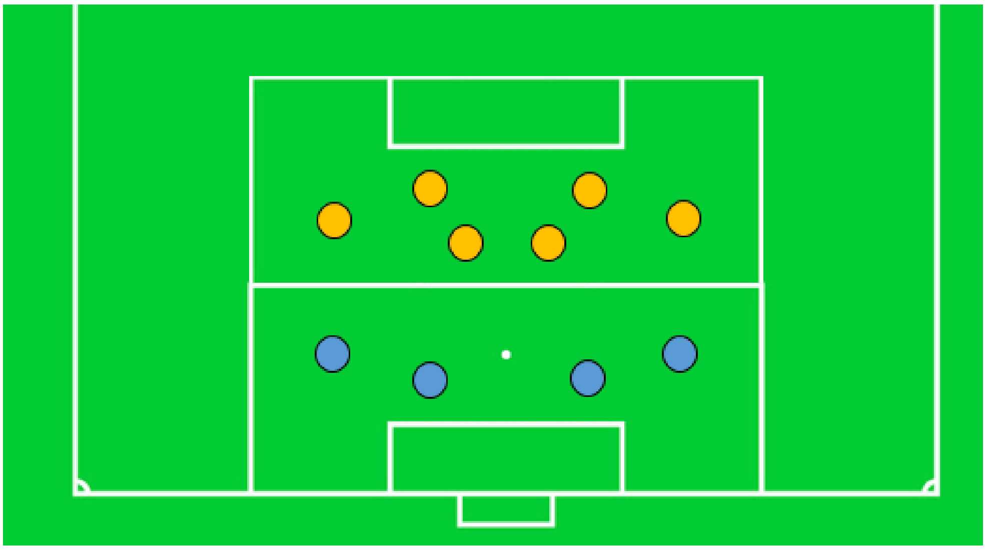

Figure 2: A figure showing the 6 vs 4 set-up used in the present study.

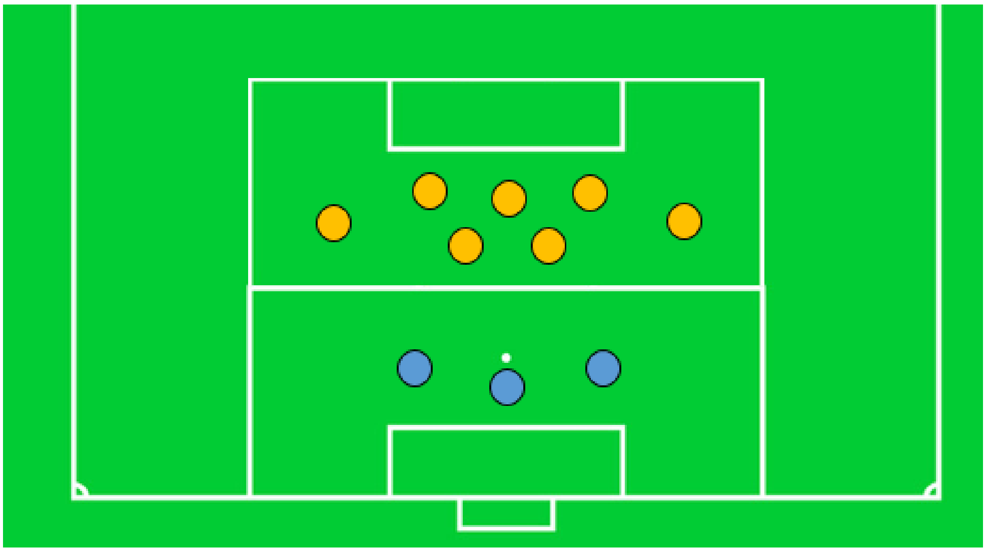

Figure 3: A figure showing the 7 vs 3 set-up used in the present study.

2.4 Control Variables

Test days were exclusively conducted 4 days before a match (match day -4). This day was always the day following a rest day. Given the periodisation model used by the club, every day (relative to the next match) is highly replicable in terms of training load. On a match day -4 (MD -4), the final training drills are always SSGs. For convenience, my study was conducted at the end of these sessions in place of the usual SSGs. My study was conducted at the same time of day (12:00-12:30 pm) for every data collection. The offside rule was used throughout. Without the offside rule, the team with the greatest number of players had an even greater advantage.

The pitch dimensions used in the present study was 40 x 33 m, sometimes referred to as "double box", as this is the same dimensions as 2 penalty boxes (see figure 4). These dimensions were chosen as they are typical of the pitch size used for a 5 vs 5 SSG with GKs, in addition they are easily replicable due to the standard size of a soccer penalty box. The camera was positioned 15 m perpendicular to the halfway line (see figure 4) and was mounted on a tripod at a height of 1.5 m. All games were played on an Astroturf pitch.

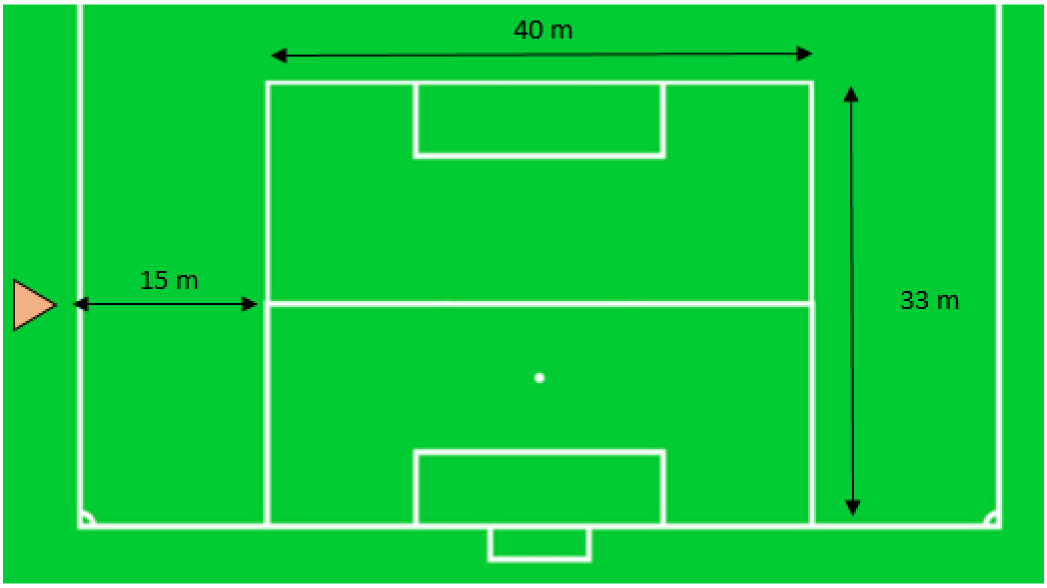

Figure 4: The pitch dimensions and camera (triangle) set-up used in the present study.

2.5 Dependent Variables

2.5.1 External Load

Most measures of external load used in this study were in the form of locomotor variables: TD; distance per minute; maximum velocity; and the distance covered in 4 different speed zones (See table 3).

Table 3: The different velocity zones used in this study and their corresponding movement classification

Velocity Zone	Velocity Range ($km.h^{-1}$)	Movement Classification
1	< 14	Walking/jogging
2	14 - 16.9	Low-intensity Running
3	17 – 20.9	Medium-intensity Running
4	≥ 21	High-intensity Running

The other external load variables used in this study were the number of accelerations and decelerations. These variables are not locomotor variables derived from the GPS, but rather mechanical variables derived from the integrated accelerometer.

2.5.2 Internal Load

The internal load variables used were a combination of subjective assessments (rating of perceived exertion) and physiological measures (HR data). A rating of perceived exertion (RPE) were taken after every training session for the study participants prior to the study therefore they were familiar with what training intensity corresponded to which RPE. During the 4 month familiarisation phase, athletes had a tendency to overestimate RPE on challenging training days. To overcome this, we described to the athletes that the highest RPE corresponds with a cup final where you have worked intensely for an entire match. Ideally we would have trained each athlete in using RPE individually. This can be achieved by bringing athletes up to a number of specific HRs and telling the athletes that this intensity corresponds to a specific RPE value. This allows athletes to better couple a set of internal perception with a specific RPE on a scale. The RPE given was told to reflect both work and rest periods during the experiment. To improve accuracy, RPE was taken immediate after the experiment which was always within 5 minutes. HR was expressed as a percentage of age-predicted maximum HR (220 - age) and split into 5 zones (see table 4). HR was expressed as the time within each of these HR zones. In addition, the maximum HR was also recorded and HR zones 4 and 5 were combined. This is because training above 85% maximum HR has been shown to produce desired physiological adaptations.

