Comparison of physiological variables in elite youth and recreational soccer players and an age matched control group

Andrew Murray

September 2005

The following was submitted in fulfillment of the requirements of the MSc degree at the University of Glasgow.

UNIVERSITY
of
GLASGOW

1.0 Abstract

Scotland is currently ranked 88th in the world for soccer. It has also been dubbed the 'sick man of Europe' with life expectancies less than former communist states and low levels of physical activity that may contribute to the declining attainment levels in Scottish soccer. Current soccer literature has a gap concerning the physiological characteristics of today's elite youth soccer players in comparison with recreational athletes and sedentary individuals. An analysis of the differences between sedentary, recreational and elite sporting individuals may establish if there is an additional health or physiological benefit of being an elite athlete compared to simply a recreational one.

The aim of this project was to compare a range of physiological variables in male, elite {E} and recreational soccer players {R} and non-soccer players {NON-S} aged 16 years and to try and establish a test battery that would give baseline values for a Scottish population. Following institutional ethics approval, 20 elite soccer players (16.6±0.3 years, 176.2±5.3 cm, 67.5±6.5 kg, 12.2±4.8 %BF), 21 recreational soccer players (16.5±0.4 years, 172.6±5.7 cm, 64.3±7.3 kg, 18±4.8 %BF) and 13 non-soccer playing (16.3±0.4 years, 173.7±7.4 cm, 67±13.3 kg, 20.5±6.7 %BF) individuals were recruited. All subjects provided signed assent along with signed parental consent.

Over a two-day assessment period (separated by 7 days) all subjects completed an identical test protocol. On day one, physical activity levels were determined via questionnaire before height and body mass were measured. Skinfold measurements were used to estimate % body fat (BF). Sprint speed over 10 and 20 m was measured, with the fastest of 3 sprints taken as a representative score for

each subject. A sit-and-reach test was used to measure subject flexibility (best of 3 trials). Balance and ankle strength (dorsal/plantar flexion) were assessed before a treadmill determination of $\dot{V}O_{2\,peak}$ completed testing for day one. Day two consisted of isokinetic strength assessment of the hamstrings and quadriceps muscles of both legs at 30 °/s and 180 ° /s in concentric and eccentric actions. Following appropriate checks on underlying assumptions, a fully repeated-measures factorial analyses of variance (ANOVA) was used to determine if there were any differences between groups. Significance level was set at $P \leq 0.05$.

Significant differences were detected in % BF, $\dot{V}O_{2\,peak}$ and sprint times ($P <$ 0.0005) and flexibility ($P = 0.001$). The elite players had higher scores than the non-soccer players for $\dot{V}O_{2\,peak}$ {E} 50.1±4 ml.kg^{-1}.min^{-1} {R} 48.3±5 ml.kg^{-1}.min^{-1} and {NON-S} 39.4±4 ml.kg^{-1}.min^{-1} ($P < 0.0005$). For sprint speed all 3 populations were significantly different for 10 m split times {E} 1.44±0.05 s (over 10 m), 1.28±0.04 s (over 2nd 10 m of 20) {R} 1.61±0.16 s, 1.33±0.06 s and {NON-S} 1.87±0.11s, 1.44±0.11. The elite players were significantly more flexible than the other 2 populations {E} 36.8±8.3 cm {R} 27.4±8.9 cm and {NON-S} 25.5±9 cm ($P = 0.001$). Concentric quadriceps peak torque was, on average, greatest for the elite players, {E} 184.6±36.8 Nm {R} 166.2±28.9 Nm {NON-S} 148.3±42.9 Nm, ($P < 0.02$). There were no significant differences between groups for age, height, body mass or total physical activity.

The results show that elite youth soccer players have higher $\dot{V}O_{2\,peak}$, sprint speed, concentric quadriceps peak torque and lower % BF on average than non-soccer players. Recreational soccer players had, on average, a higher $\dot{V}O_{2\,peak}$ and shorter sprint times than the non-soccer players. The differences between elite and recreational players are not as wide as might be expected. Comparison with elite youth soccer players in other countries shows that Scottish youth players have lower scores for $\dot{V}O_{2peak}$. The lower aerobic fitness scores for the non-soccer players suggest that increased activity levels will promote enhanced fitness levels in this population.

Contents

List of figures

List of tables

2.0 Introduction

2.1 Soccer in Scotland

Soccer in Scotland has held a place in people's hearts since its inception in the 1100s. Popularity has previously reached such heights that Parliament decreed; *"That na man play at the Fute-ball"* (James I, 1424).

Today soccer is the world's major sport, played in every nation without exception (Reilly & Williams, 2003) with 120 million competitive players (Ekblom, 1986) and billions of spectators around the world (an estimated 1.5 billion watched the 2002 World Cup final between Germany and Brazil), though recent statistics rank it as only the 4th top 'ball' game in the UK based on adult participation behind snooker/pool (17%), tenpin bowling (15%) and golf (12%), (National Statistics, 2004). It originated in Britain with the first recorded game of 'soccer' occurring between London schoolboys on Shrove Tuesday in 1175 though there is scientific evidence of an exercise of controlling a ball with the feet, dating back to 2500 B.C. in China.

Throughout the middle ages 'soccer' courted controversy as it was more renowned for violence and the defiance of traditional religious values when it was played on a Sunday. There were efforts to ban the game such as that of James I, though these where largely ignored. The popularity of the game waned in the working classes, though it thrived within the public school system as a vehicle to instil discipline throughout the 19th century. Football clubs began to appear in Britain in the 1850s formed largely by public school graduates such as the Edinburgh Academicals team founded in 1857. Many other teams were founded around the church; such as Glasgow Celtic founded by Brother Walfrid of the city's Marist Order in 1888.

'International' matches began in 1872 with a nil-nil draw between 'Scotland' and England. The team England played was not truly Scotland but actually the oldest Scottish club team, Queen's Park. The Scottish FA did not even exist at this point and was not founded for another three months. The popularity of the game though quickly spread and continued throughout World War One. Even though the Second Division had to be disbanded and many First Division sides struggled to field a full team as players signed up for the army. The entire Heart of Midlothian team signed up on the same day.

Between the wars the game flourished again. In 1937, 149,415 spectators watched Scotland play England at Hampden - a record for an international in Europe. A week later 147,365 people turned up to see the Scottish Cup final. After a decline during the Second World War there was again an increase in the interest in football in the post-war years; in the late 1940s and 50s Glasgow Rangers played before an aggregate of over one million people a season on several occasions. In 1952, 136,000 supporters watched the Scottish Cup Final.

Scotland continued to play on the international stage and qualified for the 1954 World Cup in Switzerland. The Scottish Football Association had a narrow-minded and out-dated approach to the competition, travelling with only 13 players, and displaying a complete lack of tactical awareness. They first lost to Austria and were then trounced 7-0 by Uruguay (Scottish Football Association

Museum). Since then Scotland's fortunes have barely improved; World Cup qualification eluded the team from 1958 until 1974, though games against England were regarded as the nation's 'world cup'. None more so when Scotland were crowned unofficial 'world champions' after beating world cup holders England 3-2 in 1967. The same year that Celtic became the first British club to win the European Cup beating Inter Milan 2-1.

Scotland still regards the greatest victories as those against the 'Auld Enemy'. Too often as a nation Scotland has flattered to deceive at many major championships, underachieving on the biggest stage. Under the stewardship of Willie Ormond, Ally McLeod, Jock Stein, Andy Roxburgh, Craig Brown and Berti Vogts, Scotland has suffered, mainly due to over optimism and heightened public opinion with each new qualifying campaign. The Scottish football team seems deemed to play the role of perennial 'bridesmaid' and never progress past the first round of a major championship.

There is an argument that Scotland should regard success merely as qualification[1] for a major tournament. Based on the size of the nation and the resources available to it, though this seems a defeatist attitude as nations with similar sizes and resources[2] flourish and surely we should strive for the pinnacle of a competition.

'If we strive for perfection we can achieve excellence'

- Vince Lombardi (1913-1970)

[1] Denmark won the European Championships in 1992 from a similar population base and are currently rated 19th in the world.
[2] Norway are currently rated 36th in the world and the Republic of Ireland 14th – 52 and 74 places above Scotland respectively – both countries having similar populations of ~5 million.

Currently the nation is undergoing a period of transition but there does not seem to be the succession of home-grown talent that there once was. Parental lineages are now researched for grandmothers and grandfathers tying mediocre talents, overlooked by other nations to Scotland. Why is this dearth of talent apparent? What happened to the days when Scotland beat the world champions on their own patch? How does Scotland compare to other nations today?

2.2 Science and soccer

Traditionally the football codes were viewed as unsuitable for scientific investigation and within soccer itself the scientist was likely to be greeted 'at worst with suspicion and hostility and at best with muted scepticism' (Reilly, 1979). While South American and Eastern European teams have utilized psychologists, nutritionists and physiologists since the 70s, it was not until the 1980s that coaches and trainers within the football industry in this country became more open to scientific approaches of preparing for competition.

Historically the problems were methodological and concerned with the time needed to construct and conduct scientific research properly, though today the approach is becoming more common at club level with sport science input at most top English Premiership clubs and throughout Europe's premier leagues. As ever Scotland seems a little behind as managers, usually ex-players, continue to coach as they were coached, believing 'the old school' to be the best way (Adams, 2003). Unfortunately in terms of physiology, nutrition and psychology this is rarely the case and a fresh approach is needed. Encouragingly this is starting to happen with more clubs and countries employing dedicated fitness coaches (Carminati, 2004), some managers even believing that fitness transcends everything that is done at the football club, meaning there is no longer a place for the traditional fitness coach (Lourenco, 2004) and believing the input of science to be important to success on the pitch, in all areas from fitness (Smith, 2004) to tactics in penalty shoot outs (Bray & Kerwin, 2004).

Research in the area of physiological fitness has grown in recent times with the discovery that fitter teams win more often, as reflected in a rank correlation between final league position and fitness in Hungary (Apor, 1988), and the differences between the top and bottom teams in the Norwegian league championship (Wisloff *et al.*, 1998). While the two teams (Rosenborg & Strindheim F.C.) were at opposite ends of the table in terms of points, they where also at opposite ends of the spectrum in terms of endurance, strength and performance. An increased fitness results in an increased involvement with the ball and therefore opportunities to influence the match (Helgerud *et al.*, 2001). Though it should be considered that fitness alone is not a pre-requisite for success and generally there are heterogeneous fitness levels between average and exceptional players (Reilly *et al.*, 2000a). Despite this if two teams of similar skill levels meet, the team with the higher aerobic fitness will probably have an advantage. By assessing the current level of fitness scientifically at youth level in Scotland, talent identification programmes can be assisted and assessments made between Scottish elite soccer players and other European nations and against non-elite youths in the same country.

2.3 Current Practice

In England all Premier League Clubs and 96% of Football League clubs who responded to Erith (2004) used some form of fitness testing. No formal data are available on the use of fitness testing in Scottish clubs though thankfully the numbers are on the increase. English clubs have between 1 and 6 test periods per season but only 7% used laboratory-based tests and only 85% tested during the pre-season period. Surely though this period would be the most pertinent time to test and should see a 100% rate of testing. Tests of fitness performance in soccer generally adopt a functional basis, reflected by the low proportion of laboratory tests reported by Erith (2004). This trend also shows that costs are kept down in today's financially restricted times but consequently so is the time dedicated to testing fitness. This may be due to commitments to other areas, such as skill acquisition or tactical awareness but the development of fitness cannot conceivably begin without its assessment and a paradigm shift may be necessary by many connected with soccer to allow this.

2.4 Soccer Performance

Performance in soccer is determined by the players' technical, tactical, physiological and psychological characteristics. These elements are closely linked to each other e.g. the technical capacity of a player may not be fully utilized if the physiological requirements exceed the capability. During a match, players perform different types of exercise ranging from standing still to maximal running and the requirement for intensity to change can happen without warning. As a consequence, soccer's demands are more complex than in many individual sports. These demands are closely related to the players' physical capacity, which can be divided into the following categories (Bangsbo, 1994a):

a) the ability to perform prolonged intermittent exercise (endurance);

b) the ability to exercise at high intensity;

c) the ability to sprint;

d) the ability to develop a high power output in a single match situation such as kicking, jumping and tackling.

When evaluating performance differences, individual technique, tactics and physical resources are all important in a first level analysis. This study aims to look mainly at the physical resources rather than the tactical or technical aspects of performance. While Scotland's footballers have a need for adequate physical resources to keep them at their peak tactically and technically during a game the population at large also has a requirement to keep their physical activity levels elevated.

2.5 Physical Activity

Scotland as a nation lived an active life for centuries – but not any more, Scotland is inactive, unfit and increasingly overweight (Scottish Health Survey, 1998).

> *'During 99% of our existence we were hunters and food gatherers. Now we are exposed to an enormous experiment with no controls'*
>
> *Åstrand (1994)*

Increasingly today's society is automated and machine driven by labour saving devices causing sedentary lifestyles to become more accessible. This style of living may be thought to coincide with a relocation of media use and the dawn of the digital era but the actual amount of 'inactive' time has not increased in children (Biddle *et al.*, 2004). Despite this, sloth causes more problems than gluttony (Prentice & Jebb, 1995). Two-thirds of the Scottish adult population is now at risk from physical inactivity, making it the most common risk factor for coronary heart disease in Scotland today (Scottish Executive, 1998). Perhaps most worryingly, this trend starts early (Reilly *et al.*, 2004) before children even reach the school leaving age. Ten percent of Scottish children are obese when they attend primary school and 20 % obese when they leave (Reilly, 2005). Energy expenditure has decreased in children (Durnin, 1992), they walk and cycle less now (DiGiuiseppi *et al.*, 1997) and according to the 'displacement hypothesis' sedentary pursuits may displace more active alternatives meaning there is less time for physical activity (British Heart Foundation, 2000). No displacement though seems to occur (Biddle *et al.* 2004). This may be as children have reached saturation point for media use, as it shows no changes from the 50s, (Schramm *et al.* 1961), to the present day (Roberts *et al.* 1999). There is even evidence to suggest there is time for sedentary behaviour and activity in young peoples lives (Marshall *et al.* 2002a, b). So if this is true and time is dedicated to both, imagine the benefits if sedentary behaviours were replaced with their active alternatives.

So why is Scotland the 'sick man of Europe'; with the worst health record in the UK and an all cause mortality higher than most of Western Europe and comparable to some former communist states? Deprivation alone cannot account for this 'Scottish effect' (PHIS, 2001) but the average life expectancy of 73 years for men and 78 years for women means that every region apart from Grampian has a mortality rate higher than England and Wales.

An explanation is the fact that a quarter of Scotland's population is sedentary (Scottish Health Survey, 1998) and at best two thirds of men and half of

Scotland's women are not meeting the current recommended levels of physical activity[3]. Inactivity in an American study was proven to be just as risky as smoking and a raised blood pressure (increasing the risk of many chronic diseases, including heart disease, high blood pressure, osteoporosis, diabetes, cancer, anxiety, depression and life expectancy), but the prevalence of inactivity was twice that of smoking and six times that of a high blood pressure (Pate *et al.*, 1995). Translating the same risk for sedentary lifestyles to the Scottish population shows why the inactivity and idleness of a quarter of the population is such a problem. Life expectancy *is* improving in Scotland and many health indices are moving in positive directions, but the improvement is unlikely to progress at a rate that will change the nation's position in comparison to the European Union.

The benefits of tackling this problem of decreased physical activity, (the 'silent killer of our time' (Morris, 2003)), are reduced healthcare costs, via the reduction of chronic disease, and the potential contribution of physical activity to support delivery of major social, economic, environmental and community policies. Increasing physical activity to achieve these benefits is "one of the best buys in public health" (Morris, 1994).

2.6 Scotland's health position

Sedentary behaviours contribute substantially to Scotland's low life expectancies of 73 and 78 years for men and women respectively (Clark *et al.*, 2004). Scotland lags behind most of western Europe in terms of life expectancy and a recent study showed that only 73 % of this life span is spent in good health (defined as free from limiting long term illness) (Clark *et al.* 2004).

[3] Any bodily movement by skeletal muscles that results in energy expenditure (Caspersen et al., 1985)

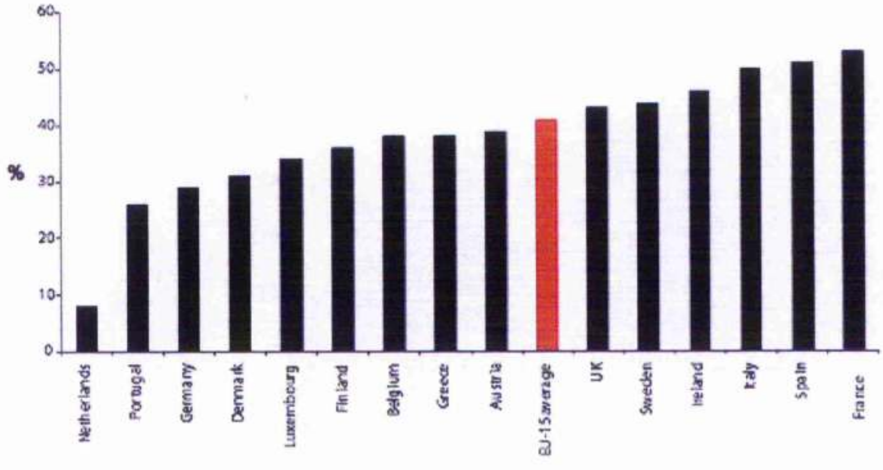


Figure 1: % of adults who do no moderate intensity physical activity in a typical week (2002)

The World Health Organization's MONICA project (Evans *et al.*, 2001), (monitoring trends and determinants of cardiovascular disease) examined the incidence of coronary heart disease in 37 populations in 21 countries. The highest incidence of coronary events, (a definite or likely myocardial infarction), across Europe occurred in Glasgow for both men and women (Evans *et al.*, 2001). This highlights Scotland's poor health position, as while 49 % of deaths in Europe are from cardiovascular disease, the worst single case of these deaths is in Scotland itself.