Table 4: The different HR zones used in this study and their corresponding thresholds.

HR Zone	**HR Range (%HR$_{max}$)**
1	< 60
2	60 – 74.9
3	75 - 84.9
4	85 – 94.9
5	≥ 95

2.5.3 Technical Actions

The frequency of the technical actions (specified in table 5) were recorded for each team in this study. The classifications chosen for table 5 were decided between the soccer club and I based on what they would find most useful. The number of goals were recorded as a measure of the success (or lack thereof) of each team size. The number of goals is not used to make up “total technical actions”. As a “goal” is a successful “shot” adding both to the total technical actions would count the same technical action twice. Due to the high relevance in this study, the tactical variable “possession” was recorded for each team size. Possession in this study was defined as the proportion of playing time a given team had the ball. Possession would cease for the team when the opposing team contacted the ball or if there was a rule-related interruption (e.g. the ball went out of play). After a rule-related interruption, possession was not counted until the goal keeper released the ball.

Table 5: A table showing the categories of technical actions recorded in the present study and the definitions used when coding the SSGs.

Technical Action	Definition
Total technical actions	The sum of all the other actions except “goal” as this is a successful “shot”
Ball Control	A players receives the ball and stops is near his feet
Pass	A player kicks attempts to kick the ball to his teammate
Dribble	A player advances with the ball while controlling the ball near his feet
Shot	A player kicked/headed the ball at the opponents net in attempt to score a goal
Interception	A player gains possession of the ball whilst being passed between 2 opponents
Tackle	A player uses his feet to take the ball away from an opponent
Goal	The ball arrives in the net of an opponent

2.5.3 Second Day Recovery Data

For the 2018/2019 season and the 2019/2020 season, second day recovery (R2) session data from the first team was compiled. Although no technical data was available, there was both HR and GPS data. Velocity zones 2 and 3 were merged in this data set as this is all that was available. This R2 session data helps illuminate the practical application of the results of the present study. As unbalancing teams may result in a significant difference in intensity, including data from a known “lower-intensity” day will help put any results into context.

2.6 Study Protocol

2.6.1 Pre-SSGs

Before the study date, the order of the next 3 game imbalances were randomised using a random number generator. This allowed the three independent variables to be randomised whilst being spread evenly throughout the data collection period. The independent variable was the same on a given study day and repeated twice. After each team imbalance was tested, the order would be re-randomised for the next 3 data collection days. Following the end of the training session, the head coach would select 10 athletes to take part in the study and 2 GKs. Using the subjective assessment of the head coach, 2 teams of 5 were selected who were evenly matched. In the 5 vs 5 group the study would then commence. In the unbalanced teams, the coach would flip a coin to decide which team would have less players. Teams were unbalanced again using the subjective assessment of the coach to match ability between teams as much as possible.

GPS and HR sensors were worn by the study participants before the commencement of training. An RPE scale was left at the entrance to the changing rooms. Pitch dimensions were measured out using a trundle wheel and a GoPro HERO7 4K video camera on a tripod was placed 15 m perpendicular to the halfway line as seen in figure 4. Extra footballs were placed beside each goal along with a person to feed in the balls to maximise the playing time.

2.6.2 During the SSGs

The two individual games lasted 4 minutes with 90 seconds of passive rest time between. There was no limit to the number of touches participants could take and the offside rule was enforced. Balls were fed in to a team's goal keeper for the following rule-related interruptions: your team scored; an opponent kicked the ball out of play; an opponent fouled one of your team members; an opponent was offside; or an opponent gave a handball. Soccer balls were located next to each goal along with a person allocated to feed in balls to minimise the time balls were out of play. Motivation was provided to the players throughout to encourage high-intensity games. All games were filmed in order to record technical actions.

2.6.3 Post-SSGs

Following the games, RPE's were taken for each player within 5 minutes which include a mix of game intensity and recovery. GPS units were retrieved, downloaded and the data was exported into excel files. The number of technical actions performed by each team (see table 5), and the possession of each team was tallied using Nacsport Scout PLUS video analysis software.

2.7 Statistical Analysis

Once all the data had been collated in Excel, data was transferred to Minitab (version 17, Minitab Inc., State College, Pennsylvania, USA) for statistical analysis. There was a total of 6 collection days with 2 SSGs per day and 10 players, resulting in 120 data sets in total for GPS and HR data. On one of the collection days, a participant failed to wear their GPS unit for both games meaning that there were 118 data sets in total. As technical actions were recorded per team there were 24 data sets. Because of the nature of unbalancing teams, the smaller team sizes have fewer data sets than the larger ones. This reduces reliability and confidence in the results of the smaller team sizes (i.e. team 3 and team 4). All data is presented as mean (*M*) ± *SD* unless stated otherwise. Statistical comparisons between all the different team sizes for all dependant variables were performed using a set of repeated one-way ANOVA and Tukey confidence interval tests. Significance was accepted at $P < 0.05$. Team size 5 vs 5 was the control group in this experiment. Although statistical comparisons were performed between all different team sizes, the effect sizes were only comparisons from the control group (5 vs 5). Effect size (*ES*) was calculated using Cohen's d test [ES=(Δ mean)/pooled SD] (Cohen, 1988) and the magnitude of effect was determined using the ranges reported by Batterham and Hopkins (2006) and Hopkins (2009). These indicate that effects < 0.2 are trivial, ≥ 0.2 but < 0.5 are small, ≥ 0.5 but < 0.8 are moderate and ≥ 0.8 are large.

3.0 Results

The results of this study are presented in 4 sections. The first section deals with the external load in the form of locomotor and acceleration/deceleration variables. External load data was recorded exclusively using GPS units. The second presents internal load measures in the form of HR and RPE data. The third explores technical actions for each team and on an individual player basis. The final section compiles two seasons of second day recovery session data to help put the data collected in the present study into context.

3.1 External Load

Table 6 compiles all external load data used in the present study collected via GPS units. The main finding present in this data is that there is no significant difference between the team of 3, 4 and the control across any external load measures. This suggest that the physical stimulus did not differ between the control and the disadvantaged teams. The mean TD ran by individuals in the team of 7 (284.2 ± 58.8 m) was significantly lower than all other team sizes. Similarly the mean distance covered by players in the team of 6 (342.3 ± 49.4 m) was significantly lower than the 3, 4 and 5 man team and higher than the 7. The team of 6 and 7 also had large negative effect sizes (see table 6) suggesting the decrease in distance covered compared with the control group is large. In table 6, TD is also written as a rate ($m.min^{-1}$) in order to help compare the present data to previous literature.

In terms of the speed at which the aforementioned distance was covered, individuals within the team of 7 covered significantly lower walking/jogging, low-, medium- and high-intensity distance than the control group (see table 6). This trend is also backed up by a significantly lower mean maximum velocity in the team of 7 compared with the control group (17.9 ± 2.9 $km.h^{-1}$ vs 21.1 ± 2.6 $km.h^{-1}$) and large negative effect sizes for all speed zones. Although there is a pattern of lower mean distance covered between different speeds zones in the team of 6 compared to the control group and disadvantaged teams, significant difference was only found in walking/jogging distance. Despite no significant difference found between the mean numbers of accelerations within different team sizes, there was significantly fewer deceleration in the team of 7 compared with the control group. This difference was accompanied by a large negative effect size suggesting a large difference. In sum, the external load data suggest that individuals in the team of 7 were exposed to significantly lower physical demands than the control group and often lower than the team of 3 and 4.

Table 6: The mean values for various external load measures for each team size. Effect sizes are in comparison to the control group (5 vs 5).

	External Load				
Game Format Team Size	**3 vs 7 3**	**4 vs 6 4**	**5 vs 5 5 (control)**	**4 vs 6 6**	**3 vs 7 7**
Total Distance					
M (m)	427.5	421.5	407	342.3*	284.2*
M (m.min^{-1})	106.9	106.4	101.7	86.5*	71.0*
SD	47.5	51.8	50.3	49.4	58.8
ES	0.42 Small	0.36 Small		-1.20 Large	-2.25 Large
Maximum Velocity (km.h^{-1})					
M	20.9	21.5	21.1	19.4	17.9†
SD	2.5	2.8	2.6	2.7	2.9
ES	-0.10	0.12		-0.66 Medium	-1.2 Large
Walking/Jogging Distance (m)					
M	348.8	338.4	329.4	285.4†	254.1†
SD	30.5	42.8	43.3	36.5	48.3
ES	0.52 Medium	0.21 Small		-1.10 Large	-1.64 Large
Low-Intensity Running Distance (m)					
M	30.1	43.7	31.9	23.0#	15.2ǂ
SD	12.2	36.0	13.3	13.3	13
ES	-0.14	0.48 Small		-0.67 Medium	-1.27 Large
Medium-Intensity Running Distance (m)					
M	16.8	19.4	16.2	14.1	8.3ǂ
SD	12.1	13.9	11.1	13.9	7.8
ES	0.05	0.26 Small		-0.17	-0.84 Large
High-Intensity Running Distance (m)					
M	7.6	6.3	6.4	2.1	0.1¥
SD	10.5	7.2	8.9	6.1	0.7
ES	0.12	-0.02		-0.50 Medium	-1.32 Large
Number of Accelerations					
M	0.4	1.0	0.9	0.8	0.4
SD	0.67	1.18	1.00	0.96	0.56
ES	-0.52 Medium	0.14		-0.02	-0.63 Medium
Number of Decelerations					
M	1.7	1.4	1.6	1.0	0.7 Ø
SD	10.5	7.2	8.9	6.1	0.7
ES	0.12	-0.02		-0.50 Medium	-1.32 Large

Note: * Significantly different from all. † Significantly different to team size 3, 4 and 5. # Significantly different from 4. ǂ Significantly different to team size 4 and 5. ¥ Significantly different to team size 3 and 5. Ø significantly different to team size 5 ($p<0.05$).

3.2 Internal Load

HR and RPE data is summarised and presented in table 7. Mirroring TD, mean HR in the team of 7 (73.3 ± 4.2 $\%HR_{max}$) is significantly lower than all other team sizes while the mean HR in the team of 6 (78.1 ± 3.4 $\%HR_{max}$) is significantly lower than the team of 3, 4 and 5 and higher than the 7. Both the team of 6 and 7 have very large effect sizes suggesting the magnitude of this decrease in mean HR compared to the control group was large. The team of 5 has the highest mean HR (84.6 ± 5.4 $\%HR_{max}$) although similar to the external load data, through all HR data presented there is no significant difference between the control and disadvantaged teams.

Team size 7 had the lowest mean peak HR of 84.2 ± 6.3 $\%HR_{max}$ (see table 7). This value is significantly lower than the mean peak HR of team size 4 (91.9 ± 2.9 $\%HR_{max}$), 5 (92.7 ± 4.0 $\%HR_{max}$) and 6 (89.7 ± 4.6 $\%HR_{max}$). The team of 7 had a large negative effect size compared to the control group suggesting the magnitude of the difference is in fact large. Like mean HR, the mean peak HR was largest in team size 5. The team of 3 had a large negative effect size suggesting a large decrease in mean peak HR compared to the control, however this difference was not significant. The team with the highest median RPE is team size 4 (6.5 ± 0.25) and the second highest is team size 3 (5.5 ± 0.49). This means the perceived effort of the SSGs were highest for the team of 4 and then the team of 3. The team of 5 (4.0 ± 0.12), 6 (3.0 ± 0.12) and 7 (2.0 ± 0.13) have descending medium RPE's.

There was a very small mean time spent in HR Zone 1 across all team sizes with no significant differences between team sizes (see table 7). Team size 7 spent over half of game time in HR Zone 2 (54.3 ± 23.5 %) which is significantly higher than all other team sizes (see table 7). In addition, there is a large positive effect size compared to the control group (15.5 ± 14.8 %) suggesting that there is a large magnitude of difference. The team of 6 has the highest mean time in HR zone 3 (49.5 ± 21.8 %) which is significantly higher than the control (25.8 ± 23.5 %). This is categorised by a large effect size, suggesting this difference is large. Team size 6 (19.3 ± 22.8 %) and team size 7 (3.3 ± 9.3 %) have the lowest mean time spent in HR zone 4. Team size 7 is significantly lower than team size 3, 4 and 5 and team size 6 is significantly lower from team 3 and 5. Both team size 6 and 7 have a large negative effect size compared with the control group suggesting the magnitude of this difference is large. The control group and disadvantaged teams spent roughly half their time in HR Zone 4. Little or no time was spent in HR Zone 5 in the present study with no significant differences detected.

Table 7: The mean/median values for various internal load measures for each team size. Effect sizes are in comparison to the control group (5 vs 5).

	Internal Load				
Game Format Team Size	**3 vs 7 3**	**4 vs 6 4**	**5 vs 5 5 (control)**	**4 vs 6 6**	**3 vs 7 7**
Mean HR (%HR_{max})					
M	83.9	83.2	84.6	78.1*	73.3*
SD	2.5	3.0	5.4	3.4	4.2
ES	0.20	-0.33		-1.48	-2.34
	Small	Small		Large	Large
Mean Peak HR (%HR_{max})					
M	89.5	91.9	92.7	89.7	84.2•
SD	3.3	2.9	4.0	4.6	6.3
ES	-0.88	-0.22		-0.70	-1.70
	Large	Small		Medium	Large
Time in HR Zone 1 (%)					
M	0.3	0.8	0.5	3.0	2.8
SD	0.5	1.8	2.0	7.8	4.3
ES	-0.31	0.09		0.47	0.66
	Small			Small	Medium
Time in HR Zone 2 (%)					
M	7.5	15.5	14.0	25.8	54.3*
SD	3.5	14.8	15.0	15.5	23.5
ES	-0.72	0.09		0.76	2.09
	Medium			Medium	Large
Time in HR Zone 3 (%)					
M	43.5	40.8	25.8	49.5Ø	40.3
SD	27.8	24.5	23.5	21.8	22.8
ES	0.69	0.62		1.05	0.63
	Medium	Medium		Large	Medium
Time in HR Zone 4 (%)					
M	50.0	42.8	54.8	19.3¥	3.3†
SD	30.0	28.3	28.0	22.8	9.3
ES	-0.17	-0.43		-1.40	-2.77
		Small		Large	Large
Time in HR Zone 5 (%)					
M	0	0.1	4.5	2.8	0.1
SD	0	0.3	9.0	10.5	0.3
ES	-1.01	-0.95		-0.17	-0.95
	Large	Large			Large
RPE					
Median	5.5	6.5	4	3	2
SE	0.49	0.25	0.12	0.12	0.13

Note: * Significantly different from all. † Significantly different to team size 3, 4 and 5. ¥ Significantly different to team size 3 and 5. Ø significantly different to team size 5. • Significantly different from 4, 5 and 6 ($p<0.05$).

3.3 Technical Actions

3.3.1 Team Technical Actions

As shown by table 8, both disadvantaged teams (the team of 3 and 4) had significantly lower possession than their advantaged counterparts (the team of 6 and 7). Despite this, no team had a significantly different possession from the control group. A similar trend is shown for goals scored, where the advantaged teams scored significantly more goals than their opposing team but not the control group. No goals were scored by the team of 3 in any of the 3 vs 7 SSGs.

Overall the team of 3 had the lowest number of technical actions throughout the SSGs (32 ± 6.5). The team of 3 had significantly lower technical actions than the team of 5, 6 and 7. In addition, the team of 3 had a large negative effect size, suggesting the magnitude of this decrease in technical actions was large in comparison to the control group. The team of 4 has the second lowest mean number of technical actions (44 ± 6.1) which was significantly lower than the team of 6. The team of 6 (78 ± 16.5) and 7 (73 ± 19.1) had a medium and small positive effect size respectively when compared to the control group. These differences were, however, not significant.

The lowest mean number of ball controls, passes and shots performed by each team was by team size 3 (12 ± 1.9, 8 ± 1.3 and 4 ± 2.6 respectively) and this is seen in table 8. The team of 3 had significantly lower ball control, pass and shot frequency than the team of 6. The team of 7 (12 ± 1.3) has the highest number of shots and this mean was significantly higher than team size 3, 4 and 5 (see table 8). Compared to the control (7 ± 2.1), the team of 7 had a large positive effect size, which suggests that a large increase in the number of shots. No significant differences were found between the mean number of interceptions, tackles or dribbles.

Table 8: The mean number of technical actions performed by each team and the mean possession (%). Effect sizes are in comparison to the control group (5 vs 5).