In Europe as a whole, 3 % of all the problems associated with disease originate from physical inactivity (World Health Report 2002) and around 20 % of coronary heart disease can be attributed to inactivity (defined as less than 2.5 hours a week of moderate exercise or less than 1 hour a week of vigorous exercise). Though these statistics are accepted, only 2 pan-European studies have been completed (IEFS 1999; EEIG 2003) so minimal data are truly available on physical activity across continents (Petersen *et al.*, 2005). What can be said though is that generally the proportion of regular exercisers is low throughout Europe. In 2002 over 40 % of adults in the 15 member states of the European Union (prior to its expansion in 2004), reported no moderate physical activity in a week and 49 % sat for in excess of 4.5 hours a day. The average for the UK as a whole was higher at 5.6 hours a day though no data are available for Scotland alone. Figure 1 shows the UK's position in 2002 for the percentage of adults who completed no physical activity in the previous week – which is sixth worst in Europe and higher than the European average.

This increase in physical inactivity is not heavily reflected in the body mass index (weight / height^2) of Scottish adults in Glasgow aged 35-64 in comparison to other European cities (table 1). This measure is simply an index of weight against height and so may not be representative of the population. It may be the case that the population generally have a high percentage body fat held on a large frame, hiding this measure of obesity.

Table 1:

Body mass index of selected European cities by sex for adults aged 35-64

(Evans *et al.*, 2001)

City	BMI (weight / height^2)					
	25 - < 30 Overweight (%)		>30 Obese (%)		Average BMI	
	Male	Female	Male	Female	Male	Female
Glasgow (1995)	42	36	23	23	26.8	26.9
Belfast (1991/2)	49	30	14	16	26.3	25.6
Glostrup (1991/2)	41	26	13	12	26	24.7
Augsburg (1994/5)	55	33	24	23	27.8	26.8

This though cannot hide the increasing trend for the United Kingdom as a whole to become increasingly overweight (figure 2) which can be attributed to an increase in energy intake, a decrease in energy expenditure or a combination of the two. Physical activity may make a contribution to this and in Scotland it is generally at low levels with 7 % of men and 18 % of women aged 16-24 taking no physical exercise in a week (Scottish Health Survey, 1998) and of children aged 14 to 15, 16 % of males and 39 % of females do less then 30 minutes activity a day. Twenty two percent of boys and 49 % of girls in the same age range spent no days in a week playing sport or exercising, which suggests that this lack of physical activity starts in Scotland at an early age.

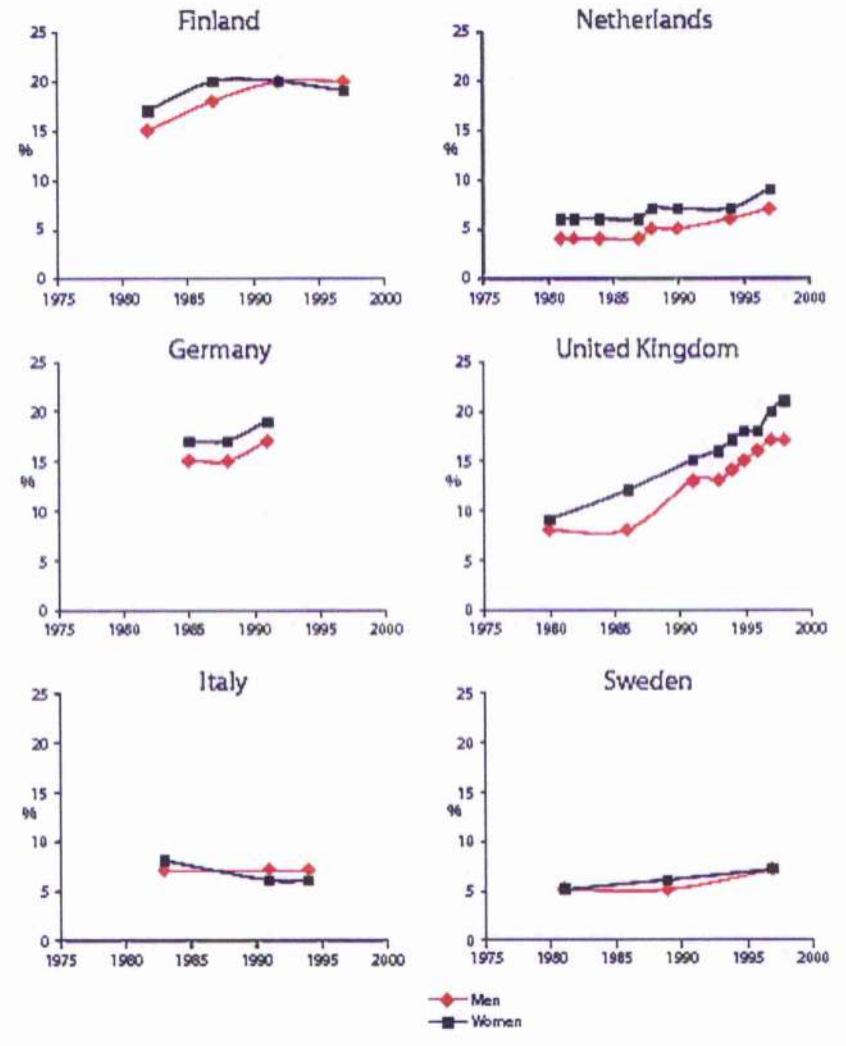


Figure 2: Prevalence of obese adults by sex 1991-1998

2.7 How much physical activity is enough?

So the nation as a whole needs to increase its physical activity and it is common for this to be gained through exercise[4] but physical activity does not need to be strenuous to have significant effects on health, wellbeing and productivity. Reviews have led to two well-accepted health messages:

[4] Exercise: Structured planned and repetitive physical activity (Caspersen et al., 1985).

- The traditional message of 3 sessions of 20 minutes of vigorous activity in a week (ACSM, 1990)

OR

- The active living message of accumulating 30 minutes of moderate[5] physical activity on most days of the week, in a minimum of 10-minute bouts (the 5 x 30 message). (HEBS, 1997)

In 1998 only 34% of the Scottish population were aware of this alternative message (Scottish Health Survey, 1998). Blair *et al.* (1995) showed inactivity to be an independent risk factor for all-cause mortality as individuals with a high fitness level and 3 independent risk factors were actually at less risk than individuals with low fitness and no other risk factors. Lee and Paffenberger's Harvard Alumni study (2000) shows that moderate physical activity actually significantly decreases the risk of all-cause mortality ($P = 0.07$). However the application of these results is limited due to an all male sample group and the high soci-economic status of these subjects.

Currently one third of Scotland's population meet the criteria for active living (Scottish Health Survey, 1998) and they are benefiting from the prevention and treatment of diabetes, depression, osteoporosis and high blood pressure as well as lowering their coronary heart disease risk factors (US Surgeon General, 1996). The major concerns though are the sedentary and low fitness groups, which are the biggest burden to the public health budget. Pate *et al.* (1995) described a dose-response association between activity and its benefits, with the most important change coming with moving from sedentary to moderate exercise rather

[5] 'Moderate physical activity' being the equivalent of brisk walking.

than moderate to high. In America it is estimated that changing the inactive group to moderate exercise could save $77 billion and 250,000 lives per annum. How these groups could be moved is a discussion for elsewhere (Biddle and Mutrie, 2001; Biddle *et al.,* 2004) but two thirds of the population currently are not active enough to meet the alternative 5 x 30 message.

In health terms this is bad, but in terms of footballing success the outlook is similarly bleak. Whilst two thirds of the population are inactive a lower percentage of the population will be active footballers, leaving the nation at a disadvantage internationally (as if the small population was not limit enough!). If not all of the available pool are playing the sport, how can Scotland hope to cease the sliding ranking in the international stakes (88th place in the 2005 FIFA world rankings, behind Burkina Faso, Syria and Togo from 20th in the year 2000).

2.8 Is reduced physical activity reflected by decreased sporting success?

Scotland's sporting performance has declined on an international level over recent years. Is this decline related to falling physical activity levels and the supposed increase in sedentary living? Soccer in particular seems to have suffered from the 'video-game age', though sedentary behaviours are not more prevalent than in the past (Sallis *et al.*, 1992) and there is time for activity and inactive behaviours (Marshall *et al.*, 2002a; Marshall *et al.*, 2002b). Fewer children are playing soccer in today's society and the current soccer literature does not document the physiological characteristics of today's elite youth soccer players in comparison to recreational athletes and sedentary individuals. This is not to say that data on youth footballers are not available from around the world (see table 2), though no one has investigated Scottish players and no one has compared elite individuals with other groups. There is also a need for more data from young players in different areas of the world (Malina, 2003). The establishment of baseline data would allow a meaningful comparison between the equivalent groups and even with subject groups in other countries. This would also allow an analysis of the differences between sedentary and elite sporting individuals and if there is an additional health or physiological benefit by being an elite performer rather than simply a recreational one.

Table 2: Information on youth footballers (mean±SD)

Source	Nationality	Level	N	Age (years)	Height (cm)	Mass (kg)	Body fat (%)	$\dot{V}O_{2\,max}$ ($ml.kg^{-1}.min^{-1}$)
Leatt *et al.* (1987)	Canadian	U-16 National	8	15.4±0.5	171±0.04	62.7±2.8	*	59.0±3.2
Leatt *et al.* (1987)	Canadian	U-18 National	9	16.7±0.5	176±0.04	69.1±3.4	*	57.7±6.8
Bell (1988)	Welsh	*	18	12.3	160± 3.0	38.6± 5.4	*	51.4±7.0
					148± 4.8	37.5± 4.6		55.1±6.4
					148± 3.4	35.3± 2.7		61.1±3.4
					152± 6.8	39.8± 2.8		55.9±4.8
					150± 5.5	37.8± 3.9		56.2±5.8
Jankovic *et al.* (1993)	Croatia	National	*	16.0±0.5	176±0.1	66.2±5.6	*	59.9±6.3
Jones & Helms (1993)	English	Professional	*	15.8±1.1	175±0.1	66.3±7.3	*	60.2±6.0
Tumilty (1993)	Australian	Institute	16	16.1±0.7	178±0.1	71.3±6.7	*	61.4±4.0
Hugg (1994)	Australian	U-17 National	23	*	174±0.1	65.1±6.0	*	55.7±4.2
Di Salvo *et al.* (1998)	Italian	Professional	44	17.8±0.6	181.3±4.4	72.6±4.7	*	*
Franks *et al.* (1999)	English	National U-16	64	*	176±0.1	69.9±6.3	*	59.3±3.8
Rico-Sanz *et al.* (1998)	Puerto Rico	Olympic	8	17.0±2.0	170±6.5	63.4±3.1	7.6±3.1	69.2± *
Rico-Sanz *et al.* (1999)	Swiss	Professional	17	17.5±1.0	177.±5.3	69.4±6.4	*	*
Reilly *et al.* (2000b)	English	Elite & Sub elite	31	16.4± *	171± 0.1	63.1± 1.1	11.3± 2.1	59.0± 1.7
					175± 0.0	66.4± 2.5	13.9± 3.8	55.5± 3.8
Tschopp *et al.* (2003)	Swiss	Junior National	48	15.0±3.0	172± 6.4	62.3± 8.0	*	*
				16.8±0.2	177± 6.0	68.5± 6.2		
				18.9±0.8	179± 3.7	73.9± 6.5		

Legend: anthropometric data compiled from a variety of sources.

Where numerical data is given it is shown as means±standard deviation.

*denotes value not given

3.0 Physiological basis for testing

> *'Football clubs are jealously guarded worlds. Like governments, clubs are interested in good publicity or no publicity at all. They are, therefore, quite suspicious of researchers.........whose interests lie in anything other than straight reports or novelty items' Tomlinson, p120 (1999)*

Fitness profiling for sport is achieved via a battery of tests (Reilly and Doran, 2003), particularly in the case of soccer, as fitness for this sport cannot be determined by a single parameter due to its large ensemble of requirements; from the physical to the psychological via the physiological. Table 3 lists the objectives of a physiological programme of testing and in the case of this study points 2-5 were examined cross-sectionally. If testing was undertaken in a longitudinal manner, points 1, 6, 7 and 8 could also be addressed.

Table 3: Guidelines for laboratory and field-testing of athletic potential and performance (Hawley, 1999).

1. Aid in talent identification
2. Determine the physiological and health status of an athlete
3. Construct a sports-specific profile of an individual athlete or team
4. Provide baseline data for individual training programme prescription
5. Indicate athlete's strengths and weaknesses relevant to his/her sport and/or position.
6. Monitor selected physiological and performance changes in an athlete
7. Provide scientific feedback to coaches to evaluate the efficacy of their training interventions.
8. Act as a motivational tool and educational process so athlete and coach better understand the physiological components of their sport

3.1 Testing continuum in the present study

To evaluate the points outlined, based on previous literature encompassing a range of test batteries (see table 8) and choosing tests within the confines of time available (of school children and elite footballers) and expense, it was decided that the most pertinent measures for a test battery in the present study would be;

1. Height
2. Body Mass
3. Percentage body fat
4. Sprint / Agility tests
5. Flexibility
6. Balance
7. Isokinetic assessment of dominant ankle
8. Isokinetic testing of hamstrings and quadriceps (both legs)
9. Maximal aerobic power ($\dot{V}O_{2\,max}$)

4.0 Aims

The aims of this research study are:

1. To compare the physiological characteristics of three distinct groups (elite soccer players, recreational soccer players and sedentary individuals).
2. To investigate if there is an additional health or physiological benefit of being an elite performer rather than simply a recreational one.
3. To establish a test battery that could be used to gather baseline information on Scottish youth footballers to allow comparisons with similar groups in other countries.

5.0 Methods

5.1 Subjects

Three distinct groups were recruited; these were elite youth soccer players, recreational soccer players and 'sedentary' individuals aged 16-16.9 years. Twenty elite subjects were recruited from Scottish Premier League clubs (all full-time, training 5 days per week); 18 of whom had represented their country at some level and 11 of whom were current internationals at under-17 or under-18 level. Twenty-one recreational players were recruited from 3 Glasgow Secondary Schools. These players played soccer only for their school and no other club and trained formally at most twice per week. Two Glasgow schools provided 13 subjects between them, 11 of whom were non-footballers rather than truly sedentary individuals; the remaining 2 were truly sedentary (as assessed by a questionnaire of physical activity – appendix 1). Table 4 shows the characteristics of all participants. All subjects provided signed *assent* (appendix 2b) along with signed parental *consent* as legally all subjects were minors (appendix 2a). Appendix 3 shows the remaining paperwork; the information sheet (3a), the medical questionnaire (3b) and the record of any previous injury (3c).

Table 4: Demographic characteristics of participants

Group		Age (years)	Height (cm)	Body mass (kg)	Sum of skinfolds (mm)	Body fat (%)
Elite (n=20)	mean±SD	16.6±0.3	176.2±5.3	67.5±6.5	20.5±8.7	12.2±4.8
	range	16.0 -16.9	166.3-187.6	54.3-81.1	8.9-43.8	3.2-22.4
Recreational (n=21)	mean±SD	16.5±0.4	172.6±5.7	64.3±7.3	33.0±13.9	18.0±4.8
	range	15.8-16.9	158.5-182.7	51.2-77.8	14.3-67.5	8.8-27.9
Sedentary (n=13)	mean±SD	16.3±0.4	173.7±7.4	67±13.3	43.3±28.3	20.5±6.7
	range	15.9-16.9	163.0-188.0	48.5-100.9	19.6-121.8	12.5-35.7
All (n=54)	mean±SD	16.5±0.4	174.2±6.1	66.1±8.8	30.8±19	16.5±6.3
	range	15.8-16.9	158.5-188.0	48.5-100.9	8.9-121.8	3.2-35.7

5.2 Test Protocol

All tests were conducted at Hampden Park in Glasgow over two days. Tests followed the order of administration given in Table 6.

5.2.1 Physical Activity

Physical activity was assessed by means of a questionnaire (appendix 1). Modified from the Scottish Physical Activity Questionnaire (to include 'school' as well as 'work'), that was designed to aid seven-day total physical activity recall, and which holds good test-retest reliability, concurrent validity, and limited criterion validity (Lowther *et al.*, 1999). The null hypothesis was that there would be no difference in the physical activity levels between the three populations.

The questionnaire also places subjects in one of the five stages of change (Marcus *et al.*, 1992) that a person moves through from being sedentary to regularly active. These stages are precontemplation (regularly inactive and no intention of change), contemplation (regularly inactive, but intending to change in next six months), preparation (active, but not regularly), action (regularly active but only in last six months) and maintenance (regularly active for longer than six months). These stages differentiate between how subjects view the positives and negatives of exercise.

5.2.2 Anthropometry

The height of the subjects was assessed with a wall-mounted stadiometer (Holtan Ltd., Crymych, Dyfed, Wales, UK). Height was measured in cm (±0.1cm). Body mass was taken with scales (Salter scales, Tonbridge, Kent, UK) and was measured in kg (±0.1g). The 4 skinfold sites detailed by Durnin & Womersley (1974), of the biceps, triceps, subscapular and suprailiac crest were used as a measure of body fat and taken in triplicate on the right side of the body with Harpenden callipers (Baty, British Indicators, London, UK) that were regularly calibrated in-house. The equation of Durnin & Rahaman (1967) was used to estimate body fat.

5.2.3 Sprint tests

Following an individual warm-up of the subject's choice for the standard time of 8 minutes, each subject completed 3 sprints from a standing start over a distance of 22 m within the indoor warm up area at Hampden Park, Glasgow (see appendix 4). The surface was an indoor astrograss and all subjects wore training shoes. Their sprint time was recorded from 2-22 m using Brower timing gates (Utah, USA). They sprinted from a point 2 m back from the first gate and when they broke the beam their time began. A beam at 12 m was broken for a 10-m split time and finally a beam at 22-m was broken for the second 10-m split time. The fastest overall time was used to determine 10 m split times and total 20 m time, regardless of whether there were faster splits in two separate runs. Between sprints subjects jogged back to the start ready to run again 60 s after completion of the previous sprint.

5.2.4 Flexibility test

Immediately upon completion of the sprints, the flexibility of the hamstrings and lower back was assessed via a sit-and-reach test performed after the sprints within the warm-up area. The sit-and-reach test followed the protocol of Williams *et al.* (1997) which is given in table 5 and was performed with a sit-and-reach box constructed by the mechanical workshop of Glasgow University. The subjects removed their training shoes to complete the procedure.