	Team Technical Actions				
Game Format **Team Size**	**3 vs 7** **3**	**4 vs 6** **4**	**5 vs 5** **5 (control)**	**4 vs 6** **6**	**3 vs 7** **7**
Total Technical actions					
M	32$	44ø	64	78	73
SD	6.5	6.1	18.7	16.5	19.1
ES	-2.55 Large	-1.59 Large		0.79 Medium	0.47 Small
Ball Control					
M	12ø	16	23	28	26
SD	1.9	3.1	7.7	7.5	10.2
ES	-2.33 Large	-1.20 Large		0.62 Medium	0.36 Small
Pass					
M	8ø	12	19	24	20
SD	1.3	2.1	7.7	10.7	6.4
ES	-2.62 Large	-1.54 Large		0.49 Small	0.04
Dribble					
M	6	7	10	13	9
SD	3.3	1.4	4.2	1.7	3.4
ES	-1.19 Large	-1.06 Large		0.84 Large	-0.26 Small
Shot					
M	4ø	6	7	9	12†
SD	2.6	2.1	2.1	2.6	1.3
ES	-1.49 Large	-0.73 Medium		0.53 Medium	2.54 Large
Interception					
M	1	2	3	2	4
SD	1.3	1.4	1.6	1.4	0.6
ES	-1.29 Large	-0.74 Medium		-0.74 Medium	0.34 Small
Tackle					
M	2	1	1	3	3
SD	1.4	1.3	0.9	2.2	1.4
ES	0.65 Medium	0		1.29 Large	1.52 Large
Goal Scored					
M	0	2	2	4∆	4 €
SD	0	1.3	1.5	1.0	1.5
ES	-2.92 Large	-0.45 Small		1.35 Large	1.44 Large
Possession (%)					
M	35	37	50	63 €	65 €
SD	12.2	7.7	15.0	7.7	12.2
ES	-1.10 Large	-1.16 Large		1.16 Large	1.10 Large

Note: $ Significantly different from 5, 6 and 7. ø Significantly different from 6. € Significantly different to team size 3 and 4. ∆ Significantly different from 4. † Significantly different to team size 3, 4 and 5 ($p<0.05$).

3.3.2 Individual Technical Actions

Individuals within the team of 5 (13 ± 3.7) and the team of 6 (13 ± 2.8) have the same mean number of technical actions (see table 9). After breaking down the frequency of different technical actions between each team to individuals, all statistical significance diminishes. As the greater frequency of technical actions performed by larger team is divided over a greater number of soccer players, the frequency of technical actions balance out compared to the team data.

Table 9: The mean number of technical actions accumulated by each player within each team. Effect sizes are in comparison to the control group (5 vs 5).

	Individual Technical Actions				
Game Format **Team Size**	**3 vs 7** **3**	**4 vs 6** **4**	**5 vs 5** **5 (control)**	**4 vs 6** **6**	**3 vs 7** **7**
Total Technical actions					
M	11	11	13	13	10
SD	2.2	1.5	3.7	2.8	2.7
ES	-0.76 Medium	-0.66 Medium		0.06	-0.73 Medium
Ball Control					
M	3.8	4.1	4.6	4.6	3.7
SD	0.6	0.8	1.5	1.3	1.5
ES	-0.66 Medium	-0.42 Small		0.02	-0.56 Medium
Pass					
M	2.5	2.9	3.9	4.0	2.8
SD	0.4	0.5	1.5	1.8	0.9
ES	-1.37 Large	-0.89 Large		0.07	-0.87 Large
Dribble					
M	1.8	1.8	2.0	2.1	1.3
SD	1.1	0.4	0.8	0.3	0.5
ES	-0.17	-0.42 Small		0.15	-1.07 Large
Shot					
M	1.3	1.4	1.5	1.4	1.6
SD	0.9	0.5	0.4	0.4	0.2
ES	-0.31 Small	-0.03		-0.08	0.65 Medium
Interception					
M	0.4	0.5	0.6	0.3	0.5
SD	0.4	0.4	0.3	0.2	0.1
ES	-0.56 Medium	-0.37 Small		-1.03 Large	-0.61 Medium
Tackle					
M	0.7	0.3	0.3	0.5	0.4
SD	0.5	0.3	0.2	0.4	0.2
ES	1.28 Large	0.25 Small		1.07 Large	0.94 Large

3.4 Second Day Recovery Comparative Data

Table 10 shows that a typical second day recovery session lasts 40 ± 8.6 minutes, and that players cover a mean distance of 1500.5 (± 498.2) m. This results in a distance per minute of 38.3 (± 12.1) $m.min^{-1}$. More than 90% of the distance covered walking/jogging or low-/medium-intensity running. The mean maximum velocity reached in the second day recovery session is 19.9 (± 3.2) $km.h^{-1}$. Finally, mean HR during second day recovery sessions was 50.5 (± 20.4) $\%HR_{max}$ and mean maximum HR was 84.8 (± 10.3) $\%HR_{max}$.

Table 10: A table showing the mean data of two seasons of second day recovery days.

	Second Day Recovery Data	
Variable	*M*	*SD*
Duration (min)	40.0	8.6
Distance (m)	1500.5	498.2
Distance per minute ($m.min^{-1}$)	38.3	12.1
Walking/Jogging Distance (m)	1361.5	449.3
Low/Medium-Intensity Running Distance (m)	130.6	95.7
High-Intensity Running Distance (m)	8.4	21.2
Maximum Velocity ($km.h^{-1}$)	19.9	3.2
Mean HR ($\%HR_{max}$)	50.5	20.4
Maximum HR ($\%HR_{max}$)	84.8	10.3

4.0 Discussion

4.1 Summary Statement

The present study shows no significant differences in individual physical or technical demands between the disadvantaged teams (team of 3 and 4) and the control group (5 vs 5). In contrast, the team of 6 and 7 had significantly lower TD and distance per minute, walking/jogging distance, mean HR and time in HR zone 4 than the control group. In addition, the team of 7 had significantly lower maximum velocity, low-intensity running distance, medium-intensity running distance, high-intensity running distance, decelerations and mean peak HR compared to the control group. On an individual level, the technical output of each team size was not significantly different. The differential physical demands between unbalanced teams, especially the similarity with of team of 7 within the 3 vs 7 format with the R2 data (see table 6 and 10), allows for different training periodisation targets to be achieved within the same SSG. There is great opportunity for the current second day recovery (R2 or match day +2) sessions to use the 3 vs 7 format to increase technical training, training enjoyment, and coaching from head coaches. The team of 3 and 4 had significantly lower total technical actions and possession than the opposing teams of 7 and 6 respectively (table 8). This disparity is likely related to the increased tactical dominance of the advantaged teams. This dominance is highlighted by both the significantly higher number of goals scored and possession (table 8) of the opposing advantaged teams. More players resulted in an abundance of technical/tactical options in advantaged teams. With greater technical solutions when attacking, the ball could “do the work” to a greater degree in advantaged teams, resulting in a lower physical response. This is because without passing options, soccer players had to physically run with the ball whilst attacking. Decreased possession and likely motivation from disadvantaged teams may have prevented the intensity of the SSGs from raising significantly higher than the control or each other.

4.2 Physical and Technical Demands

The team of 6 and 7 covered significantly lower distance than the non-advantaged teams (the team of 3, 4 and 5) as shown in table 6. In terms of $m.min^{-1}$, the players in the team of 3, 4 and 5 ranged from 101-107 $m.min^{-1}$. These values fall near the medium pitch size (50 x 35 m) in Casamichana and Castellano 2010 study. These researchers found a mean intensity of 113.6 $m.min^{-1}$ during their 5 vs 5 SSGs. With the pitch dimensions having a shorter pitch length (33 m compared to 50 m), it is expected that the intensity would be slightly lower (Casamichana et al., 2018). In the study by Casamichana et al., (2018) the closest pitch size to the one used in the present study was the short-narrow pitch. This pitch had the same pitch width and a shorter pitch length by 7 m (25 x 40 m) and resulted in a similar intensity of 101.2 $m.min^{-1}$. Distance covered per minute with the team of 3, 4 and 5 were not significantly different and matched closely that of similar studies. The significantly lower mean distance covered in the team of 6 and 7 (86.5 and 71.0 $m.min^{-1}$ respectively) is therefore a tangible decrease in intensity, also evidenced by the very large negative effect sizes compared to the control. Having more players on a team means that there are more passing options. Whilst in possession, this may allow the ball to cover distance, therefore demanding less movement from the players, resulting in a lower distance covered by each player. Allowing the ball to cover more distance reduces the intensity which is useful for players in a recovery phase of their weekly periodisation cycle opposed to an acquisition phase. A style of play with greater passing and less running also more closely resembles "Scottish style" soccer and may be superior for skill development.

Distance covered per unit time ($m.min^{-1}$) is a metric that globally quantifies external load. Each player, however, has a different subjective experience of this covered distance. This is due to differences in physiology and actions such as technical skills, HIR, accelerations/decelerations, changing direction etc. Mean HR data is an alternative measure of intensity that accounts for any actions that increase energy expenditure. Interestingly, mean HR follows the same pattern as distance covered (or distance per minute). The team of 6 has a significantly lower mean HR (78.1 $\%HR_{max}$) than the non-advantaged teams (83.2 - 84.6 $\%HR_{max}$) whilst the team of 7 has a significantly lower mean HR (73.3 $\%HR_{max}$) than all teams (see table 7). Mean HRs from non-advantaged teams closely resemble that of the short narrow and short wide pitch sizes (83.4 and 84.3 $\%HR_{max}$ respectively) seen by Casamichana et al., (2018). Despite this, these values are lower than that reported for the medium and small SSGs by Casamichana and Castellano in 2010 (88.5 and 86.0 $\%HR_{max}$ respectively). The higher HRs reported in this study may be due to increased thermal stress compared to the cooler Scottish climate. Studies recording similar mean HRs found in the present study (Casamichana et al., 2018; Casamichana and Castellano, 2010) fail to mention that the evidence of significant increases in both aerobic fitness and match performance require a higher mean HR of 90-95 $\%HR_{max}$ (Impellizzeri et al., 2006; Helgerud et al., 2001). Although work and rest periods remained the same, Impellizzeri et al., (2006) used smaller numbers of players (3 vs 3 and 4 vs 4 with GKs), larger pitch dimensions (40 x 50 m), decreased the number of touches (2-3 ball-touches) and possessional games were also used (in addition to games with GKs). These manipulations are all shown to increase SSG intensity (Dellal et al., 2011; Katis and Kellis, 2009; Mallo and Naverro, 2008; Owen et al., 2004).

Soccer training does not always need to develop physiological capacities. In fact, the “tactical periodisation model” used by the present soccer club splits training into “acquisition days” and “recovery days” (Oliveira et al., 2006). Acquisition days are split into strength (MD -4), endurance (MD -3) and speed days (MD -2). Recovery days include reaction/activation (MD -1), off days (MD +1) and recovery sessions (MD +2). Although training can focus on recovery and skill development, the present study was conducted on a higher-load acquisition day. On strength and endurance days, the club targets aerobic adaptations by accumulating several minutes at a high HR (> 85 $\%HR_{max}$). In addition, athletes aim to reach a volume of HIR that mimics that received in matches for the individual player. The rationale being that training athletes at or above the physical demands of matches result in adaptations that allow athletes to safely handle match demands. The control group was the established training strategy for this stage of the training week, meaning that the club already used this 5 vs 5 training format consistently before and between testing weeks. I would suggest moving this SSG format to a MD -2 or alternatively, change the format until the desired intensity (90 – 95 $\%HR_{max}$) is reached.

Due to the lower intensity of play, team size 7 spent significantly more time (over half of the game duration) in HR Zone 2 than other team sizes with a very large effect size (see table 7). Red zone minutes (RZM), or time above 85 $\%HR_{max}$ (HRZ 4 and 5) is an important metric for determining the stimulus of aerobic adaptations (Buchheit and Laursen, 2013.). In HRZ 4, the team of 5 spent significantly greater mean time (54.8 $\%HR_{max}$) than the team of 6 (19.3 $\%HR_{max}$) and 7 (3.3 $\%HR_{max}$) but not from the team of 3 (50.0 $\%HR_{max}$) and 4 (42.8 $\%HR_{max}$). The above findings suggest that the teams of 3, 4 and 5 will likely be similar in their ability to invoke aerobic adaptations and are more effective than the team of 6 and 7. The second measure of internal load was recorded using RPE. Interestingly the highest median RPE was reported in the team of 4 (6.5) which is shown in table 7. Given the lack of significant differences between the team of 3, 4 and 5 in the individual HR, physical technical demands, it was unexpected that the RPE would be the highest for the team of 4. In the 3 vs 7 SSGs, the team of 3 never scored a goal, whereas the team of 4 scored a mean of 2 goals against the team of 7 (see table 8). It is plausible that it was psychologically more stressful to lose a game with a minor disadvantage than with greater disadvantage, resulting in a higher subjective difficulty of the game. Although this potential explanation is speculative, the present author could not find any supporting evidence in the scientific literature.

Although TD is highest in the team of 3, 4 and 5, previous literature shows that the speed in which the distance is covered is important. For example, Mohr et al., (2003) found that HIR in matches is more effective than TD at predicting competitive level. Mean walking/jogging distance was significantly lower in the advantaged teams than the other 3 teams (see table 6). This is expected as the non-advantaged teams covered significantly greater TD, and the distance covered walking/jogging was the greatest proportion of TD for all team sizes. Similarly, Casamichana and Castellano, (2010) found most distance covered in SSGs was below 12.9 km.h^{-1} and this trend was amplified with smaller pitch dimensions. For all running speeds, the team of 7 covered significantly lower distance than the control with large negative effect sizes (see table 6), further confirming the lower physical demands. There is large variation in low-, medium- and high-intensity running distance within teams, evidenced by the large standard deviations. This is likely due to highly variable individual running patters between athletes and the fact that the level of error increases in the GPS units with an increasing speed of movement (Johnston et al., 2014). HIR is monitored closely in soccer in order to expose athletes to the demands of match play and ensure a taper towards matches. The team of 7 has a mean HIR distance of around 10 cm which, physiologically, is not meaningful (see table 6). Therefore athletes can be trained in the team of 7 within the format used in the present study without accumulating significant amounts of HIR.

The team of 7 has a significantly lower mean maximum velocity (17.9 km.h^{-1}) than the disadvantaged teams and control group (20.9 – 21.5 km.h^{-1}) as shown in table 6. The team of 7 has a mean maximum velocity similar to the small pitch size (18.1 km.h^{-1}) used by Casamichana and Castellano, (2010) and the disadvantaged teams are closer to the medium (20.4 km.h^{-1}) and large (23.1 km.h^{-1}) pitch sizes (see table 1). This suggests that increasing the number of players in a SSG relative to the other team has a similar effect on the velocities achieved as using a smaller pitch size. The team of 6 had a mean maximum velocity of 19.4 km.h^{-1} which, although not significantly different, has a medium negative effect size compared to the control. When the advantaged team attacked, the ball could easily be passed around defenders. In contrast, when a disadvantaged team attacked, players more frequently had to physically evade their opposition as their teammates were often marked. When the disadvantage team was defending, however, players had a tendency of clustering around their net as opposed to pressing the opposition. The combination of less pressure from the opposition and more passing options may have led to the decreased maximum velocities measured in the advantaged teams. Table 10 shows both values for team 6 and 7 fall below the mean maximum velocity reached in a R2 session (19.9 km.h^{-1}). This suggests that the advantaged teams could be used for an R2 session without fear of exposing players to higher speeds than is appropriate.

The GPS component of the GPS-accelerometer units measures locomotor variables. Focusing solely on locomotor variables prevents the consideration of important mechanical stimuli. For example, accelerations or decelerations can cause significant neuro- and musculoskeletal strain (Osgnach et al., 2010). Accelerations and decelerations are present in SSGs but not recorded by locomotor variables, especially when there is not enough space to reach higher speeds. Unlike previous studies focussing on HR and/or locomotor variables (Casamichana and Castellano 2010; Katis and Kellis, 2009; Kelly and Drust 2009; Mallo and Navarro 2008; Owen et al., 2004; Hoff et al., 2002), the present study measured the total number of accelerations and decelerations. There were no significant differences in the number of accelerations found between athletes in the present study (see table 6). The team of 3, 4 and 5 have a similar mean number of decelerations (1.4 – 1.7) compared to the team of 6 (1.0) and 7 (0.7). The team of 7 had a significantly lower mean number of decelerations compared to the control group, and a large negative effect size. This suggests that individuals in the team of 7 would be subject to less neuromuscular fatigue than the control. Casamichana et al., (2018) found that shorter pitch length (distance between goals) leads to more accelerations and decelerations. The authors of the aforementioned study suggest that increased player density as the major cause for this trend. Similarly to mean maximum velocity, the trend towards more decelerations in the disadvantage teams may be due to the increased number of opposition to evade and less technical/tactical options due to less supporting team mates. The disadvantaged teams did not have a greater mean number of decelerations compared with the control group. This could be due to the disadvantaged teams having less possession than the opposition, since in possession there is a greater likelihood of performing a large deceleration to evade the opposition.