Table 5: Sit and Reach protocol

1. Sit on the floor with buttocks, shoulder and head in contact with a wall.
2. Extend legs with knees straight and soles of the feet against a sit-and-reach box
3. Place hands together with no fingers extending beyond the others
4. Touch top of box with head and shoulders still in contact with wall. This sets the zero mark for the test
5. Lean forward, move head, shoulders and trunk away from wall in 3 stages
6. Hold the third stretch for 3 s and read off distance
7. Take best score from 3 attempts

5.2.5 Test of $\dot{V}O_{2peak}$

Following measurement of blood pressure with a standard manual syphgnamometer and a value within the accepted World Health Organization guideline, ventilatory gas exchange variables were measured using a Medgraphics CPX/D breath-by-breath analyser with Breeze suite 6.0 software (Medical Graphics Corp., St Paul, Minnesota, USA). The subjects were asked to breathe through a mouthpiece with low dead space (85 ml) while wearing a nose clip. The mouthpiece was connected to a pneumotachograph, which calculated expired gas volumes. Expired oxygen (O_2) and carbon dioxide (CO_2) were sampled continuously. The breath-by-breath analyser allowed determination of minute ventilation ($\dot{V}E$), O_2 consumption ($\dot{V}O_2$), minute CO_2 excretion ($\dot{V}CO_2$) and calculated respiratory exchange ratio (RER), respiratory rate, and tidal volume from these variables. Pre-test calibration for gas and volume was performed for every subject's test. The treadmill was calibrated for speed and gradient on a fortnightly basis. Heart rate was determined via a T1 POLAR heart rate monitor (Kemple, Finland).

The difficulty in obtaining a real plateau in children has been well established (Åstrand, 1952; Ritmeester *et al.*, 1985; Armstrong *et al.*, 1990; Armstrong *et al.*, 1995; Armstrong *et al.*, 1998) and so the term $\dot{V}O_{2peak}$ was preferred to $\dot{V}O_{2max}$.

As this study encompassed a range of fitness from sedentary to elite athletes a protocol had to be chosen that could be utilised across this range to elicit a peak $\dot{V}O_2$ in them all. The only comparable studies that have encountered a problem of this type were longitudinal studies looking at a range of ages. Armstrong and Welsman (2001) used a progressive treadmill test to voluntary exhaustion on children aged 11 to 17 years. After a 3-min warm-up at 6 $km.h^{-1}$ and a brief rest, speed was increased to 7 or 8 $km.h^{-1}$ for the initial 3-minute stage then increased by 1 $km.h^{-1}$ each stage until a speed of 10 $km.h^{-1}$ was attained. Belt speed was then held constant and further increments in intensity were achieved by 2.5 % increases in gradient until exhaustion. Each 3-minute stage was separated by 1-minute rest periods to allow lactate sampling. This discontinuous protocol was used to elicit a steady state of lactate in the blood (Foxdal *et al.*, 1995) for determination of the lactate threshold, this study was not concerned with lactate threshold so a modified Armstong protocol was used; it entailed starting at 9 $km.h^{-1}$, with 2-min stages as LeMura *et al.* (2001) utilised and without the 1-minute rest periods. This elicited a test end point within the recommended time period of 8 – 17 minutes in pilot studies. In a pilot study, using the Armstong protocol as described, without rest periods, led to test times of over 20 minutes. This means that general fatigue could cause the cessation of the test rather than limitation of the oxygen uptake (Buchfuhrer *et al.*, 1983).

5.2.6 Isokinetic dynamometry tests

Following a non-specific warm-up run on a treadmill at a self-selected speed for 8 minutes, the subject sat upright on the isokinetic dynamometer (REV 9000, Technogym, Italy) at a seat angle of 100°. The leg to be tested was secured to the dynamometer chair with a thigh restraint roller just above the knee. Seat belts across the waist and upper torso were used to stabilise the torso. The axis of rotation of the dynamometer lever arm was aligned with the lateral femoral condyle of the knee joint at 90° knee flexion. The lever arm pad was positioned distally on the shin, immediately above the malleoli. Subjects were required to cross their arms over their chests as further provision against synergistic muscle actions. The range of motion was set at 90° to 10° knee flexion to minimize the injury risk at the extremes of movement. Finally, the gravity correction procedure was performed.

Before commencement of the isokinetic assessment a specific warm-up was completed, where the subjects performed 4 discrete pairs of leg actions (concentric knee extension followed by concentric knee flexion) at 50-75% of estimated maximum effort at 30°/s (0.52 rad.s^{-1}), followed by 4 sub-maximal eccentric quadriceps and eccentric hamstrings muscle actions, again at 50-75% of estimated maximum effort. This specific warm-up was then repeated at the other test velocity of 180°/s (3.14 rad.s^{-1}).

Two minutes after completion of the specific warm-up, concentric peak torque of the quadriceps and hamstring muscle groups of the leg to be tested were measured at a test velocity of 30°/s from 4 maximal efforts. Then, after a 90 s recovery period the effort was repeated at 180°/s. The subject then completed 4 maximal eccentric muscle actions of the hamstrings at the same speeds and with the same 90 s rest period between speeds. After a further one minute recovery, 4 maximal eccentric quadriceps muscle actions were performed at the two speeds with a 90 s rest in-between. Finally after a 2-minute recovery period, peak isometric angle-specific torques for the quadriceps and hamstrings were completed at both 70° and 25° knee flexion by 5 s efforts interspersed by 30 s recovery periods. After a further 3-minute non-specific warm-up, the non-tested leg was then assessed. Administration of first leg testing was balanced across subject groups with every subject alternating beginning testing with their strongest and weakest leg.

5.3 Time of testing

While the time period of the testing protocol is stated in Table 6 the period of examination within the year is crucial. If this experiment was carried out in the close season, the results may be very different. During the 6 weeks off the de-conditioning of elite soccer players may be very rapid and it is hypothesized that more homogeneous results between the three sub-populations may be found if testing occurred during this period. Testing took place from January to December, avoiding the close season and pre-season periods when the players may have been below their peak levels of physical fitness. In season they are simply maintaining the levels of fitness that they have built up during the pre-season (Bangsbo, 1994b). The $\dot{V}O_{2\,max}$ does not keep increasing throughout the year as training is adapted to more tactical aspects throughout the year and more time is attributed to game playing instead of fitness. It may though decrease over the year due to injury or time spent on the sidelines through non-selection but while it fluctuates it is usually at the same high level by the mid-point of the season (Brady *et al.*, 1997).

5.4 Power and population size

Rarely is a calculation of sample size included in research on soccer and so the power of the data could be questioned. Taking $\dot{V}O_{2\,peak}$ as the most important measure of fitness for the 3 sub-populations, the sample size for this study was based on assuming that the smallest average difference of interest in $\dot{V}O_{2\,peak}$ between the three groups would be 2 $ml.kg^{-1}.min^{-1}$ and that the underlying standard deviation of all three groups would also be around 2 $ml.kg^{-1}.min^{-1}$. Hence, on the basis of a one-way ANOVA with significance level of 5% and a required power of at least 80%, the study requires at least 13 subjects in each of the three samples.

5. 5 Statistics

Each variable, in each sample, was assessed separately with respect to whether or not it was reasonable to assume normality by means of probability plots and Anderson-Darling tests. Most variables could, in fact, be assumed to be normally distributed and subsequent analysis of these variables involved repeated measures analysis of variance with Tukey-based multiple comparisons used to identify among which groups any significant differences lay. For the few variables (such as sub-categories of 'time spent on physical activity') where normality was unlikely, Kruskal-Wallis tests were used to compare groups with follow-up Bonferroni-based multiple comparisons using Mann-Whitney tests.

'Perfect'

- %BF & skinfolds
- Height
- Weight
- Lipid profile
- BP at rest

- $\dot{V}O_{2\,max}$
- Isokinetic assessment
- Jump tests
- Sprint test
- Lactate threshold
- Flexibility - sit and reach

Acceptable

- %BF & skinfolds
- Height
- Weight
- Total Cholesterol
- BP

- $\dot{V}O_{2\,max}$
- Jump tests
- Sprint/Agility test
- Flexibility
- Isokinetic assessment

Reasonable

- %BF
- Height
- Weight

- $\dot{V}O_{2\,max}$
- Jump tests
- Sprint/Agility test

Minimal

- $\dot{V}O_{2\,max}$
- Height
- Weight

Figure 3: Testing continuum (Murray, 2004)

%BF = % body fat, BP = blood pressure

6.0 Justification of protocol used in present study

Table 6: Test protocol

DAY 1	DAY 2
A – 10 minutes	E – 5 minutes
B – 5 minutes	F – 10 minutes
C[6] – 20 minutes	G – 40 minutes
D – 30 minutes	
Total ≈ 65 min	≈ 60 min

A= Sprints (3x20 m), B= Flexibility, C= Balance/Ankle, D= $\dot{V}O_{2\,max}$, E= Paperwork, F= Anthropometric tests, G= Isokinetic assessment of hamstring/ankle (both legs)

This chosen battery falls more towards the minimal end of a continuum of testing (Murray, 2004) (figure 3) due to time constraints. It was not possible to carry out tests in one day because of fatigue effects that may affect the results. Due to these fatigue and time constraints the protocol in Table 6 was devised. This minimized the disruption to subjects to one school period or one morning training session. The period between day 1 and day 2 was always 7 days.

6.1 Sprint

On average a player sprints around every 90 s (Reilly and Thomas, 1976), but just one of these sprints may decide the outcome of the match if a forward moves in front of a defender and scores or if the defender wins the race and makes a vital saving tackle. Soccer utilizes a combination of short (e.g. 5-10 m), and more

[6] The assessment of balance and ankle strength was taken by another PhD student at the University of Glasgow for his own thesis and for this reason this element shall not be discussed further here.

sustained sprints (e.g. 20-40 m), (Young & Pryor, 2001), 96% of which are under 30 m in length and 49% under 10 m (Valquer *et al.*, 1998).

Kollath & Quade (1993) completed a study on sprint speed in soccer players and found that in a 30 m sprint the first 10 m, was most important in determining final sprint time[7]. Comparing amateur and professional players, it was found that over 10 m the amateurs were already 49% behind the professionals in terms of distance, due to a slower running speed.

The null hypothesis in this case is that there will be no differences between the groups in terms of sprint speed over 10 and 20 m.

6.2 Flexibility

Soccer players should have a good degree of flexibility to stretch for misplaced passes and for the constant cutting nature of the sport that requires on average 50 changes of direction per match (Withers *et al.*, 1982). Participation in these activities could result in muscle strains and tears if there is not good general flexibility. The hamstrings and lower back are particularly important in this aspect. Generally though the flexibility of soccer players is poor (Ekstrand, 1982; Davis & Brewer, 1993).

The null hypothesis is that there will be no difference between the three populations in terms of their sit-and-reach performance.

[7] Defined as the initial acceleration phase (Delecluse, *et al.*, 1995).

6.3 Oxygen uptake ($\dot{V}O_{2\,peak}$)

Soccer players can use up to 5700 kJ (Reilly *et al.*, 2000a) of energy in every game and can cover distances of on average 8-12 km (Reilly and Thomas 1976; Withers *et al.,* 1982; Ekblom, 1986; Van Gool *et al.,* 1988). To enable players to cover these distances, they must have well-developed aerobic fitness levels as it is the main source of energy provision (Bangsbo, 1994c) in off the ball activities (Table 7). These last for the majority of the game, with only 2% of the game spent in possession of the ball (Reilly, 1994b).

Table 7: Modes of travel without the ball for a soccer player in 90 minutes. (Williams et al. 1997)

Time	%	Action
18-27 minutes	20-30%	Walking
27-36 minutes	30-40%	Jogging
13-23 minutes	15-25%	Running
9-13 minutes	10-15%	Sprinting
4-7 minutes	4-8%	Walking backwards

Despite this major aerobic component, soccer is intermittent in its nature and utilizes an anaerobic movement on average every 90 s (Reilly *et al.,* 2000a). Previous studies have demonstrated a significant relationship between $\dot{V}O_{2\,max}$ and both distance covered and number of sprints attempted (Smaros, 1980; Helgerud *et al.,* 2001). The average intensity of a game is close to the lactate threshold or 80-90% of the maximum heart rate (Davis & Brewer, 1993; Reilly, 1994a). These high intensity bouts, which depend on anaerobic energy sources, are only restored using aerobic energy.

The null hypothesis is that there will be no difference between the groups in terms of $\dot{V}O_{2max}$. Due to their daily involvement in training and the larger amounts of high intensity activity that they perform it is the authors opinion that the elite players aerobic fitness will exceed both other groups.

6.4 Isokinetic dynamometry

In soccer the strength of the lower limbs and in particular the quadriceps, hamstrings and triceps surae is of particular importance. Isokinetic dynamometry has been shown to be both a reliable and objective measure of muscular strength (Pincivero & Heller, 2002). It has been used to determine between elite and sub-elite performers (Oberg *et al.*, 1986; Rochongar *et al.*, 1988) and it has shown isokinetic strength to be relevant to sprinting and jumping (Wrigley, 2000).

As soccer requires static and dynamic balance, lower extremity muscle strength imbalances between the hamstrings (H) and quadriceps (Q) can predispose towards injury (Burkett, 1970; Orchard *et al.*, 1997; Hamzeh & Head, 2004). The hamstrings have a key role in maintaining knee joint stability by increasing the stability of the joint and supporting the action of the anterior cruciate ligament (More *et al.*, 1993). Muscle imbalance between the hamstrings and quadriceps may predispose towards injury and values for the traditionally recommended H:Q ratio to prevent injury have been reported from 0.4 to 0.9 based on peak moments and dependent on contraction mode, velocity, use of gravity correction and population (see Nosse, 1982; Kannus, 1994 for review). There seems little consensus of a normative value for this conventional ratio, though 0.6 appears to have gained general acceptance since Steindler (1955) first advanced a generalized ratio of 0.66, at a speed of $60^{o}.s^{-1}$ (Heiser *et al.*, 1984). This is the most commonly reported ratio but it is for concentric contractions of both muscles. This is not a functional measure as concentric quadriceps movement does not occur with concentric hamstring movement (Coombs & Garbutt, 2002), due to their antagonistic actions. The conventional ratio has been suggested to indicate merely whether a qualitative similarity exists between the moment-velocity patterns of the hamstring and quadriceps as suggested by a constancy in conventional H:Q ratios across contraction modes and speeds (Aagaard *et al.*, 1995).

Studies on running gait have concluded that the hamstrings work eccentrically to decelerate the forward movement of the foot and the leg in the late forward swing phase of the running cycle (Agre, 1985; Coole & Gieck, 1987). During a sprint the deceleration phase of the running cycle shortens. This requires a higher eccentric activation of the hamstrings to compensate the forward momentum and so higher forces that may cause injury through a tearing of the muscle–tendon unit. This increased acceleration is also seen when kicking in soccer, when the hamstrings act to decelerate the leg after the quadriceps have forcefully contracted to propel the soccer ball in motion. DeProft *et al.* (1988a, b) suggested that training the quadriceps concentrically and the hamstrings eccentrically will improve kicking performance. This implies that the eccentric hamstring to concentric quadriceps ratio (H_{ecc}:Q_{con}) is more functionally important in injury prevention, as it looks at the degree that the hamstring muscles can provide dynamic joint stability during knee extension. Fast isokinetic knee extension has a H_{ecc}:Q_{con} ratio of around 1 (Baltzopoulos & Brodie, 1989) i.e. the hamstrings can act eccentrically to produce as much force as the quadriceps concentrically to prevent a tearing of the muscle-tendon unit though studies are equivocal as to whether there is a velocity specific effect (Duncan *et al.*, 1989; Ryan *et al.*, 1991; Seger *et al.*, 1998).

The null hypothesis is that there will be no difference in terms of peak torque for hamstrings or quadriceps or functional ratios between the three groups. In the author's opinion the elite soccer players will have higher peak torques for both hamstrings and quadriceps. In addition, he believes that their functional ratio will be closer to 1 than the recreational or sedentary groups.

Table 8

Table 8 shows previous test batteries that have been used in the literature for a range of ages. The table is arranged in chronological order and spans 5 subsections (a-e). Each part of the table is governed by the same legend, which is given below.

Table 8 Legend

Abbreviations used

Gk = goalkeeper

def = defender

mid = midfielder

stk = attacker

Test Battery

%BF = percentage body fat

MSFT = Multi-stage fitness test

1RM = 1-rep maximum strength test

T_{lac} = Lactate threshold

Range of tests

The test ranges of studies are rated up to a maximum of 5*. Stars are awarded if studies meet certain criteria. Additional * are awarded if the criteria are met i.e. if the study tests for height, mass, $\dot{V}O_{2\,max}$, % body fat and sprint speed it receives 2*:

1* = Height, mass and $\dot{V}O_{2\,max}$.

2* = addition of jump or sprint tests or %body fat.

3* = addition of flexibility or isokinetic tests or strength tests.

4* = addition of lactate threshold or lipid profiling.

5* – addition of cholesterol or blood pressure measurements.

Overall rating

Studies are rated as a whole up to 5* in the same manner as for the test range. 1* is awarded for each of the following included in the paper; quoted p-values, a power calculation, anthropmetric data stated (including playing position), testing across a range of levels or repeated testing.

Table 8a: Previous test batteries in the literature for a range of ages and number of subjects

Paper	Mass (kg) Mean±SD	Height (m) Mean±SD	Age (yr) mean±SD	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1}) mean±SD	Position or Level	Test Battery	n	Range of tests[δ]	Overall rating[δ]
Bell (1988)	38.6±5.4 37.5±4.6 35.3±2.7 39.8±2.8 37.8±3.9	1.60±3.0 1.48±4.8 1.48±3.4 1.52±6.8 1.50±5.5	12.3	51.4±7.0 55.1±6.4 61.1±3.4 55.9±4.8 56.2±5.8	Gk Def Mid Stk Total	Height Mass %BF[δ] $\dot{V}O_{2\,max}$ (protocol not identified in paper)	18 (2 gks, 7 def, 4 mid, 5 stk)	**	**
Van Gool *et al.* (1988)	-	-	19-23	-	Belgian University	$\dot{V}O_{2\,max}$ test (Taylor protocol – constant speed 11.2km.h^{-1}, increase incline 2.5% / 3min)	7	*	*
Dunbar & Power (1995)	77.7±7.6 69.6±6.8 73.8±5.8 72.3±8.4 73.4±8.0	-	-	60.7±2.9 58.1±3.1 58.8±3.2 61.1±5.6 58.7±5.2	Premiership Senior Prem junior Div 3 senior Div 3 junior Vauxhall	Body mass %BF (skinfold) Sit and reach test 30m sprint 6 x 20m shuttle (endurance Progressive shuttle (to exhaustion)	18 14 14 12 12	***	**

[δ] See pages 44-45 for explanation of legend.