Much of the differences in physical data, is perhaps explained by the technical/tactical differences. As expected, the disadvantaged teams had significantly lower possession (35 – 37 %) than the advantaged teams (63 – 65 %) and all had large effect sizes compared to the control (see table 8). Despite the above trend, the greater imbalance of the 3 vs 7 format did not amplify the trend, with only 2 % more possession in the advantaged team. This is likely due to the significantly higher number of shots in the team of 7 (12 shots) than the non-advantaged teams (4-7 shots) as shown in table 8. For the disadvantaged teams, possession was difficult to regain directly from the opposition. Because of this, a GKs save, or a rule-related interruption was a likely way for disadvantaged teams to gain possession, increasing their overall possession. The significantly greater number of shots seen by the team of 7, without an increase in goals compared to the team of 6 (see table 8), may have increased the possession of the team of 3. This led to a similar possession and a prevention of an amplification of the trend. Overall the team of 3 had significantly lower technical actions than the team of 5, 6 and 7, with the team of 4 following the same trend. The team of 7 had the highest mean number of shots and interceptions (see table 9) highlighting the dominance of the team of 7 despite less technical actions in other categories. Katis and Kellis, (2009) found that, when using balanced teams, less players resulted in a significantly greater number of short passes, tackle's, shooting dribbling and goals. Our study found that, with unbalanced teams, fewer players shows a trend towards fewer team technical actions which is likely due to having lower possession and fewer technical options. Another study looked at technical actions across different SSG pitch sizes and only found a significantly greater number of tackles and shots with smaller pitch dimensions (Kelly and Drust, 2009). All other technical actions did not significantly differ.

After breaking down technical data per person, statistical significance disappears between teams. Owen et al., (2004) found that increasing the number of players in SSGs increased the total number of technical actions however, when expressing data per person, the lager teams had fewer technical actions. A similar effect was found in our study using unbalanced teams. The decrease number of players likely increased technical actions per person relative to the advantaged teams but not of a high enough magnitude to offset the difference in possession seen. For the disadvantaged teams, lower possession and fewer passing options likely led to less passes per person than the control. Increased passing option for the team of 6 increased the total number of passes (see table 8) however after being split between a greater number of players (expressed per person) there is a trivial difference compared with the control (see table 9). Although there is increased passing by the team of 7 compared with the control, the decreased pressure presented by the opposing team of 3 may mean less passing was required per person. The advantaged teams have decreased physical demands compared to the team of 3, 4 and 5. This is likely linked to the increased number of total passes, allowing the ball to be passed around the opposition, as opposed to a larger physical exertion by the players. Despite this, per person, all team sizes had a very similar technical output. This suggests the team of 6 and 7 can be used to reduce the physical load, or the team of 3 and 4 can be used to practice defensive situations whilst maintaining similar technical stimulus.

The individual physical and technical demands of the team of 3, 4 and 5 do not differ significantly suggesting that the control group and the team of 3 and 4 can be used interchangeably. The 5 vs 5 game format used in the present study are commonly used on a MD -4 or MD -3. The advantaged team, however, have significantly lower physical demands. Table 10 gives the mean demands of specific GPS and HR metrics for a second day recovery (R2) session taken over two seasons. The content of these sessions consist of a warm-up, rondos (a piggy-in-the-middle style passing drill with two people working at a time), followed by some low-intensity running. The aims of this session is to get athletes outside and moving but allow them to be physically and mentally recovered for the following day. This means providing low-level mechanical stimulus, practicing technique whilst avoiding a high HR/speed or any talk of the upcoming game. A 2016 study that quantified training load throughout the weekly periodisation of players in the English Premier League found very similar load values for R2 sessions (Anderson et al., 2016) to what was found in the present study (see table 10). For example, during an R2 session players covered a mean of 1453 m TD and an average of 8 m HIR distance while the present study had a mean of 1500 m TD and 8.4 m HIR distance. Table 8 shows that the mean maximum velocity reached by the team of 6 and 7 (19.4 ± 2.7 and 17.9 ± 2.9 $km.h^{-1}$ respectively) are both lower than the mean maximum velocity reach in an R2 sessions

(19.9 ± 3.2 km^{-1}) and have less variation about the mean. The team of 7 also had a lower mean HR_{max} (84.2 ± 6.3 $\%HR_{max}$) than the mean of the R2 group (84.8 ± 10.3 $\%HR_{max}$) with less variation about the mean. The team of 6 had a higher mean maximum HR of 89.7 ± 4.6 $\%HR_{max}$ then that measured in the R2 session which was significantly higher than the team of 7 (see table 7). This potentially makes the 6 vs 4 format less suitable for use in a R2 session than 7 vs 3. The mean HR for the team of 6 and 7 were 78.1 ± 3.4 and 73.3 ± 4.2 $\%HR_{max}$ respectively (see table 7). These means were significantly lower than all other team sizes with very large negative effect sizes compared to the control, following the same pattern as distance per minute (table 6). The mean R2 HR was 50.5 $\%HR_{max}$ however this had a large amount of variation with a *SD* of 20.4 % (see table 10).

Two important questions arise from the physical data, (1) why do advantaged teams have a significantly lower intensity than the other teams and (2) why do the disadvantaged team not have a significantly higher intensity than the control group? The greater number of supporting players allows the advantaged teams to split the demands among more athletes and also provides various technical/tactical solutions to moving the ball around the playing area. Together, this allows for decreased physical demands. Interestingly, the reverse of this finding is not true. In a disadvantaged team, athletes had highly similar physical demands to the control group. I hypothesise that, whilst in possession, disadvantaged teams had greater physical demands as outlined by smaller team sizes in balanced SSGs (Katis and Kellis, 2009; Owen et al., 2004). This is because of the increased pressure placed by the opposition and battling towards the net is likely more arduous than defending the goal. Despite this, for disadvantaged teams, there is a trade-off between the increased demands of possession and the lower percentage of overall possession (see table 8). Therefore the lower possession measured in the present study is likely the chief reason why the demands of the disadvantaged teams were not greater than the control group. But why does the team of 3 not have greater demands than the team of 4 if they have a similar possession? Two reasons could contribute. Firstly, there could be lower physical demands of defending. With less players, there is less available players to press attacking players as they sink back into a more passive defensive position to try and block the path to goal. Secondly, the greater imbalance may lead to lower motivation for the team of 3. This is supported by the higher median RPE (see table 7) found for the team of 4 (6.5) than the team of 3 (5.5) suggesting a higher effort. Players could have felt that because they were unlikely to win, they found it more difficult to work harder.

4.3 Practical Applications

On an individual basis, in all physical and technical metrics measures used there was not a single case of significant difference between the team of 3, 4 and 5. This means that unbalancing the teams likely has a limited difference in the training stimulus for the disadvantaged team compared to a regular 5 vs 5 training format. The physical training stimulus for the advantaged teams, however, were often significantly lower than the other game formats. With elite soccer players playing up to 3 games per week during the competitive season, they have many recovery sessions in order to aid recovery from the busy match schedule (Anderson et al., 2016). In contrast some players do not get any game time whilst others may play partial games. This results in many different athletes requiring a different training stimulus on the same day. This also occurs when reserve team or academy athletes move up a competitive level to make training numbers up who are usually in a different phase of their periodisation. With athletes requiring a different training stimulus, one of two things usually happens. (1) Athletes complete the same session and obtain a suboptimal stimulus or (2) the training group is split into separate groups for the whole training session. Realistically, option 1 occurs when younger athletes move up an age group and number 2 takes place within the same squad. The results of this study show that athletes who have played a high number of match minutes can play unbalanced SSGs (in the advantaged team) as drills within the R2 session in place of low-intensity running. This can be completed while simultaneously giving the disadvantaged team a highly similar physical and technical stimulus to a balanced SSG they would ordinarily perform in a separate training group. This not only has the benefit of improving team cohesion and a more equal distribution of attention from management, but also allows more time to practice technical skill and is likely more enjoyable than generic training.

Although mean R2 session HR is much lower than that measured in the present study, it is important to point out that very little time is spent around 50 % HR_{max}. Instead, the HR is higher during drills or lower during the time between the drills or playing rondos. The present study measured HR exclusively during work periods of SSGs (i.e. did not include rest period HRs) which explains the higher HRs found. It is more illuminating, therefore, to focus on absolute values rather than mean values of intensity. Based on the mean data obtained from this study, completing 3 x 4 minute of SSGs in a 3 vs 7 format would result in a distinct physical profile. TD 1283 vs 853 m, low/medium-intensity running 141 vs 71 m, HIR 23 vs 0 m and RZM 6.0 vs 0.4 minutes for 3 vs 7 respectively. Based on mean R2 data presented in table 10 and mean training values from Anderson et al., 2016 study, 3 x 4 minutes in the team of 7 would result in a physical stimulus that fits into the goals of the session. Instead of including low-intensity runs across the pitch, R2 players can play as part of a 3 vs 7. An example session would could include a 10 minute warm-up, 15 minutes unbalanced games (3 x 4 min work periods plus 2 x 1.5 minute rest periods between) followed by 15 minutes of rondos (40 minutes total session time). The disadvantaged team would split off from the R2 session after the games and complete the rest of their session. Depending on the intensity of the warm-up, this would comprise around the same physical stimulus of an average R2 session for the advantaged team and comprise a good aerobic training stimulus for the disadvantaged team, as evidenced by the number of RZM (Buchheit and Laursen, 2013).

In soccer, it is common for soccer player of younger age groups to be promoted (often at short notice) to a higher age group. This benefits the older/higher-level soccer players as they achieve the required training numbers for a given training session and benefits the younger soccer players as they get to practice with higher-level soccer players. The problem with this common occurrence is that different age groups have a different game schedule and therefore different periodisation targets on any given day. For the lower-level team, this can lead to missed matches if they have a demanding session 1 or 2 days before a match. Alternatively, this can lead to an insufficient intensity of training if they are 3 or 4 days before a match and the higher-level team is 1 or 2 days away from a match. Individual missed matches or insufficient training intensities will likely have little difference. Over a season however, could have significant detrimental effects on long-term athletic development. Using imbalanced teams like the ones laid out in the present study can help overcome this limitation by giving athletes a different physiological stimulus that aligns closer to their current periodisation targets.

The final application of using the unbalanced SSGs in the present study is to achieve technical/tactical training aims. In a game of soccer, there are many occasions where players are outnumbered in smaller areas of the pitch. Soccer coaches looking to work on the defensive ability of players when they are outnumbered by opposition attacking players can use the unbalanced drills. This study found that the disadvantaged teams had significantly less time in possession of the ball (35 – 37 %) than the advantaged teams (63-65 %) as seen in table 8. This means that the disadvantaged team will spend significantly more time defending, and in this case defending against more opposition players. Similarly, if coaches want to work more on shooting, we know that the team of 7 in the 3 vs 7 format had significantly more shots than the opposing team of 6 (see table 8). Manipulating technical/tactical outcomes using variations of SSGs may have more specificity and therefore transfer compared to more traditional reductionist drills e.g. shooting drills. Mimicking the dynamic performance of match play within soccer drills likely has more transfer (Davids et al., 2013). This is because it involves constantly changing perceptual information for the athletes to practice making decisions and couple tactically effective action within a given scenario. Overall, the findings of the present study provide tremendous value in optimising individual squad training strategies and, in my opinion, could improve the long-term athletic development of lower-level athletes attempting to build a career in professional soccer.

4.4 Strengths and Weaknesses

4.4.1 Strengths

The mean age of participants used in this study was 19.1 (± 1.1) years and formed the reserve team. This age group is older than those used in most SSG studies and therefore more closely replicates the performance of elite first team squad. As the implications of this study provides a useful training tool for R2 sessions (see section 4.4), the busier game schedule of first team squads means there is more R2 sessions and therefore greater application in a first team environment. It is important to note that although it replicates elite first team soccer more effectively than other studies, it is not a perfect replication as most reserve team members do not perform well enough to play with the first team consistently. In addition the reserve team are shorter, younger and have a lower body mass on average. This study reduced unnecessary variation using a variety of methods. The present study used a relatively large sample size (n = 20) and collected significant amounts of data for analysis (118 individual data sets) over a moderate time range (October to February) during in-season of the 2019/2020 season. A longer time range may increase variability however in return is more representative of a fuller season. This study used a 4 month familiarisation phase to allow participants to get used to wearing GPS units and HR belts. Month 1 of this phase was preseason and months 2 - 4 were in-season training and game schedule. This allowed a significant amount of time for the study participants to adapt to “in-season” condition before the commencement of the study took place. Testing days were conducted on the same day relative to the next upcoming match (MD -4). This is important as the club has a distinct periodisation strategy for each day of the week. The study was conducted at the same time of day (12:00 – 12:30 pm) to minimise the impact of their circadian rhythm. Testing took place at the end of the MD -4 training session so that athletes had a similar level of fatigue for each data collection day. A single SSG format (e.g. 4 vs 6) took place each day to eliminate unnecessary variation through the order effect. Finally, all participants were assigned their own GPS units to eliminate any inter-unit variability (Johnston, et al., 2014). The rules of the present study were designed to be practical to the SSG format. The number of touches was unlimited as the unbalance was greater for the disadvantage team when less touches were allowed. Similarly, the offside rule was included in the present study. Again, this rule allowed the disadvantaged teams a greater chance of winning the game.

4.4.2 Weaknesses

Although the study took place at a consistent time and position within the session (at the end), the differing contents of the session likely added variability. The club has a highly consistent periodisation strategy in terms of physical demands, however there is meaningful variation between individual training sessions of the same type (e.g. MD -4). This results in a differing level of fatigue and therefore performance in the study. To improve this protocol, the study could have been completed immediately following a standardised warm-up. Another weakness of this study is that the teams were chosen using the subjective appraisal of the head coach to keep the SSGs more competitive. Soccer performance cannot be completely quantified. Other researchers have tried to remove this bias from the studies by quantifying performance using multiple metrics and ranking players across multiple dimensions (Casamichana and Castellano, 2010). This method may be superior, but as performance is not just separate qualities (physical capacities, technical skill or tactical ability) but an amalgamation of factors in a given performance context (Bradley and Ade 2018), its reliability might be questioned. As research progresses, so will the ability to quantify performance and therefore remove bias more effectively.

4.5 Future Research

This study provides good evidence for the differential physical and technical responses between teams in unbalanced SSGs and the application of this evidence for a given training week. Further research should look to quantify tactical differences between teams. Tactical differences shape the physical and technical demands but in practice, tactical demands can be difficult to quantify. A high quality study including tactical analysis was completed by Ade, Fitzpatrick and Bradley in 2016. This study quantified all physical, technical and tactical data of a team within the English Premier League during all high-intensity actions (defined as over 1 s < 21 km^{-1}). The data was broken down in and out of possession, pre/post & during a high-intensity efforts, player position, location on the pitch (the length and width was split into thirds) and various tactical outcomes (Ade, Fitzpatrick and Bradley, 2016). This analysis was conducted on a match play using sophisticated multi-camera technology (Prozone). Despite this, similar analysis can be conducted on SSGs using GPS units and a camera. Player position would be removed in SSGs as fewer players prevent classical positional roles from emerging. Player location could be tracked using flat markers to divide the pitch up and tactical information can be collected using video analysis. This research will help improve our understanding of what happens during unbalanced SSGs.

Further research should also investigate whether increasing the pitch area (particularly pitch length) increases the intensity to that seen by other studies (Casamichana et al., 2018) and what effect this has on unbalanced teams. I hypothesise that increasing pitch length would have a greater impact on the disadvantaged team than the advantaged team. This may allow a greater contrast in physical and technical stimulus between teams. Researchers should investigate different demands of different combination of team sizes. This study used 10 players, using more players would allow a less drastic change in the ratio of team imbalance. Finally, in future, research should look at unbalancing teams in possessional games. Possessional SSGs have no GKs and no goals. The teams are usually scored by whichever team accumulates the most passes. We know that removing goal keepers and scoring SSGs by the number of successful passes has been shown to increase the intensity (Mallo and Navarro, 2008). Before COVID-19 brought the present study to a halt, data was gathered on possessional games and we had preliminary data to show the opposite physical response (greater intensity for the advantaged team). Identifying another distinct physical response has further implications for managing overtraining and optimising training within soccer teams.