Table 8b: Previous test batteries in the literature for a range of ages and number of subjects

Paper	Mass (kg) mean±SD	Height (m) mean±SD	Age (yr) mean±SD	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1}) mean±SD	Position or Level	Test Battery	n	Range of tests	Overall rating
Mercer *et al.* (1995)	78.1±9.2	1.79±0.1	24.7±3.8	56.8±4.9 62.6±3.8	English 1st Division	9.25am –11:50am %BF, height, weight Isokinetic leg strength test Sit and reach test Illinois Agility run Vertical Jump (with and without counter-movement) 11:55-12:40 Group warm up MSFT$^{\delta}$ 12:25am-14:00 Snack break & questionnaire 14:05-15:00 8 x 50m sprint (turn at 25m)	15	***	***
Reilly *et al.* (2000b)	63.1±1.1 66.4±2.5	1.71±0.1 1.75±0.1	16.4 (mean)	59.0±1.7 55.5±3.8	Elite (pro) & sub-elite	Height Mass 7 skinfolds 2 diameters, 4 circumferences $\dot{V}O_{2\,max}$ 5, 15, 25, 30m sprints 40m sprint with turns 7x 30m sprints Standing vertical jump	31	**	***

Table 8c: Previous test batteries in the literature for a range of ages and number of subjects

Paper	Mass (kg) mean±SD	Height (m) mean±SD	Age (yr) mean±SD	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1}) mean±SD	Position or Level	Test Battery	n	Range of tests	Overall rating
Casajus (2001)	78.6±6.6	1.8±0.1	25.8±3.2	65.5±8.0	Spanish 1st Division	Body composition (6 skinfolds) $\dot{V}O_{2\,max}$ (3% @ 8km.h^{-1}. Increase speed 1km.h^{-1}.min^{-1}) Jump	15	***	***
Dowson *et al.* (2002)	53.3±8.9 69.9±6.6 70.7±6.8 78.9±6.0 65.9±9.8	1.68±8.6 1.75±5.8 - 1.79±6.8 1.66±5.6	-	51.0±4.2 56.1±5.2 - 60.5±2.6 49.1±5.5	u-15 u-17 u-19 Senior men Female	Body composition MSFT Vertical Jump Sprints (3 x 20m)	56 23 19 21 20	**	***
McMillan *et al.* (2002)	-	-	17.8±1.3	-	Scottish Premier	%BF Densinometry Yo-Yo & Incremental treadmill Jumps 5 m & 20 m sprint Agility 1-RM$^{\delta}$	39	****	*
Aziz *et al.* (2003)	70.2±8.7	1.74±6.5	25.3±4.3	55.3±3.8	Singapore Premier	Height Mass %BF (bio-impedance) MSFT 5 & 20 m (over 20m) counter-movement arm swing (outdoors)	147 (16 gks 50 def 54 mid 27 stk)	**	*

Table 8d: Previous test batteries in the literature for a range of ages and number of subjects

Paper	Mass (kg) mean±SD	Height (m) mean±SD	Age (yr) mean±SD	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1}) mean±SD	Position or Level	Test Battery	n	Range of tests	Overall rating
Bangsbo *et al.* (2003)	76.9±1.1	1.80±1.0	24.7±0.9	58.3±0.1 61.1±1.0 56.3±1.0 56.9±0.5	Danish prem mid def fwd	3 x 6min submax run (10, 14 & 16 km.hr^{-1}) Incremental run to exhaustion	47 (15 def, 16 mid, 16 stk)	**	***
Brick and O'Donoghue (2003)		-	24.6±5.0 28.8±3.9 21.2±2.2 23.6±3.4 26.6±3.5	51.3±4.4 54.1±2.6 59.6±4.7 57.0±3.9 53.2±4.0 (no Gks, all estd.)	Leading teams in Derry	Mass %BF (3 folds) handgrip 1-RM sit & reach vertical jump Beep test 40 m sprint (split for soccer)	22 soccer 9 RU fwds 5 RU backs 25 Gaelic 20 Hurlers	***	***
Dunbar and Treasure (2003)	80.4±5.9 74.9±7.3	- -	25.7±4.5 20.7±3.0	- -	English Prem	10 & 20 m sprint vertical jump Illinois agility test Intermittent sprint test Incremental treadmill test Lactate profile	89(61 first team 28 reserves)	**	***
Hood *et al.* (2003)	-	-	9-16	-	Elite Youth	On 4 occasions; 10 and 30 m sprint 10 m 'flyer' 35 m multidirectional run Standing jump	98	*	**
Kemi *et al.* (2003)	73.3±9.5	1.79±0.1	21.9±3.0	65.6±7.1 65.7±5.1	Norwegian 1st Division	$\dot{V}O_{2\,max}$ (inclined 3°– larger muscle mass, true max, dribbling on flat compensates for gradient)	10	*	**

Table 8e: Previous test batteries in the literature for a range of ages and number of subjects

Paper	Mass (kg) mean±SD	Height (m) mean±SD	Age (yr) mean±SD	$\dot{V}O_{2\,max}$ (ml.kg^{-1}.min^{-1}) mean±SD	Position or Level	Test Battery	n	Range of tests	Overall rating
Tschopp, *et al.* (2003)	62.3±8.0 68.5±6.2 73.9±6.5	1.72±6.4 1.77±6.0 1.79±3.7	15.0±3.0 16.8±0.2 18.9±0.8	-	Swiss Junior National	Occurred over 4 years in lab on 1 day 5 x 10 m shuttle 10 & 20 m sprints (measured 2nd 10m of 20) $\dot{V}O_{2\,max}$ on treadmill (increasing velocity) Speed at T_{lac} $^{\delta}$ Isokinetic strength tests (Knee extensor & flexor)	48	****	****

7.0 Results

7.1 Anthrompometric data

7.1.1 Age

As a check on the sampling procedure a one-way analysis of variance (ANOVA) was carried out on the ages of the three samples/groups. This was to ensure that all groups were similar in terms of their maturational development. No significant differences were found between the three groups ($P = 0.173$) so it can be assumed that all three groups were, on average, at a similar stage of maturation, based on their chronological age.

7.1.2 Height, body mass, %BF

As a further check on the comparability of the three samples, height, body mass and % body fat were assessed for any possible average differences between them. While a one-way ANOVA showed no differences among the three samples in terms of both height and body mass ($P = 0.150$ & 0.462 respectively) across the three groups, there was a significant difference in the sum of skinfolds ($P = 0.002$) and % body fat ($P < 0.0005$). Figure 4 shows boxplots of the % body fat data and indicates that the elite group had a lower average % of body fat than the other two groups. The boxplot indicates the median, or middle, of the data by the line drawn across the box. The bottom and top edges of the box mark the first (25th percentile) and third (75th percentile) quartiles, respectively, these mark the points at which 25 or 75 % of the data values are less than or equal to this value. The arms from the box extend to the highest and lowest data value within the limited range[8]. Outliers out with this range are unusually large or small observations and are marked by an asterisk.

[8] Defined as [25th percentile - 1.5*(75th percentile - 25th percentile)] to [75th percentile + 1.5*(75th percentile - 25th percentile)]

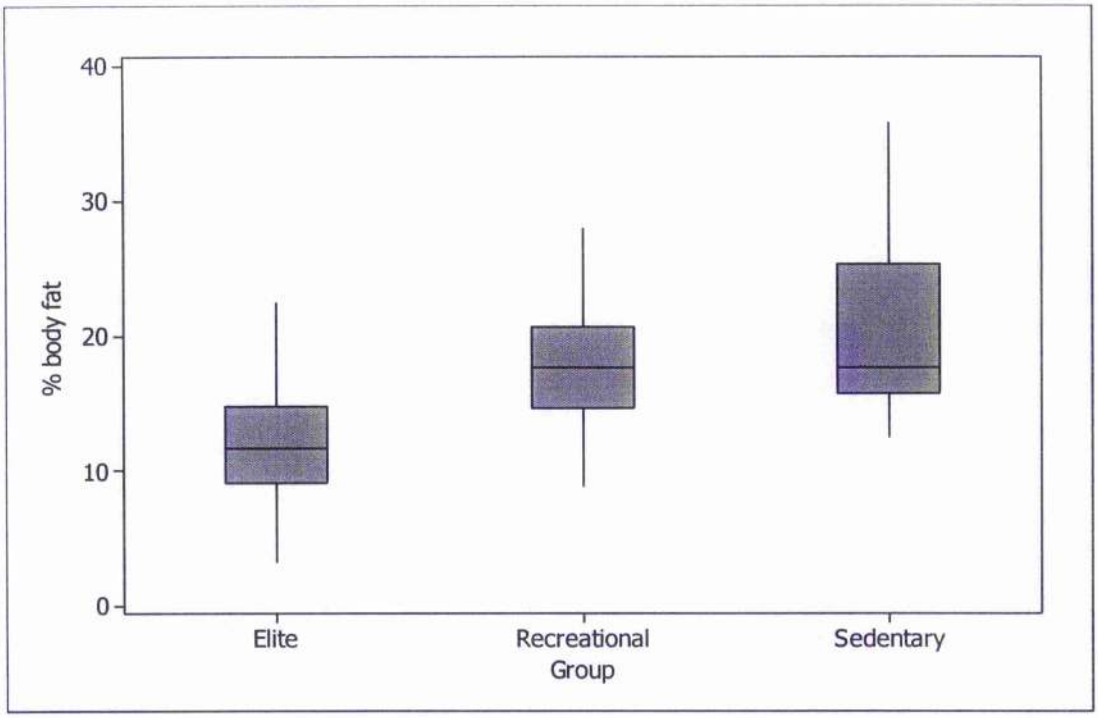


Figure 4: Boxplots of percentage body fat by group

Tukey-based pairwise multiple comparisons confirmed that the elite group had a significantly lower body fat than the other two groups. This procedure showed that the elite footballers had significantly lower body fat than the other two groups with, on average, between 2 and 10% less fat than recreational footballers and between 4 and 13% less than sedentary males of the same age.

7.2 $\dot{V}O_{2\,peak}$

The three populations were compared by a one-way ANOVA, which was significant ($P < 0.0005$). A Tukey based multiple comparisons procedure showed the sedentary individuals had a significantly lower $\dot{V}O_{2\,peak}$ on average than both elite (by between 5.1 and 12.7 $ml.kg^{-1}.min^{-1}$) and recreational footballers (by between 6.9 and 14.5 $ml.kg^{-1}.min^{-1}$) but that there was no difference between elite and recreational footballers. The box-plot in figure 5 clearly backs up these conclusions.

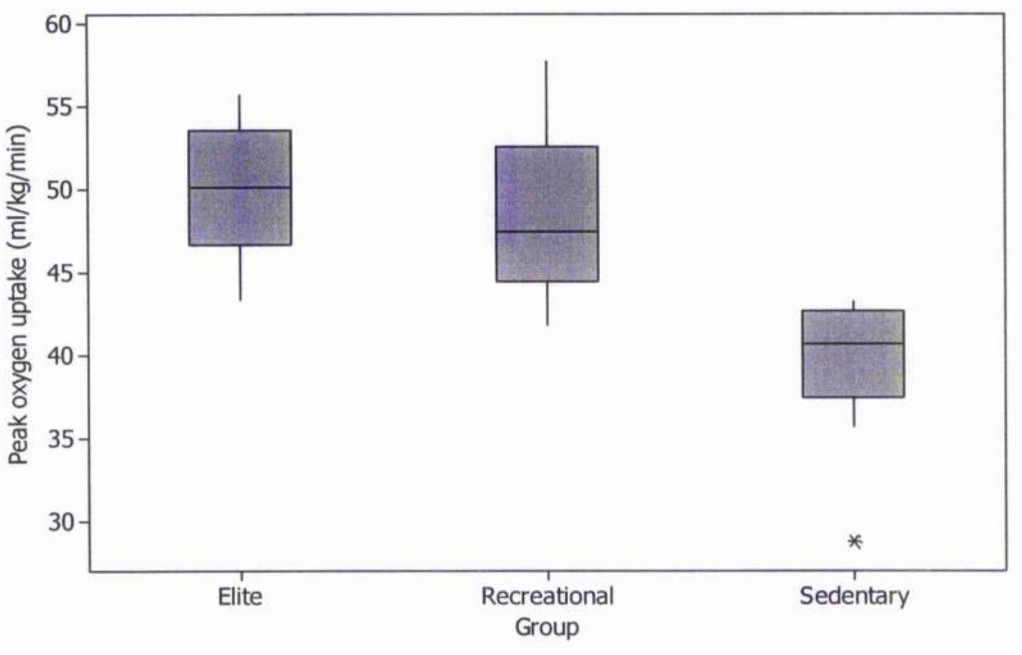


Figure 5: Boxplot of peak oxygen uptake for each group

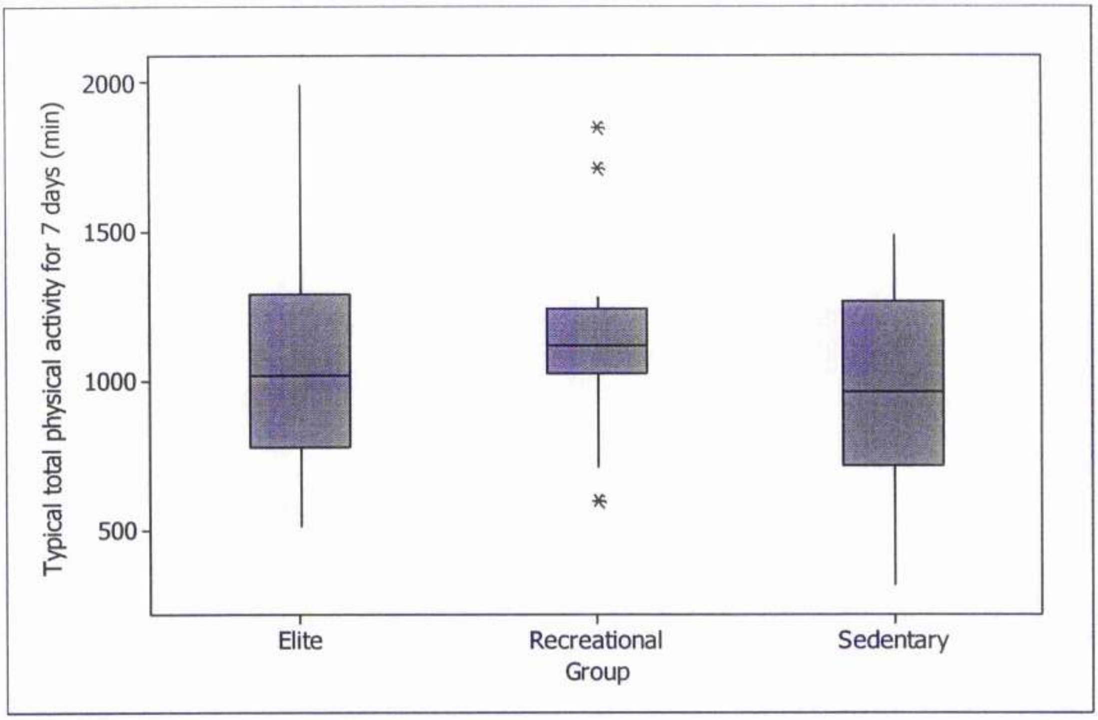


Figure 6: Boxplots of total 'typical' physical activity for each group

7.3 Physical Activity

Another important aspect of this study was to investigate whether 'sedentary' individuals in this age group actually spent less time being physically active than the other two populations. To measure this, the total 'typical' physical activity time was assessed by means of the questionnaire in appendix 1. The subsequent totals for time spent on different activities generated from this questionnaire were tallied as the total 'typical' physical activity and were analysed by one-way ANOVA. Figure 6 shows the total PA time for the three samples. Analysis of the results shows that there are no significant differences, on average, in the total typical active time of the groups ($P = 0.46$).

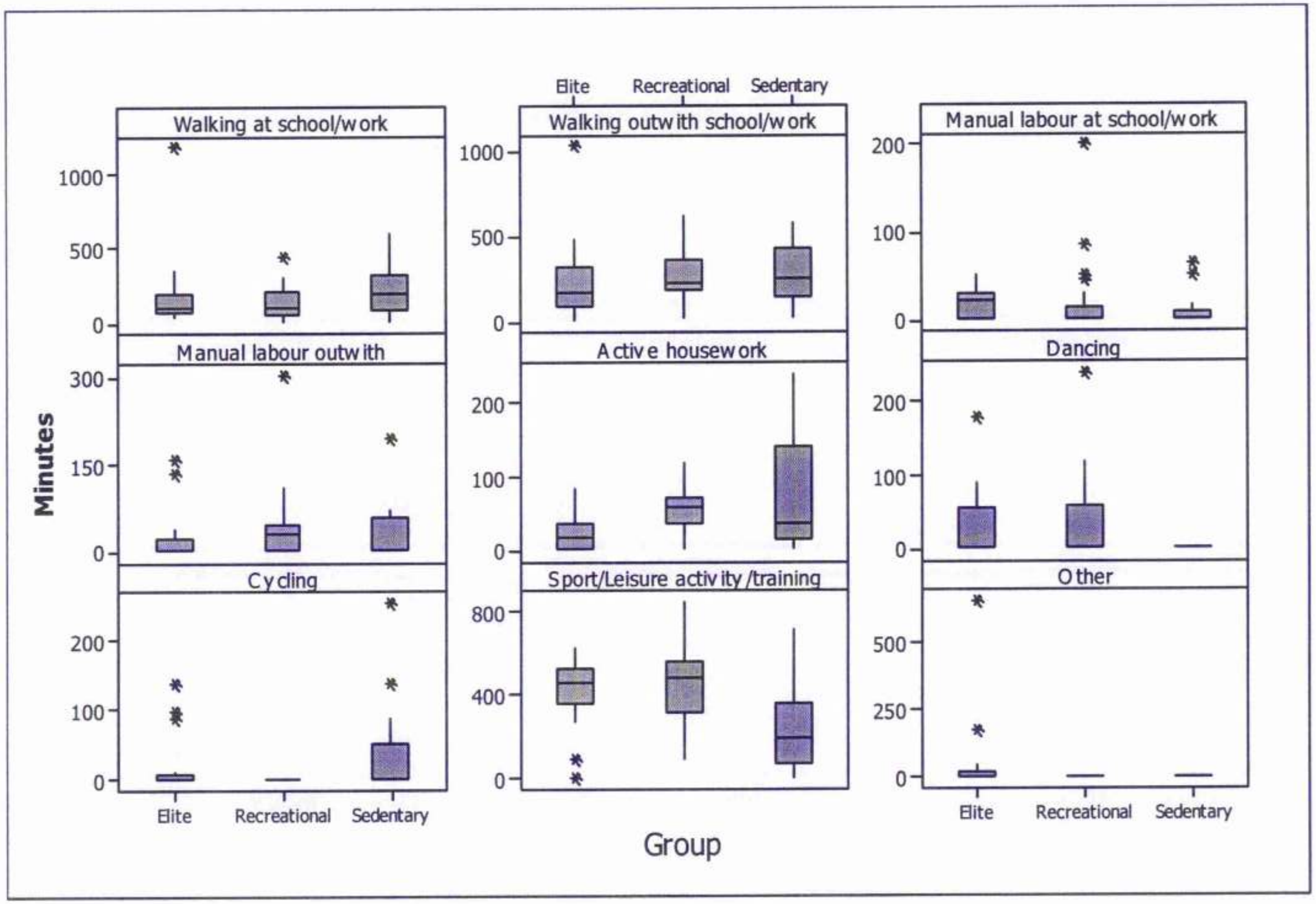


Figure 7: Types of physical activity by population

The times spent on individual categories of physical activity were then investigated separately. Figure 7 displays the results for each category from the questionnaire in appendix 1. One-way ANOVAs revealed that seven of the categories assessed in the questionnaire showed no significant differences between the three populations (see table 9).

Table 9: Categories of physical activity

Category	P-value
Walking at school/work	0.45
Walking outwith school/work	0.81
Manual labour at school/work	0.68
Manual labour outwith school/work	0.53
Dancing	0.12
Cycling	0.26
Other	0.54

Legend: the significance levels show that there is no difference between the groups

However, it would be fair to say that the times spent on several of these categories certainly do not arise from normal populations (e.g. Cycling, Other, Dancing) and so one-way ANOVAs were not appropriate. These could also be influenced by some of the clearly 'odd' observations such as the sedentary individual who spends over 200 minutes cycling and the recreational footballer who spends more than 200 minutes dancing. Accordingly it was more appropriate to use the non-parametric Kruskal-Wallis test to compare the three population "averages".

For cycling there was a difference between the elite and sedentary populations of between 0.03 and 15 minutes, though this is a minimal difference and withdrawing the one observation of 200+ minutes (from a paperboy) from the data set results in no differences between the groups. For the category of 'other', there were differences between the elite and other two populations though in both cases they are less than 0.02 minutes – not a truly meaningful difference. Removing the outlier in this case (660 minutes, from a keen golfer) also removes the differences. For the category of 'dancing' there was no difference between the elite and recreational groups though both are significantly different from the sedentary group where no subject spent any time dancing in a 'typical' week.

One category that did show significant differences was time spent on active housework ($P = 0.004$). Elite footballers did significantly less housework than their counterparts with between 3 and 71 minutes less than recreational footballers and 13 to 91 minutes less than sedentary individuals per week. Participating in sport or training also showed, perhaps not surprisingly at all, a significant difference between groups ($P = 0.005$) with sedentary individuals completing significantly less time in this category over the week (66 to 397 minutes less than recreational footballers and 15-349 minutes less than elite footballers).

Table 10: Stage of change

Population	(i)	(ii)	(iii)	(iv)	(v)
Elite	0	0	0	0	20
Recreational	0	0	0	0	21
Sedentary	0	1	2	0	10

*(i) Precontemplation (ii) Contemplation (iii) Preparation (iv) Action (v) Maintenance

Another assessment from the questionnaire of physical activity was the 'stage of change' that the subject was in (see appendix 1, question 3). Table 10 shows the counts for each stage of change for each population. It shows as expected that all the elite subjects are simply maintaining a sustained level of physical activity, as are the recreational group. A surprisingly high number of 'sedentary' subjects meet the criteria for maintenance though this reflects the nature of this population being simply non-soccer players.

7.4 Background

The next stage in the study was to compare the years spent playing soccer across the three populations as well as the number of hours spent training per week.

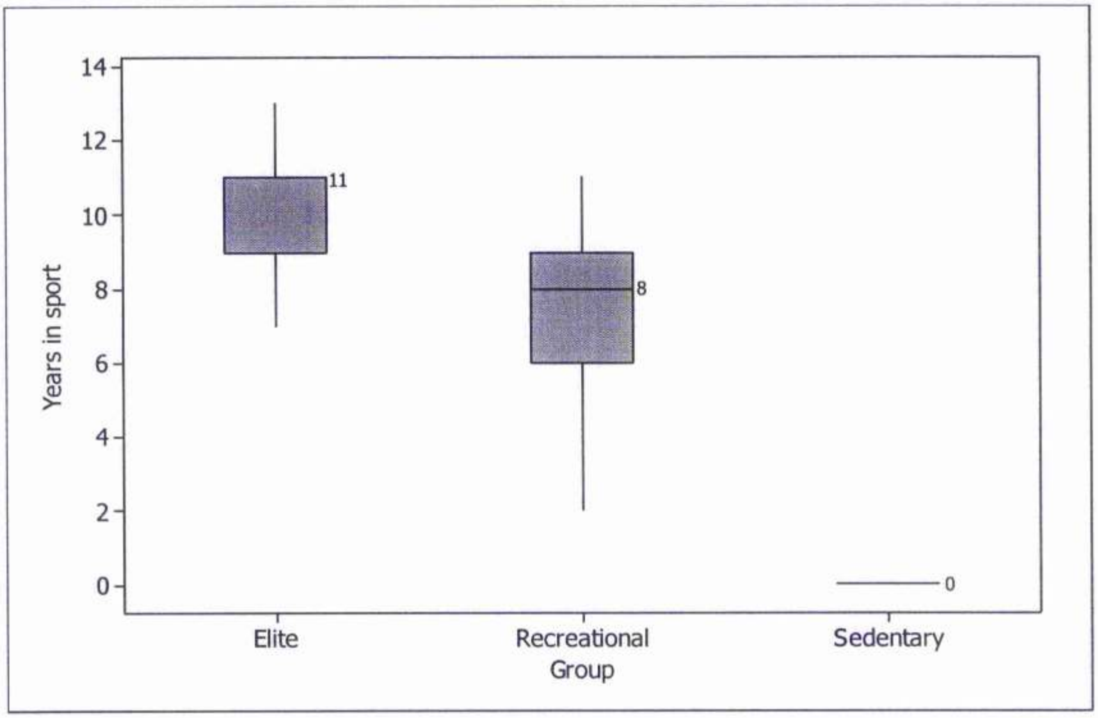


Figure 8: Years in sport for each group

Figure 8 shows the number of years spent playing soccer per population (with the median values) and it appears that all three populations are different. As all of the sedentary subjects have 0 values, as they have not been involved in sport, a 2-sample t-test was performed between elite and recreational populations. This showed that on average the elite population had been involved in sport between 1 and 4 years more than recreational subjects ($P < 0.0005$).

The average number of hours spent training a week was also assessed by means of a questionnaire; there was a significant difference in the time spent training between the elite and recreational populations ($P < 0.0005$). Two-sample t-tests of these populations (who undertake training on a weekly basis) showed that elite subjects trained between 3 and 6 hours more a week than the recreational players did.

7.5 Sprint times

From figure 9 it can be seen that there was separation between all 3 populations over the 20-m sprint with a bigger difference between the first and second 10-m split time(s) for the sedentary population than the elite population. It can be seen that the second 10-m split time was shorter than the first 10-m with the differences between the populations decreasing.

It was useful to compare the results for the two splits (over 10 and 20-m) and differences respectively as can be seen from the boxplot of both variables by population (figure 10). It appears that the elite group were fastest over both 10 and 20-m. For all populations the second 10-m times were shorter – the question is by how much?

Using a repeated measures ANOVA with one grouping factor (Group – elite, recreational or sedentary) and one repeated measures factor (first or second 10-m split time) to look at the data, not only were there significant main effects of group and 10-m splits but also a significant interaction of these (all $P < 0.0005$). Using Tukey-based multiple follow-up comparisons to look at combinations of variables (group & split) separately and especially for the differences between the first and second split times, there is a significant difference between the first and second 10-m split times for all three groups ($P < 0.0005$).

Since all of the intervals are 'significant', it can be concluded that the differences in the first and second sprint times were on average different for all 3 groups with a significantly bigger difference for sedentary subjects than for recreational and a bigger difference for recreational than for elite.

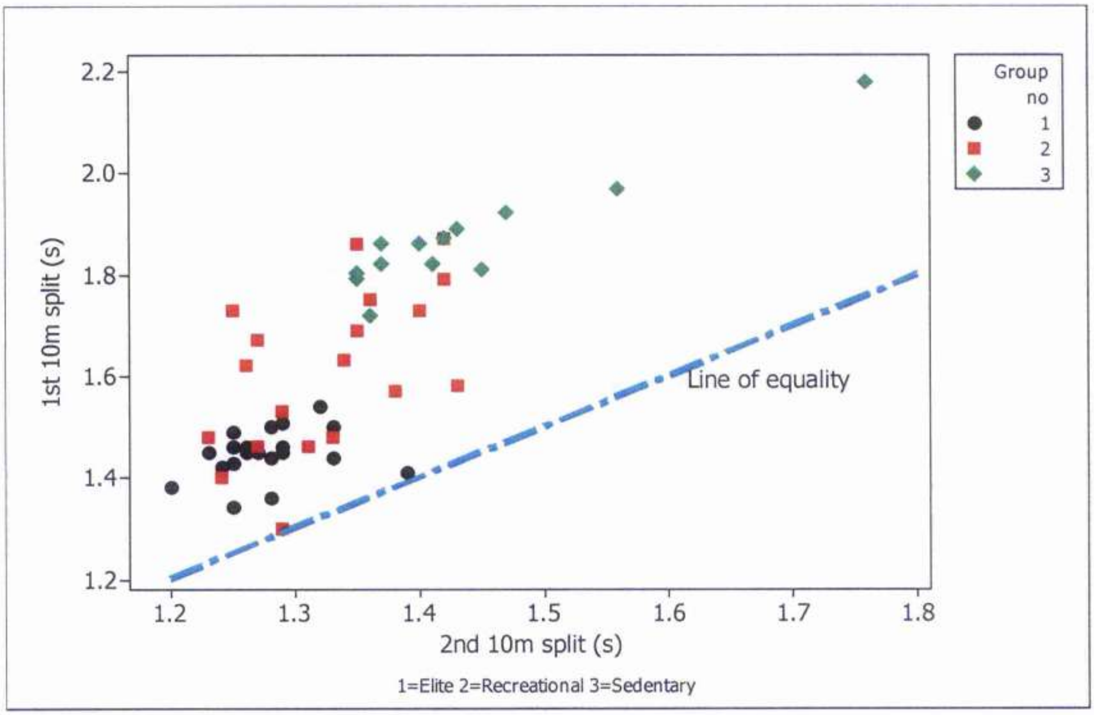


Figure 9: Scatterplot of 10-m split times

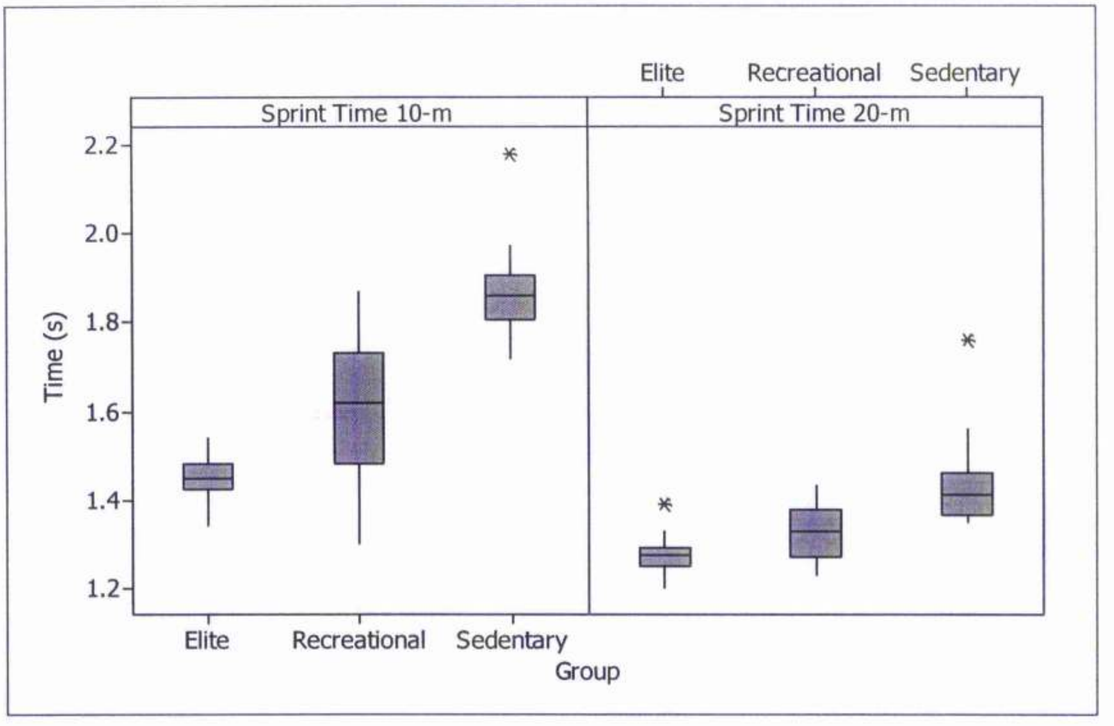


Figure 10: 10 & 20-m split times by group

As a further illustration of this, 95% confidence intervals comparing elite with recreational and sedentary with recreational across both splits are given in Table 11.

Table 11: Differences between groups in s

Difference between…	Time differences
Recreational and elite subjects - first 10 m	0.08-0.24 s more for recreational
Recreational and elite subjects - second 10 m	0.01-0.08 s more for recreational
Recreational and sedentary subjects - first 10 m	0.16-0.36 s more for sedentary
Recreational and sedentary subjects - second 10 m	0.04-0.19 s more for sedentary

One can see how the differences between each of the pairs of groups reduce, significantly from the 1st 10 m to 2nd 10 m – with a corresponding pattern for elite and sedentary populations. In distance terms this means that after elite subjects have completed 10 m, the recreational subjects are on average already 10 % (1 m) behind and the sedentary subjects 22 % (2.24 m). By the end of 20 m for elite subjects, the recreational subjects have on average only completed 18.6 m of the 20 while the sedentary subjects have covered 16.5 m.

7.6 Isokinetic assessment

Figure 11 shows 4 separate boxplots for each of the combinations of type (concentric or eccentric) by muscle (hamstring or quadricep) for each of the combinations of side (left or right) and speed of contraction (30°/s or 180 °/s). The plots are arranged so that both hamstring plots are on the same scale as are both quadriceps plots.

In Figure 11 there appears to be a pattern of very slight reduction from elite (1) to recreational (2) to sedentary (3) across both legs and both speeds of contraction for the quadricep measurements, especially in the concentric contractions, although there appears to be little pattern for the hamstrings at all. It is also strange that both speeds of contraction for the hamstrings produced a similar peak torque for each group and there was no reduction with increased speed.

Using a full repeated measures ANOVA for the formal analysis, the aim was to investigate any effects of population – in particular whether or not the populations are different across all combinations of the other factors (type of contraction, side, speed, muscle), or interactions of population with any of the other factors.

This analysis showed that there are a number of significant factors though the only ones involving the different populations were the interactions with muscle and side ($P < 0.0005$ & $P = 0.067$ respectively) and the three-way interaction of all of these ($P = 0.052$). Looking at the sample means of the peak torque for hamstrings and quadriceps by population helps to explain this. The only thing happening is the strange phenomenon of the sedentary population tending to have a stronger left hamstring on average than right – unlike all of the other muscle and population combinations.

There was also an interaction between muscle group and population. This involved a greater difference between hamstrings and quadriceps for the elite population although the three populations are not appear too different (especially the recreational and sedentary populations).

There was only one significant difference in peak torque between elite and recreational populations, which is for the left quadricep at 180°/s ($P = 0.032$), where the elite population on average produced a peak torque that was between 2 and 46 Nm greater. The significant differences between the elite and sedentary populations are given in table 12, all differences were found for concentric contractions of the quadriceps.