5.0 Conclusion

In the 1980's/90's, high aerobic capacities were found to be correlated with the position of elite soccer teams within their league (Wisloeff et al., 1998; Apor, 1988). An intervention study then provided strong evidence that improving $\dot{V}O_{2max}$ also improves physical output and performance in matches (Helgerud et al., 2001). Since SSGs were found to be, in some cases, just as effective at improving $\dot{V}O_{2max}$ as generic training (Impellizzeri et al., 2006), a great deal of SSG research has since been conducted. This research has looked at various ways to manipulate the training stimulus by changing the parameters of the game (e.g. with and without GKs, number of touches per possession, pitch dimensions, player number, rule alterations etc.). To the knowledge of the present author, no one has conducted empirical research on the effects of unbalancing teams in SSGs. The summary of the findings of the present study is that unbalancing the team size in SSGs significantly lowers the physical demands of the advantaged teams across many GPS and HR metrics. Interestingly, the disadvantaged teams did not have significantly greater physical demands than the control group. This pattern is expected to be caused by a trade-off between the likely increased demands in the disadvantaged team whilst in possession (attacking), and the lower possession and motivation of the disadvantaged teams. Significant differences in the individual technical demands were not found in the present study however there was useful significant differences in team technical actions and possession. The significantly different physical demands between unbalanced teams has great application in the world of soccer. With many athletes playing a different number of minutes during games (0 – 90 minutes) and athletes being pulled up from the reserve team and academy teams, athletes often require a different physical stimulus to meet their periodisation strategy during a training session. The results in this study show that using unbalanced SSGs can provide a physical stimulus that fits into a typical R2 session for the advantaged team whilst the disadvantaged team acquires a physical stimulus that does not significantly differ from a typical SSG on a MD -4 or MD -3, designed to elicit physiological adaptations. The different physical demands of unbalanced teams can allow younger soccer players to receive a more suitable physical stimulus relative to their next match. Implementing unbalanced SSGs can potentially distribute the attention of the head coaches and manager more equitably across the squad, allow a greater volume of technical practice within a given week, and improve training enjoyment, motivation and team cohesion. Unbalanced SSGs can also selectively reduce overtraining for select athletes and provide tactical/technical overload for certain players. Thus, the present study has discovered another tool in the arsenal of coaches and applied scientists working in elite soccer.

6.0 References

Ade, J., Fitzpatrick, J. and Bradley, P.S., 2016. High-intensity efforts in elite soccer matches and associated movement patterns, technical skills and tactical actions. Information for position-specific training drills. *Journal of sports sciences*, *34*(24), pp.2205-2214.

Anderson, L., Orme, P., Di Michele, R., Close, G.L., Morgans, R., Drust, B. and Morton, J.P., 2016. Quantification of training load during one-, two-and three-game week schedules in professional soccer players from the English Premier League: implications for carbohydrate periodisation. *Journal of sports sciences*, *34*(13), pp.1250-1259.

Apor, P. Successful formulae for fitness training. In:*Science and Football*, T. Reilly, A. Less, K. Davids, and W. J. Murphy (Eds.). London: E. & F.N. Spon, 1988, pp. 95-107.

Bangsbo, J., Mohr, M. and Krustrup, P., 2006. Physical and metabolic demands of training and match-play in the elite football player. *Journal of sports sciences*, *24*(07), pp.665-674.

Batterham, A.M. and Hopkins, W.G., 2006. Making meaningful inferences about magnitudes. *International journal of sports physiology and performance*, *1*(1), pp.50-57.

Bradley, P.S. and Ade, J.D., 2018. Are current physical match performance metrics in elite soccer fit for purpose or is the adoption of an integrated approach needed? *International journal of sports physiology and performance*, *13*(5), pp.656-664.

Buchheit, M. and Laursen, P.B., 2013. High-intensity interval training, solutions to the programming puzzle. *Sports medicine*, *43*(5), pp.313-338.

Casamichana, D. and Castellano, J., 2010. Time–motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: Effects of pitch size. *Journal of sports sciences*, *28*(14), pp.1615-1623.

Casamichana, D., Bradley, P.S. and Castellano, J., 2018. Influence of the varied pitch shape on soccer players physiological responses and time-motion characteristics during small-sided games. *Journal of human kinetics*, *64*, p.171.

Castellano, J., Blanco-Villaseñor, A. and Alvarez, D., 2011. Contextual variables and time-motion analysis in soccer. *International journal of sports medicine*, *32*(06), pp.415-421.

Davids, K., Araújo, D., Correia, V. and Vilar, L., 2013. How small-sided and conditioned games enhance acquisition of movement and decision-making skills. *Exercise and sport sciences reviews*, *41*(3), pp.154-161.

Dellal, A., Hill-Haas, S., Lago-Penas, C. and Chamari, K., 2011. Small-sided games in soccer: amateur vs. professional players' physiological responses, physical, and technical activities. *The Journal of Strength & Conditioning Research*, *25*(9), pp.2371-2381.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P. and Drust, B., 2009. Analysis of high intensity activity in Premier League soccer. *International journal of sports medicine*, *30*(03), pp.205-212.

Helgerud, J., Engen, L.C., Wisloeff, U. and Hoff, J., 2001. Aerobic endurance training improves soccer performance. *Medicine & Science in Sports & Exercise*, *33*(11), pp.1925-1931.

Hoff, J. and Helgerud, J., 2004. Endurance and strength training for soccer players. *Sports medicine*, *34*(3), pp.165-180.

Hoff, J., Wisloeff, U., Engen, L.C., Kemi, O.J. and Helgerud, J., 2002. Soccer specific aerobic endurance training. *British journal of sports medicine*, *36*(3), pp.218-221.

Impellizzeri, F.M., Marcora, S.M., Castagna, C., Reilly, T., Sassi, A., Iaia, F.M. and Rampinini, E., 2006. Physiological and performance effects of generic versus specific aerobic training in soccer players. *International journal of sports medicine*, *27*(06), pp.483-492.

Johnston, R.J., Watsford, M.L., Kelly, S.J., Pine, M.J. and Spurrs, R.W., 2014. Validity and interunit reliability of 10 Hz and 15 Hz GPS units for assessing athlete movement demands. *The Journal of Strength & Conditioning Research*, *28*(6), pp.1649-1655.

Katis, A. and Kellis, E., 2009. Effects of small-sided games on physical conditioning and performance in young soccer players. *Journal of sports science & medicine*, *8*(3), p.374.

Kelly, D.M. and Drust, B., 2009. The effect of pitch dimensions on heart rate responses and technical demands of small-sided soccer games in elite players. *Journal of Science and Medicine in Sport*, *12*(4), pp.475-479.

Laursen, P. and Buchheit, M., 2019. *Science and application of high-intensity interval training*. Human kinetics.

Little, T., 2009. Optimizing the use of soccer drills for physiological development. *Strength & Conditioning Journal*, *31*(3), pp.67-74.

Mallo, J. and Navarro, E., 2008. Physical load imposed on soccer players during small-sided training games. *Journal of sports medicine and physical fitness*, *48*(2), p.166.

Mohr, M., Krustrup, P. and Bangsbo, J., 2003. Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of sports sciences*, *21*(7), pp.519-528.

Oliveira, B., Amieiro, N., Resende, N. and Barreto, R., 2006. Mourinho: Porquê tantas vitórias. *Lisboa: Gradiva*.

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R. and Di Prampero, P.E., 2010. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc*, *42*(1), pp.170-178.

Owen, A., Twist, C. and Ford, P., 2004. Small-sided games: the physiological and technical effect of altering pitch size and player numbers. *Insight*, *7*(2), pp.50-53.

Pinder, R.A., Davids, K., Renshaw, I. and Araújo, D., 2011. Representative learning design and functionality of research and practice in sport. *Journal of Sport and Exercise Psychology*, *33*(1), pp.146-155.

Reilly, T. and Gilbourne, D., 2003. Science and football: a review of applied research in the football codes. *Journal of sports sciences*, *21*(9), pp.693-705.

Reilly, T., 1997. Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *Journal of sports sciences*, *15*(3), pp.257-263.

Reilly, T., 2005. An ergonomics model of the soccer training process. *Journal of sports sciences*, *23*(6), pp.561-572.

Reilly, T., Morris, T. and Whyte, G., 2009. The specificity of training prescription and physiological assessment: A review. *Journal of sports sciences*, *27*(6), pp.575-589.

Smaros, G., 1980. Energy usage during a football match. In *Proceedings of the 1st International Congress on Sports Medicine Applied to Football* (Vol. 11, pp. 795-801). Rome: D. Guanello.

Strudwick, T. and Reilly, T., 2001. Work-rate profiles of elite Premier League football players. *Insight*, *2*(2), pp.28-29.

Wisloeff, U.L.R.I.K., Helgerud, J.A.N. and Hoff, J.A.N., 1998. Strength and endurance of elite soccer players. *Medicine & science in sports & exercise*, *30*(3), pp.462-467.