Table 12: Elite & sedentary differences in peak torque

Side	Speed (°/s)	P-value	Range of difference (Nm)
L	30	0.05	0.2-73
R	30	0.01	9.7-62.8
L	180	0.04	0.8-52.6
R	180	0.02	4.1-47.6

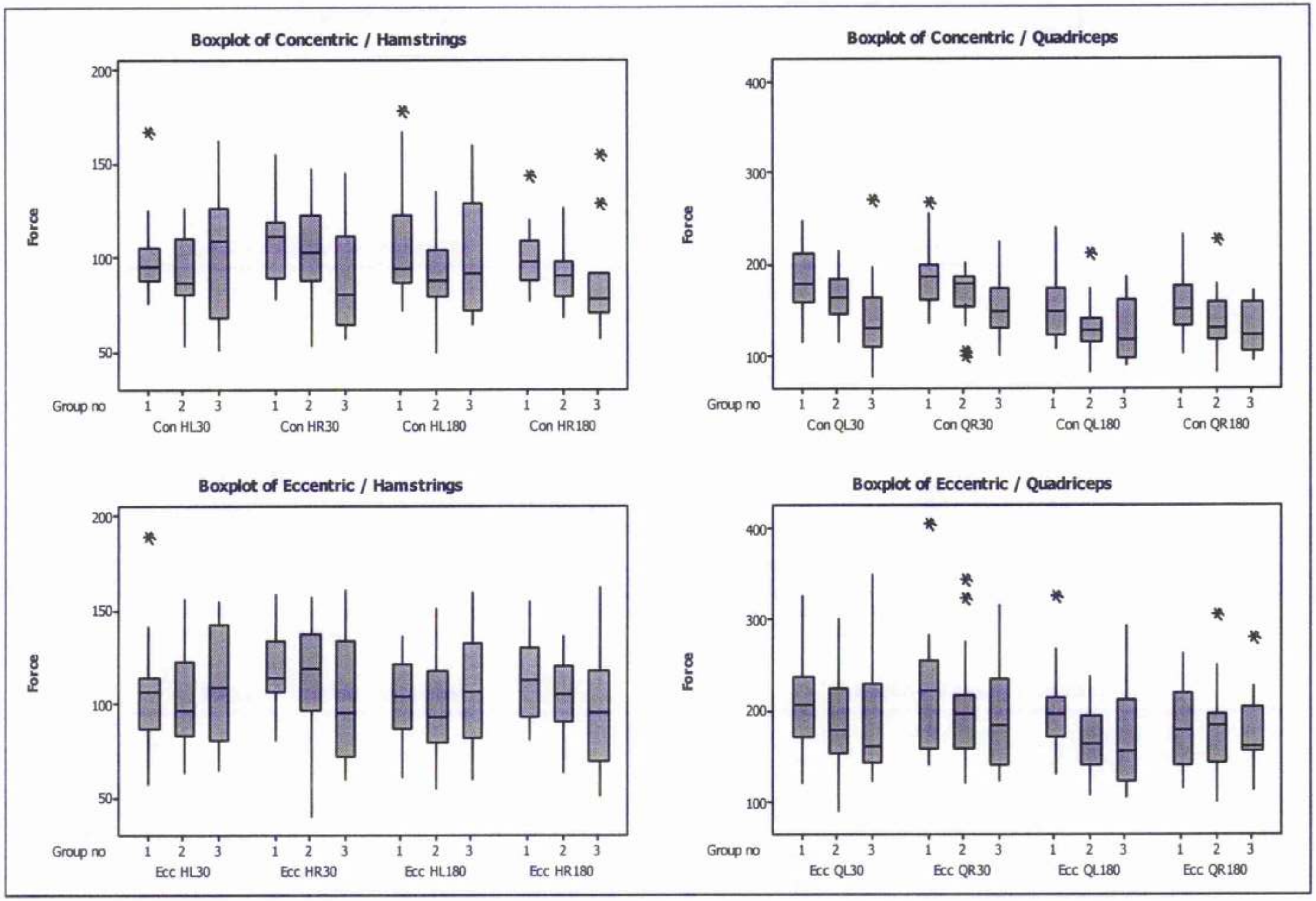


Figure 11: Peak torque of hamstrings and quadriceps by side, action and speed

Con = Concentric **H** = Hamstring **L** = Left **180** = 180 °/s **1** = Elite **3** = Sedentary
Ecc= Eccentric **Q** = Quadriceps **R** = Right **30** = 30 °/s **2** = Recreational

Table 13: P-values for interactions for each muscle type

	Hamstring	Quadricep
Contraction type	0.01	0.01
Side	0.63	0.04
Speed	0.01	0.01
Population*Side	0.01	0.45
Type*Side	0.02	0.69

Looking at the two muscles separately suggested what is seen in the full analysis of both muscles together (i.e. there were significant main effects – simple consistent differences – of type of contraction and speed with a lesser effect of side for quadriceps and more diffuse for hamstrings but no real effect of population at all for quadriceps and only this diffuse interaction with side for hamstrings – table 13).

To look at the ratio of hamstrings to quadriceps, the logarithm of the peak torques was analysed. Taking the log of hamstrings and quadriceps and analysing the interaction between muscle, side, speed and type of contraction looks at the log of the hamstrings peak torque minus the log of the quadriceps peak torque; essentially the ratio of hamstrings to quadriceps. Any significant interaction involving the muscle factor would reflect an interaction with the ratio. There was little real difference identified in this analysis, if anything the full repeated measures ANOVA revealed a simpler final model with less significant terms and little evidence of any population effect or interaction except for the same curious anomaly of the three-way interaction of population, muscle and side ($P < 0.005$) which was again due to the sedentary population's left side.

In conclusion there were no differences in the peak torques of hamstrings or quadriceps either viewed separately by side or combined, between the recreational and sedentary populations for either muscle or speed. For both speeds of contraction the concentric peak torque of the quadriceps (both sides combined) was higher for the elite population than either of the other two ($P < 0.02$), (184.6±36.8 Nm (elite 30 °/s), 166.2±28.9 Nm, (recreational 30 °/s), 148.3±42.9 Nm (sedentary 30 °/s); 155.6±33.2 Nm (elite 180 °/s), 134.9±32.2 Nm (recreational 180 °/s), 129.3±29.3 (sedentary 180 °/s)). For hamstrings the only difference was at 180°/s where on average the elite group had a higher peak torque by a range of 3-22 Nm ($P = 0.01$).

7.6.1 Functional Ratios

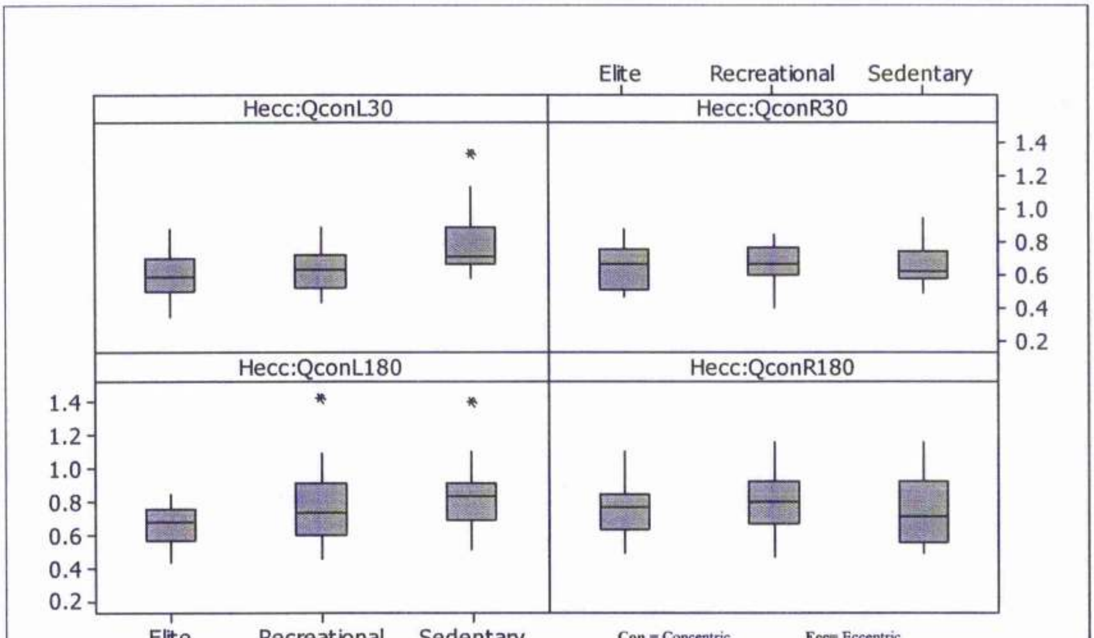


Figure 12: Functional ratio by group

The ratio of eccentric hamstring to concentric quadriceps peak torque (the functional ratio) to evaluate which population is better protected from injury (via a ratio of ~1) is shown in Figure 12. A closer evaluation using a one-way ANOVA revealed differences only on the left side. At 180°/s the difference was between only the elite and sedentary populations ($P = 0.043$); the elite population having a lower ratio by between 0.007 and 0.36. For 30°/s the difference was between the sedentary subjects and both other populations ($P = 0.002$). On this occasion the sedentary populations ratio was between 0.07 and 0.36 greater than the elite population and 0.04 to 0.33 bigger than the recreational populations.

7.7 Flexibility

The null hypothesis was that there would be no difference in flexibility for the 3 groups. Figure 13 shows box plots of the 3 groups, here it appears the elite subjects actually have the highest flexibility. The three populations were compared by a one-way ANOVA, which was significant ($P = 0.001$). A Tukey based multiple comparisons procedure showed the recreational and sedentary populations had a significantly lower flexibility on average than the elite population. This difference was of a similar magnitude for both recreational (2.6-16.1 cm) and sedentary populations (3.8-18.7 cm).

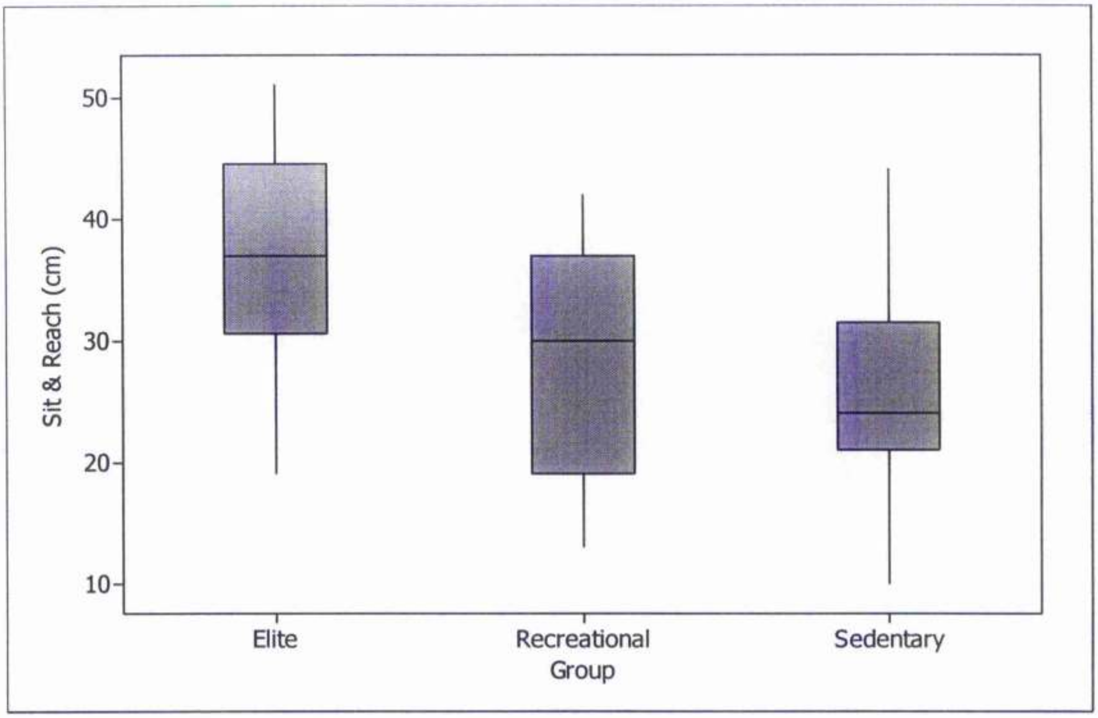


Figure 13: Flexibility by group

8.0 Discussion

8.1 Anthropometric data

In terms of soccer, while a range of heights is observed throughout the literature (Bangsbo, 1994a; Bangsbo, 1994b; Wisloff *et al.*, 1998; table 8) there is no 'perfect' height as it were to play the game. Taller players may be predisposed to certain positions though such as goalkeepers, 'target men' centre forwards or central defenders where heading or reach is more important and it is beneficial to tower over your team mates. Ekblom (1986) found that the anthropometric characteristics of soccer players (i.e. mass & height) were within the normal ranges for the general population and not significantly different to them and so it was probably of minor importance to performance. This is true here also where all three populations had similar heights. Norton & Olds (2001) found that soccer players are of a similar height to the general population as holds true across the three sub-populations in this study.

Percentage body fat is an important measure as any superfluous adipose tissue acts as a dead weight when the body's mass is lifted against the force of gravity. Indeed Hergenroeder & Klish (1990) found that increased body fat was associated with a decreased performance in sports that required body mass to be moved horizontally and vertically such as soccer.

Malina (2003) reported combined cross-sectional data from Austrian, Belgian, Croatian, Danish, Finnish, German, Hungarian, Italian, Portuguese, Russian, British, Welsh, Czech, French, Argentinean, Brazilian, Chilean, Mexican and American subjects aged 9-18 years obtained from 1964-2000. Plotting this relative to United States growth charts for the general population at this age, he found that for height and body mass soccer players are almost entirely contained within the 25 and 75 percentiles for the American population. For height, the general trend is to be slightly below the median while for body mass the general muscular somatotype of soccer players is reflected by an increased weight-for-height that probably lends itself to the selection process for soccer. This is also reflected in a higher lean body mass and therefore reduced body fat for these soccer players. In comparison to the results in the present study this heterogeneity with the general population for height and body mass is reflected and while somatotype was not measured, the reduced body fat for elite body group suggests a higher lean body mass that Malina alluded to.

Previously discriminators between populations have been established. Reilly *et al.* (2000b) found that % body fat, along with the sum of skinfolds and the endomorphy component of somatotype are the three best anthropometric measures to discriminate between elite and sub-elite populations. The sum of the skinfolds was the superior measure. Anthropometric data are commonly used as a discriminating factor for talent identification programmes and while the population of elite subjects proved fairly homogeneous in this sample there is a debate in the literature over whether they can be used as a predictor of success (see Jankovic *et al.*, 1997; Franks *et al.*, 1999; Franks *et al.*, 2002). Though anthropometrical development is linked to maturational status with soccer tending to favour the early developers, talent identification programmes that rely on physical characteristics have their place, but choosing size over inherent skill biases against late developers.

In terms of fitness for soccer these results are easily interpreted but in general health terms what do the results from the current study show? From Table 1 it can be seen that Glasgow's average BMI in 1995 was 26.8 (equivalent to borderline obesity); coupling this with the dramatic increase in the number of overweight individuals in the UK (figure 2) brings the anthropometric data of this study sharply into focus. The elite population had a significantly lower body fat than the sedentary or recreational populations (P <0.0005) but similar weights.

In Scotland as a whole at least 10 % of children were obese at primary school entry in 2003, and at least 20 % were obese in primary 7 (Reilly, 2005). Ten per cent of the world's children carry excess fat and around a quarter can be classed as obese (Lobstein *et al.*, 2004). Recent studies claimed that concern over childhood obesity is unjustified (SIRC, 2005) so why the concern?

The SIRC report mistakes changes in average mass with changes in obesity. The mass or BMI changes that have taken place have affected the population disproportionately and obscure average weight changes (Reilly, 2005). Body mass is largely used on a national scale in health surveys to assess obesity, but evidence on changes in body fat mirror what was found in the present study. While children can weigh the same, their body fat can dramatically differ (as the elite and sedentary populations did: 4-13 % difference in body fat).

Modern children are fatter, have less muscle and a more central deposition of fat - even today's thinnest children are fatter than the generation previous (Reilly, 2005). The common school of thought is that this increased abdominal adiposity leads to the consequences of obesity in the long term such as heart disease and diabetes. Dramatic increases in children's waist sizes and body fat content have occurred with limited changes in body mass; because their reduced muscle mass has limited the increase in body mass. Is this caused by a reduction in activity? A recent study of three to six-year-olds in Glasgow showed that they spent less than 30 minutes per day in moderate to vigorous physical activity, half the amount currently recommended (Reilly *et al.*, 2004) and the Scottish Health Survey (1998) found 16 % of males and 39 % of females aged 14 –15 do less than 30 minutes activity a day. Interventions for obesity prevention typically target an increase in physical activity and decreased inactivity (Reilly & McDowell, 2003), so if the activity level does change but the obesity caused by this period of inactivity remains is it as big a problem?

One school of researchers suggests that a sustained level of physical activity can overcome the detrimental effects of obesity. A review of articles looking at fitness and 'fatness' found that increased activity levels attenuated the increased risk of obesity and that active, obese individuals actually had a lower morbidity risk than thin sedentary individuals (Blair & Brodney, 1999). Unfit lean[9] men have been shown to have twice the all-cause mortality risk of fit lean men (Blair & Church, 2004) and higher all-cause mortality than fat but fit men. While the health benefits of leanness may be limited to fit individuals, simply being fit may lower the obesity risk (Lee *et al.*, 1999). These results are limited in their application due to an exclusively male study group of a high social class and the fact that only the elite population in the present study would be classed as 'lean'[9] males (see table 4). In the present study the body mass of all three populations did not differ but the estimated % body fat was lower for the elite population.

[9] Lean being defined as < 16.7 % body fat

8.2 $\dot{V}O_{2\,peak}$

It was expected that, in terms of $\dot{V}O_{2\,peak}$, the elite individuals would greatly exceed the sedentary sub-population and would be greater than the recreational athletes. This was not the case, the elite population's aerobic fitness exceeded that of the sedentary population and it was not possible to distinguish between recreational and elite subjects. This is in opposition to the findings of Reilly *et al.* (2000b) who reported that $\dot{V}O_{2\,max}$ measures discriminated between elite and sub-elite populations. In association with the data on the higher obesity of the sedentary population in comparison to the findings of Blair & Brodney (1999) that fitness protects from the problems of obesity, it would seem that the sedentary subjects in the present study are in line for health trouble as they have the highest body fat and the lowest aerobic fitness. Their increased adiposity is not protected by Blair & Brodney's findings as their fitness is low and according to the more conventional school of thought their adiposity will lead to consequences in the long-term such as heart disease and diabetes.

Top-level adult soccer players frequently have values of 55-70 $ml.kg^{-1}.min^{-1}$ (Reilly & Doran, 2003), which leads to the assumption that aerobic fitness is of great importance in soccer as it is the main source of energy provision (Bangsbo 1994c). This as not the case here as the elite youths averaged a mean $\dot{V}O_{2\,peak}$ of 50.45 ± 3.75 $ml^{-1}.kg^{-1}.min^{-1}$ and the elite seniors tested averaged 51.77 ± 4.24 $ml^{-1}.kg^{-1}.min^{-1}$ (appendix 5). These values are obviously low in comparison to the literature (Table 2 & Table 8) and may go some way to explaining Scotland's world ranking of 88! Reilly *et al.* (2000b) found that for 16 elite youths with a mean age of 16.4 their $\dot{V}O_{2\,max}$ was on average 59 ± 1.7 $ml^{-1}.kg^{-1}.min^{-1}$ which is approaching the levels observed in professional players (Reilly & Doran, 2003). This is a difference of around 9 $ml.kg^{-1}.min^{-1}$ between two samples of the same supposed elite population.

Obviously this value varies throughout the season and is generally lowest at pre-season and higher throughout the year when games keep the maximum oxygen uptake maintained at the levels it reached pre-season. It is for this reason that this study was conducted during the playing season for soccer players, to give them the best possible chance of scoring highly. Reilly *et al.* (2000a) argued that, while $\dot{V}O_{2\,max}$ alone does not predispose towards soccer success, a threshold value of 60 $ml.kg^{-1}.min^{-1}$ can be applied, with those below the threshold struggling to make the grade as they cannot cover as much ground in the game (Wisloff *et al.*, 1998). Obviously these players measured have 'made the grade' as they are full time professionals. For the youths this is not as much of a concern as they should be more concerned with skill acquisition at their age and stage of development, though for the current elite seniors this is a worry as they seem to be lagging behind in fitness terms in comparison to their peers in other countries. These low levels of aerobic fitness are not just a reflection on Scots as many nationalities were comprised within the squads tested. The observed results for $\dot{V}O_{2\,peak}$ may though go some way to explaining Scottish clubs' poor performances in Europe, comparing these values with those of Rosenborg from Norway (67.6 ± 0.4 $ml.kg^{-1}.min^{-1}$, Wisloff *et al.*, 1998), a club which has qualified for the Champions League for the last 5 successive seasons, highlights the deficit and shows again that fitness can conquer skill. These are the highest values currently published for a soccer team, but even Strindheim, who were promoted and immediately relegated from the Norwegian Premier League in 1997, had a $\dot{V}O_{2\,max}$ exceeding that of the elite Scottish players (59.9 ± 4.1 $ml.kg^{-1}.min^{-1}$, Wisloff *et al.*, 1998).

There is an argument that scaling relative to body mass can cause problems of expression (Wisloff *et al.*, 1998) and so raising the body mass to the power of 0.75 may be more appropriate. It is the author's belief that in football circles it is probably more pertinent to report absolute values, where as scaling to 0.75 is more important for research purposes. Here the relative units of $ml.kg^{-1}.min^{-1}$ are used to allow comparison with other studies. Generally there is heterogeneity in $\dot{V}O_{2\,max}$ values between average and exceptional players (Reilly *et al.*, 2000a) suggesting that the inherent skill level can be more important than just aerobic fitness itself. This would seem to be the case here as the differences between elite and recreational subjects cannot be determined by aerobic fitness alone.

A possible criticism is that the chosen protocol has not been previously used and validated, although it is derived from a hybrid of two established protocols (Armstrong & Welsman, 2001; LeMura *et al.*, 2001). Is this of major importance though? Getting to the point of $\dot{V}O_{2\,max}$ or $\dot{V}O_{2\,peak}$ is what is important not the protocol used to achieve this, though it is acknowledged that the choice of protocol can influence the result[10]. The same protocol, whether established or not is essentially different for everyone anyway due to differing levels of inherent fitness.

[10] Discontinuous and continuous protocols can affect the maximum aerobic fitness level measured as can the length of each stage.

Another consideration is of whether the criteria of a maximal effort require a plateau in oxygen uptake. A.V. Hill and co-workers demonstrated a critical velocity beyond which further increases in speed were not matched by a corresponding increase in $\dot{V}O_2$ in 1924 but the theoretical (Noakes, 1988) and methodological (Myers *et al.*, 1990) validity of the plateau paradigm have since been questioned despite its wide spread acceptance (Åstrand & Rodahl, 1986; Myers *et al.*, 1990; Thoden, 1991) as a criteria for establishing $\dot{V}O_{2\,max}$. In minors only around 30-50% exhibit a plateau (Ritmeester *et al.*, 1985; Armstrong *et al.*, 1991; Kemper, 1994) but other studies have failed to elicit a difference between the maximal values of subjects who display a plateau and those who do not (Cunningham *et al.*, 1977; Cooper *et al.*, 1984; Rivera-Brown *et al.*, 1994) and supramaximal bouts of exercise in those subjects who do not display a plateau failed to elicit an increase in $\dot{V}O_2$ (Armstrong *et al.*, 1996). For this reason if a plateau has not been elicited, it is more pertinent to use the term $\dot{V}O_{2\,peak}$ as adopted in the present study.

8.3 Physical Activity

Surprisingly the 'total' physical activity of the three samples was the same (P = 0.46). This may be a limitation of the questionnaire used to measure activity. It is acknowledged that main limitation in SPAQ appears to be the measurement of occupational walking (Lowther *et al.*, 1999) and this may have affected the results. Investigation of several sub-categories of activity found no differences between the groups either (table 9), though none of these categories was surprising in its lack of difference.

The differences in active housework ($P = 0.004$) are probably explained by elite footballers living away from home. They may be looked after and so not have to complete as much housework, as landladies take care of this while they are at training. In contrast the other two populations are completing this task, usually for financial rewards (which the paid elite sample have no need of), while the elite sample is resting and recovering from a day's training.

It is surprising that that there was no difference between elite and sedentary subjects as the elite subjects train actively daily while the non-soccer players are essentially sedentary in school. It is also surprising that there was no difference between the elite and recreational soccer players as the elite subjects formally train every day in comparison to the recreational subjects who train on average twice a week. There was no difference in the total physical activity, which may suggest that the questionnaire is not sensitive to detecting these differences. More likely though is the explanation that while the elite subjects train and then rest, the recreational subjects and non-soccer players are active outside of their football and school and so the 'total' physical activity score may be similar over the course of a week once manual labour jobs or leisure activities are considered. The relative intensities of activity may though be very different. A difference in the participation times in sport between the groups was found. It is probably safe to assume that the elite group partake in higher intensity exercise more regularly. They are able to undertake a higher volume of high intensity exercise due to their daily training providing more time for fitness work (on average they train for 3-6 hours more a week). This increased volume of high-intensity fitness work in elite subjects is speculated to be one factor that influences their lower body fat.

Table 14: Major barriers to exercise in 16-34 year olds

Not 'sporty type'
Need to rest
No Time
Injury

Overcoming the barriers listed in Table 14 (Biddle & Mutrie, 2001; p37), is a public health issue but also one that was encountered in simply enticing sedentary subjects into the study. The exact type of people that were aimed for study in the third sub-population are those that are turned off exercise and maximal testing may have simply reinforced their dislike of exercise to abhorrent levels. For this reason the 'sedentary' group were re-classified as non-soccer players rather than truly sedentary individuals due to the reluctance of truly sedentary individuals to be recruited for testing. Attempts were made to recruit sedentary individuals by advert and direct contact via presentations at secondary schools in the local area though only a few could be convinced to participate in the study.

Providing any external motivation to encourage sedentary individuals to participate was considered but disregarded as extrinsic motivation can decrease with the use of external rewards and so may further de-motivate the sedentary individuals to exercise. Varo *et al.,* (2003) and Bernstein *et al.,* (1999) have defined a sedentary individual as one who expends less than 10% of their leisure time energy expenditure in activities that require 4 METS or 4 times the basal metabolic rate, respectively. Following problems of recruiting truly sedentary subjects the criteria used in the present study were changed so that the 'sedentary' groups were simply non-soccer players – only 2 of them were sedentary by definition based on information they provided in the 7-day physical activity recall questionnaire and it was still a struggle to complete 13 subjects from the original target of 20. This may explain some of the homogenous results – especially in the physical activity category (section 5.2.1).

The problems encountered here are not just found in this study but highlight the problem common to all health sciences where truly representative sedentary subjects are needing to be recruited.

8.4 Sprints

The results showed that all three groups were faster over the second 10 metres of the sprint test. It was also found that the elite players were on average faster than the other 2 groups in agreement with Kollath & Quade (1993) and were 10 % ahead of recreational subjects and 22 % ahead of sedentary subjects after 10 m. This is not as much as the 49 % that Kollath & Quade (1993) found in different distances covered between elite and amateur players, though this is probably due to the older population. In the present study the population is age controlled which may explain the limited difference between subjects as they are at a similar stage of maturation.

Our elite population was fastest over 10 and 20 m. Concurring with this, Reilly *et al.* (2000b) found elite players to be faster than age matched sub-elite subjects over 15, 25 and 30 m, but not over 5 m. In that study Reilly *et al.* (2000b) also concluded that agility, speed, motivational orientation and anticipation skill appear to be the strongest predictors of talent. In this study the only discriminator between all three populations was sprint speed – this is the only common variable that was measured of the main discriminators found by Reilly *et al.* (2000b), though the findings are congruent.

Comparing the results of subjects in this study with those of soccer players at the Australian Institute of Sport (AIS, 1998) (table 15) would suggest on first assessment that our test subjects were much faster. In reality though, this is explained by the protocol; the Australian test starts 50 cm behind the line, while the test used in the present study had a 2 m run-in. Wisloff *et al.* (2004) used a 30 cm run-in with an older population (25.8±2.9 years) while Ozcakar *et al.* (2003) used a run-in of 1 m in an older population (23.62±3.57 years). Using an identical protocol (Murray *et al.*, 2005) shows more homogenous values with the present study. The population used was older (n=33, 21.1±1.8 years, 83.6±13.1 kg, 16.1±4.3 % BF) and comprised rugby and soccer players which probably explains the elite and recreational populations being faster over 10 m, when the heavier rugby players are still accelerating but more similar 20 m results once the top speed had been reached. This highlights the difficulties in comparing sprint times without taking into account differing protocols.

Table 15: Comparative sprint speeds

Squad	Sprint Times (seconds)		
	5m	**10 m**	**20 m**
AIS Youth (1998) (n=16)	1.11±0.06	1.85±0.06	3.13±0.09
Wisloff *et al.* (2004)	-	1.82±0.30	3.0±0.30
Ozcakar *et al.* (2003)	-	1.69±0.07	2.86±0.12
Murray *et al.* (2005)	-	1.70±0.06	2.94±0.11
Elite (present study)	-	1.45±0.05	2.73±0.08
Recreational (present study)	-	1.61±0.16	2.94±0.20
Sedentary (present study)	-	1.87±0.11	3.31±0.22

8.5 Isokinetic testing

While the present study found that the elite sample had the highest quadriceps peak torque of the three groups on average ($P \leq 0.02$) it was also found that in general the three groups were stronger on their right side. The sedentary group though had a stronger left hamstring than the right, which was unusual amongst the groups.

A possible criticism of the test chosen may be the speeds chosen for testing. The chosen speeds of 30°/s and 180°/s may have influenced the magnitude of torque measured (Keating and Mayatas, 1996). Generally the concentric torque decreases as the speed increases and so measurements are test specific. This was the case in the present study for quadriceps but not for hamstrings (figure 9). Eccentric forces have been found to vary little with speed (Hanten & Ramberg, 1988; Westing *et al.*, 1988; Perrin, 1993), which is more consistent with the present study (figure 9). Concentric quadriceps torque decreases more than concentric hamstring torque with increasing test velocity (Perrin, 1993) though in this case the hamstrings torque does not decrease with increasing speed. A possible reason for the discrepancy between the present study and the general findings that concentric torque falls with increasing speed may be unfamiliarity with the testing procedure. Generally concentric and hamstrings peak torque is highly reproducible (Pincivero *et al.*, 1997) though perhaps a familiarization is needed to produce the peak torques in unfamiliar machinery. It was not possible to include a separate familiarization day in the study design and the use of hamstrings in isolation is more unfamiliar to subjects than the use of quadriceps alone. It is the authors proposition that this unfamiliarity may mean that despite the best intentions of motivating subjects the peak torque at lower speeds may not be a true peak torque and so falling values at higher speeds is not seen.

Motivation of the subject to provide a maximal effort is the main objection against isokinetic testing of muscle strength (Åstrand & Rodahl, 1986). Maximal motivation is key for reproducible and valid strength test results. It has been reported that isokinetic testing has poor face validity (Wrigley, 2000) as athletes do not see it as important to athletic performance and so have a low motivation to perform. In this study subjects were informed of the procedure and how it related to soccer or health measures and they were provided with visual feedback of their performance (their own torque curve) to increase their motivation (Keating & Matyas, 1996; Campenella *et al.*, 2000).

In this study two speeds of testing were utilized. Slow-speed testing is most suitable for strength assessment (Kovaleski & Heitman, 2000; Kramer *et al.*, 2000) though it is a lot easier for the subject to perform well as only at these speeds will slow and fast twitch fibres be recruited (Perrin, 1993). Scoville *et al.* (1997) suggested that slow speed testing is more sensitive to the evaluation of ratios, though faster speeds may be better for a functional assessment of peak torque. Generally it is recommended that testing should be done over a spectrum of velocities to achieve a fuller picture of the relationship between isokinetic muscle strength, power and sporting performance (Perrin, 1993; Davies *et al.*, 2000).

It is not possible to test functionally the torque produced in a soccer kick as this occurs at velocities in the range of 773 – 1060°/s (13.5 – 18.5 $rad.s^{-1}$) (Lees &

Nolan, 2002) and the maximum angular velocity of current machinery is 300 °/s (5.25 rad.s^{-1}) but it is possible to monitor muscle strength up to this point.

The protocol followed in the present study is based on studies in the literature. Four repetitions were executed (Knues *et al.*, 1992; Perrin, 1993; Baltzopoulos & Brodie, 1998; Bennell *et al.*, 1998). Intervals of 90 s rest were used between test sections (Read *et al.*, 1990; Wilk *et al.*, 1994; Davies *et al.* 2000) and the protocol had also previously been used successfully in a young population (18.3±1.3 years) of soccer players (Ramsden, 2000).

While the speed used by Ramsden (2000) was 60°/s (1.04 rad.s^{-1}), various speeds of testing have been reported in the literature. O'Connor (1997) used 4 maximal extensions and flexions at 60 °/s and 30 repetitions at 300 °/s (5.25 rad.s^{-1}) to assess the peak torque, power, total work, endurance and peak torque ratios of the knee flexor and extensor. Togari *et al.* (1988) tested the leg extension power at 60 °/s, 120 °/s (2.09 rad.s^{-1}), 180 °/s (3.14 rad.s^{-1}), 240 °/s (4.19 rad.s^{-1}) and 300 °/s. Aagaard *et al.* (1998) assessed isometric contractions at 50°, 40° and 30° of knee flexion while isokinetically they used two speeds of 30 °/s & 240 °/s. It was decided to use the established protocol of Ramsden (2000) at the two speeds chosen by Oberg *et al.* (1984) – one to allow maximal strength assessment (30 °/s) and one for comparison at a higher speed (180 °/s).

While isokinetic testing is not motion or speed specific to the movement of the soccer kick, it still provided a reference value in the event of injury of the muscle strength ratio and any current imbalances (Cometti *et al.*, 2001). The H_{ecc}:Q_{con} ratio should ≈1 to prevent injury (i.e. the hamstrings should be able to resist as much force as the quadriceps can produce) (Scoville *et al.* 1997; Aagaard *et al.*, 1998) and this is the value that was hoped for, at least in the elite subjects. It should though be considered that the torque of quadriceps decreases more than that of hamstrings with an increased test velocity (Perrin, 1993). Therefore a lower ratio should be found at the lower speed. This was universally the case, though all of the ratios were considerably less than one, mostly in the range 0.6 - 0.8. The sedentary group had the highest ratios, mainly due to the lower peak torque produced by their quadriceps. All of the ratios are lower than 1, so on average no population appears to be protected from injury though the sedentary population tends to have the higher ratio (due to a lower peak torque from the quadriceps) and so are most protected from injury.

Despite the lack of an established equivalency in the literature between the strength assessment modes of the Technogym REV 9000 and other isokinetic testing devices in comparison to the literature, the subjects tested here generally under performed in relation to similar populations. Table 16 shows the results of the subjects in this study in comparison to two published studies, one conducted with soccer players on a Cybex machine and one with Australian Rules football (one of the footballing codes) on a Kin-com. In all cases the peak torques have been standardised to body weight to allow as fair as a comparison across ages as is able with different isokinetic equipment. In most cases the subjects in the present study have lower values than their counterparts. While the issue of maturation could be cited for the subjects of Bennell *et al.* (1998), Kellis *et al.* (2001) used subjects of exactly the same age. There is though a difference in comparison to the 13-year-old population that was also assessed by Kellis *et al.* (2001).

A possible cause of this poor performance was a lack of familiarization with the testing equipment. Some studies have used a familiarization period separate from the

Table 16: Comparative data for isokinetic strength

	Elite (present study)	Recreational (present study)	Sedentary (present study)	Bennell *et al.* (1998)[11, 12]	Kellis *et al.* (2001)[13, 14]	Kellis *et al.* (2001)[14, 15]
Quad Ecc L 180 (N.m/kgBW)	2.91±0.56	2.63±0.48	2.51±0.71	3.9±0.8	3.35±0.46	2.66±0.34
Quad Ecc R 180 (N.m/kgBW)	2.71±0.57	2.81±0.74	2.64±0.52	4.0±0.7	3.29±0.40	2.79±0.32
Ham Ecc L 180 (N.m/kgBW)	1.49±0.27	1.53±0.35	1.58±0.29	2.1±0.3	2.17±0.37	1.81±0.19
Ham Ecc R 180 (N.m/kgBW)	1.68±0.26	1.63±0.30	1.43±0.30	2.2±0.4	2.19±0.31	1.89±0.25
Quad Con L 180 (N.m/kgBW)	2.28±0.45	2.06±0.47	1.96±0.51	2.6±0.4	2.06±0.18	1.69±0.23
Quad Con R 180 (N.m/kgBW)	2.27±0.37	2.16±0.50	1.96±0.46	2.4±0.3	2.07 ±0.18	1.75±0.21
Ham Con L 180 (N.m/kgBW)	1.57±0.44	1.42±0.31	1.51±0.53	2.6±0.4	1.30±0.19	1.08±0.22
Ham Con R 180 (N.m/kgBW)	1.47±0.20	1.42±0.22	1.28±0.19	2.4±0.3	1.39±0.21	1.16±0.28

Legend: anthropometric data compiled from a variety of sources.

Where numerical data is given it is shown as means+standard deviation.

period of testing to ensure a maximal strength assessment. Generally though throughout the literature the use of a familiarization is mixed. Some studies have not used one (Bennell *et al.*, 1998; Cometti *et al.*, 2001; Kellis *et al.*, 2001) and some have (Colliander & Tesch, 1989; Orchard *et al.*, 1997; Aagard *et al.*, 1998;

[11] Data for Australian Rules footballers (n=102, 22.8+3.6 yrs)
[12] In this case L = injured leg. R = non-injured leg
[13] Data given for n=18, 16.4±0.2 yrs, soccer players of Greek talent programme
[14] In this case L = non-preferred leg and R = preferred leg

Masuda *et al.*, 2003). In retrospect a period of familiarization may have produced more favourable isokinetic results – especially for eccentric actions and those involving the hamstrings. This would also have also affected the observed functional ratios. In this project it was not possible to include a period of familiarization because of the pressure of time. It is commonplace in English academy testing to wait until at least the third visit before data is taken (Reilly, 2005 – personal communication). Any future programme of testing should look to include at least one familiarization session and ideally two before data collection.

8.6 Flexibility

Limitation of the range-of-movement can predispose individuals to injury as Ekstrand (1982) showed. He found that muscle tightness in the hamstring and adductors pre-disposed Swedish professionals to an increased injury risk but that soccer players are generally less flexible than non-athletes. Surprisingly Graham-Smith and Lees (2002) found that two-thirds of Rugby Union footballers had flexibility values poorer than non-players, which suggests that soccer players would also have a poor flexibility compared to the general population. Apor (1988) showed this when he found footballers to have a poor flexibility and Davis & Brewer (1993) also reported that female soccer players could benefit from exercise to increase the flexibility of hamstrings and lower back.

On this basis it was expected that the values of flexibility in the present study would decrease as the involvement in elite sport increases, i.e. the sedentary group would have the greatest value for flexibility with the soccer players having the

---

[15] Subjects n=18, 13.4±0.2 yrs

lowest. It was the author's initial opinion that the recreationally active group would have had the greatest flexibility due to their involvement in a number of sports, without specialisation in one particular area. This was not the case and the elite subjects had the greatest flexibility. This contrasts with reports in the literature (Ekstrand 1982; Apor, 1988; Davis & Brewer 1993; Graham-Smith & Lees 2002). A speculative reason for this is that muscular tightness is caused by an adaptation to soccer performance. The elite youth population have not been exposed to this repeated stimulus for as long (as they are 1st year full time professionals) and so their flexibility has not yet been affected. Another possibility is that the elite population pay more attention to flexibility training and so counteract the repeated muscle shortening associated with exercise. Shephard (1999) also stated that hamstring tightness can still be present and not prevent a good sit-and-reach score. A more sensitive measure of flexibility, such as using goniometry may have shown more discriminative results. Kirkendall (2000) stated that a soccer player should have a sit-and-reach score in the range of 25 to 35 cm, the elite subjects as you would expect are at the top end of this continuum, though surprisingly the sedentary subjects feature at the lower end. If they were truly sedentary they may not feature on this at all.

8.7 Testing continuum

Table 8 shows a number of protocols undertaken on primarily soccer players alone. In this case sedentary and recreational subjects were also being examined and so the protocol used has similarities with some previous protocols and striking differences to others.

A larger scale study (n=147) of similar variables was conducted in the Far East (Aziz *et al.*, 2003). In the present study a direct assessment of aerobic fitness was utilized with a progressive treadmill test rather than an estimation using a multi-stage fitness test, as this is a 'gold standard' test more suitable for a smaller sample. Field tests such as Aziz *et al.* (2003) used are feasible when testing many subjects for low costs, but in the present study precision and control (Hrysomallis, 2002) were paramount and so laboratory based tests were used.

A longitudinal study of a similarly aged population was conducted in Switzerland (Tschopp *et al.*, 2003). They sampled blood to obtain information about the lactate threshold but the increased number of ethical problems associated with sampling blood from minors outweighs the possible benefits of this procedure. As well as this, repeated sampling may have 'turned-off' minors to participate in the study as there is an association of blood sampling with pain.

The most similarities between the present and previous studies come with investigations that aimed to profile soccer players' fitness (Dunbar & Power, 1995; Dunbar & Treasure 2003). These studies used a lactate profile that was not used here due to the problems of repeated blood sampling and they investigated speed endurance, which due to time constraints and the fact that it is not crucial to the non-elite sub-populations was not assessed in the present study.

Bell (1988) performed the minimal set of tests described in figure 3. Hence its overall class rating of 2* in table 8. Bell's study was probably constrained by the subjects' age. The current study examined more variables following a protocol and time schedule similar to Mercer *et al.* (1995). While the present study only assessed subjects in pairs due to the tests being conducted in a laboratory setting, the general running order is fairly similar to that used by Mercer *et al.* (1995). The $\dot{V}O_{2\,max}$ test in the present study was administered last. While Doherty *et al.* (1991) stated 45 minutes was adequate for recovery time from an maximal aerobic fitness test, if this period of time was included in the test protocol it would have lengthened the procedure too much and made it prohibitive to the subject's participation had the testing all taken place in one day. With the introduction of a two-day protocol these problems were eliminated and it was pertinent to place this test at the end of day 1.

8.8 Paediatric Study

The population studied comprised under-17 footballers, aged 16 to 16.9 years, who are in the eyes of the law, minors. There are associated ethical considerations that had to be applied and are increasingly relevant in this age of accountability and litigation. The issues of consent in Scotland differ to the rest of the UK but as with all research it was the case in the present study that individuals were free to make a rational decision to take part or not (Jago & Bailey, 2001), but should children be able to consent to participation?

There is no precise age below 18 at which a child acquires legal capacity to consent (MRC, 1991, p16) to non-therapeutic research and it is not a legal requirement to obtain parental consent. While it was desirable to get the parents support and obtain their consent, this may have biased the results as it influenced which children could take part in the study. It could be construed that a parent believed he/she was acting with the child's best interests at heart, but the youth did not actually wish to participate or vice versa the child wished to participate and was prevented from doing so by the parent.

A better solution was to obtain parental consent along with the child's assent. While consent refers to a positive agreement, assent refers to acquiescence (British Paediatric Association, 1992, p12) and obtaining this from the child along with parental consent makes the research morally acceptable (on the grounds that the participant has agreed to participate) and legally valid, due to the parental consent.

The inclusion of youths as subjects is believed to aid their educational development. They learned how scientific research is conducted (Rowland, 1996, p 64) and while there is a negligible risk involved, the sociological benefits to the scientific community along with the educational benefits to the child outweigh this a hundred fold.

9.0 Limitations

9.1 Access to subjects

In reality, the population of professional footballers were not available above one session a week, so the continuum of testing was limited to two sessions of around 1 hour (the duration of a morning training session). This also covered the time that subjects were released from school for (i.e. one school period) so two testing periods were the maximum that could be obtained with minimum disruption.

Obviously the 'sedentary' subjects could have been truly sedentary though despite best efforts non-soccer players fulfilled the sedentary group. Truly sedentary individuals have an abhorrence of exercise and therefore it was difficult to recruit a truly representative sample for testing. The full quota of 20 subjects could have still been recruited though 13 subjects were enough to satisfy the power equation and give statistically significant results.

9.2 Exams & Close Season

During the school examination period, the subjects were not recruited, as it would have been an extra distraction for them, which contradicts the intention to make this research of an educational benefit (section 8.8). The close season was avoided for the elite subjects due to proposed changes in $\dot{V}O_{2max}$, this value varies throughout the season and is generally lowest at pre-season and higher throughout the year when games keep the maximum oxygen uptake maintained at the levels it reached pre-season. It is for this reason that this study was conducted during the playing season for soccer players, to give them the best possible chance of scoring highly.

9.3 Cholesterol

It was proposed to measure cholesterol as risk factors such as high serum cholesterol concentration measured in young adulthood can predict premature coronary heart disease (CHD) in middle-age. Total cholesterol levels are associated with CHD (Park & Ransome, 2003) and this measure along with the blood pressure would have given us an indication of CHD risk factors in the study population and any associated differences between the three reference groups.

As well as being a factor to deny inclusion in testing, due to the WHO guidelines on maximal exercise testing, high blood pressure is a potent cardiovascular disease risk factor, independent of the presence or absence of other factors that predict the likelihood of disease (Whelton, 1994). The main determinants of blood pressure in schoolchildren are body weight and height (Suurorg & Tur, 2001) and while height cannot be easily altered, regular exercise can lead to an increased cardiovascular fitness level and weight loss, which along with good nutrition can reduce the risk of CHD.

As well as reducing the levels of body fat and blood pressure, physical activity can improve the lipoprotein profiles of individuals (Bar-Or *et al.*, 1998). This is probably because age, %BF and body mass all affect the concentration of plasma lipids and lipoproteins in individuals (Berg *et al.*, 1994). Eisenmann (2002) reported the mean difference in total cholesterol levels between young athletes and controls as ± 0.26 $mmol.L^{-1}$. Sample values for soccer players of 3 years, training 6 days week are given as 4.58 $mmol.L^{-1}$ by Atomi *et al.* (1986) and as 4.24 $mmol.L^{-1}$ in 16-year-old male distance runners (Eisenmann, 2002). McArdle *et al.* (2002, p575) reported that any value under 5.2 $mmol.L^{-1}$ is desirable and so it was hoped all of the subjects would come in below this value for their health. While cholesterol would have been measured via a Analox GM7 analyser, the first few subjects tested gave unreliable results and it was decided to service the machine. As this was happening too many subjects completed the rest of the tests to make the measurement of cholesterol worthwhile.

9.4 Testosterone

While maturational differences were controlled for by chronological age this is a far from perfect marker of biological maturity, any differences detected may have been due to one of the groups being more mature (i.e. at a later stage of development) for their age, as early maturers can be at an advantage for elite soccer selection because of their size (Reilly, 2003). Often the level of maturity is not assessed due to the associated difficulties with this and so studies rely simply on the chronological age (Armstrong, 1998), but team sports, which rely on strength and power favour early maturers and as chronological age increases later maturing boys decrease (Malina, 2003). Methods to detect the chronological age range from the gold standard of skeletal age, which comes with the associated problems of exposing children to x-rays and so is not ethically or financially viable. Measurement of peak height velocity, needs repeated measurements over time (suitable for longitudinal study). Assessment of the level of secondary sex characteristics, is at best subjective and at worst carries a social stigma. Alternatively, testosterone levels could have been sampled. This can be done through serum blood samples, which as mentioned earlier, would be problematic in minors or via a salivary assay, which is extensively used in the paediatric sciences (Walker *et al.* 1980; Butler *et al.* 1989; Welsman *et al.* 1994).

Therefore it was proposed to obtain salivary samples between the hours of 09:00 and 10:00, (when diurnal variation dictates the levels are at their peak) to differentiate between the maturity levels of the subjects. Unfortunately this would have required analysis from an outside organization and so a financial hurdle prevented this meaning that chronological age was relied upon.

10.0 Future Study

Possible directions for further research in this area are as follows;

10.1 More subjects

As there is a demand for more data from populations around the world, continuing the research with elite subjects at least will provide more information on the Scottish soccer population at differing levels and may help to inform practice from year to year as coaches try to change their development techniques to maximise fitness. This approach is currently being developed via testing of youth squads from all of Scotland's divisions.

It should be considered though that to obtain enough truly sedentary subjects to allow a fuller comparison of all three groups would be problematic. To separate the three populations tested here with an 80% certainty for aerobic fitness would need over 80 subjects in each population based on the results obtained in this study.

10.2 Longitudinal testing

A continuation of testing different squads coming from the same clubs over differing seasons to assess development of fitness programmes is to monitor the same squad repeatedly over time. This obviously would be a costly business and may only be possible with the national teams or at some of the larger clubs. This investment though could only bring rewards and benefits at a time when Scotland's world ranking is as low as it ever has been.

10.3 Talent Identification

While it has been shown that generally there is a great deal of heterogeneity between populations with more numbers, it may be possible to identify clear differences between populations as was done for sprint speed. If testing of school children could become commonplace as it is in Australia with their National Talent Search programme (AIS, 2005), then perhaps a scaled down version of these tests could be developed to identify youths with the physical characteristics that pre-dispose them to a career in soccer. Obviously consideration would have to be given to the ethics of this approach and care would have to be taken to not exclude individuals on the basis of size but to merely guide their development both physically and mentally through sport.

10.4 Paradigm shift

Perhaps the most important area for future developments is to change the attitudes of those in football who are still opposed to the use of fitness testing and view it as an intrusion rather than an aid to performance. These are the greatest hindrances to Scotland's development rather than a generally poor fitness level as fitness can be changed if approaches to it are allowed to.

11.0 Conclusion

The aims of this study where to;

1. To compare the physiological characteristics of three distinct groups (elite soccer players, recreational soccer players and sedentary individuals).
2. To investigate if there is an additional health or physiological benefit of being an elite performer rather than simply a recreational one.
3. To establish a test battery that could be used to gather baseline information on Scottish youth footballers to allow comparisons with similar groups in other countries.

The study has met both aims in the following ways;

1. In comparison amongst the three groups tested the elite youth soccer players had higher $\dot{V}O_{2\,peak}$, sprint speed, concentric quadriceps peak torque and lower % BF than non-soccer players. Recreational soccer players had a higher $\dot{V}O_{2\,peak}$ and quicker sprint times than the non-soccer players. The lower aerobic fitness scores for the non-soccer players suggest that increased activity levels in this population will promote enhanced fitness levels. This may also protect the sedentary populations from the associated health problems that come with having the highest body fat and lowest aerobic fitness of the three studied populations.

2. The differences between elite and recreational players were not as wide as might have been expected prior to testing. It seems that the small but significant physiological benefits to elite soccer players in comparison to

recreational performers are a greater flexibility, a faster sprint speed over 10 and 20 m and a lower percentage body fat.

3. The battery of tests used in the study has provided a framework for a test battery that will allow baseline data to be gathered from a Scottish population of youth footballers. The main modification that would need to be made before data is gathered is to include a familiarization period in the isokinetic protocol. Comparison of the limited data set of elite Scottish youth soccer players with elite youth soccer players in other countries shows that Scottish youth players had lower scores for $\dot{V}O_{2\,peak}$.

12.0 References

Aagaard, P., Simonsen, E.B, Trolle, M., Bangsbo, J. & Klausen, K. (1995). Isokinetic hamstring/quadriceps ratio: influence from joint angular velocity, gravity correction and mode of contraction. *Acta Physiologica Scandinavica*, **154**, 421-427.

Aagaard, P., Simonsen, E.B., Magnusson, S.P., Larsson, B. & Dyhre, P. (1998). A new concept for isokinetic hamstring : quadriceps muscle strength ratio. *American Journal of Sports Medicine*, **26**, 231-236.

Adams, T. (2003). 'Why I must learn sport science'. BASES World, September Edition, 19-20.

Agre, J.C. (1985). Hamstring injuries. Proposed aetiological factors, prevention and treatment. *Sports Medicine*, **2**, 21-33.

Al-Hazzaa, H.M., Alumuzaini, K.S., Al-Rafaee, A., Sulaiman, M.A., Dafterdar, M.Y., Al-Ghamedi, A. & Khuraiji, K. (2001). Aerobic and anerobic power characteristics of Saudi elite soccer players. *Journal of Sports Medicine and Physical Fitness*, **41**, 54-61.

American College of Sports Medicine. (1990). The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness in Healthy Adults. ACSM Position Stand. *Medicine and Science in Sports and Exercise*, **2**, 265-274.

Apor, P. (1988). Successful formulae for fitness training. In *Science and Football*. (edited by T. Reilly, A. Lees, K. Davids, & W.J. Murphy), pp95-107. London: E & FN Spon.

Armstrong, N. (1998). Physical fitness and physical activity during childhood and adolescence. In *Sports and Health in Children*. (edited by K.M. Chen & L.J. Micheli), pp50-75. Hong Kong: Williams and Wilkins.

Armstrong, N., Balding, J., Gentle, P. & Kirby, B. (1990). Estimation of coronary risk factors in British schoolchildren: a preliminary report. *British Journal of Sports Medicine*, **24**, 61-66.

Armstrong, N., Williams, J., Balding, J., Gentle, P. & Kirby, B. (1991). The peak oxygen uptake of British children with reference to age, sex and sexual maturity. *European Journal of Applied Physiology*, **62**, 369-375.

Armstrong, N., Kirby, B., McManus, A. & Welsman, J. (1995). Aerobic fitness of pre-pubescent children. *Annals of Human Biology*, **22**, 427-441.

Armstrong, N., Welsman, J. & Winsley, R. (1996). Is peak VO2 a maximal index of children's aerobic fitness? *International Journal of Sports Medicine*, **17**, 356-359.

Armstrong, N., Welsman, J.R. & Kirby, B.J. (1998). Peak oxygen uptake and maturation in 12-year olds. *Medicine and Science in Sports and Exercise*, **30**, 165-9.

Armstrong, N. & Welsman, J.R. (2001). Peak Oxygen Uptake in Relation to growth and Maturation in 11 to 17 year old humans. *European Journal of Applied Physiology*, **85**, 546-551.

Åstrand, P.O. (1952). *Experimental studies of physical working capacity in relation to sex and age.* Copenhagen: Munksgaard.

Åstrand, P.O. (1994). 'Physical activity and fitness: Evolutionary perspective and trends for the future'. In C. Bouchard, R.J. Shepard & T. Stephens (eds). *Physical Activity, Fitness and Health.* pp98-105. Champaign, Illinois: Human Kinetics.

Åstrand, P.O., & Rodahl, K. (1986). Textbook of work physiology. London: McGraw-Hill.

Atomi, Y., Kuroda, Y., Asami, T. *et al.* (1986). HDL-cholesterol of children (10 to 12 years of age) related to VO2 max, body fat and sex. In *Children and Exercise: XII.* (edited by J. Rutenfranz, R. Moeellin, & F. Flimt), pp167-172. Champaign, Illinois: Human Kinetics.

Australian Institute of Sport. (1998). Protocols for the Physiological Assessment of Male and Female Soccer Players. (Report # 514321 Canberra: Australian Institute of Sport).

Australian Institute of Sport. (2005). National Talent Search Programme. (www.ais.org.au/talent/faq.asp) accessed on 15/02/05.

Aziz, A.R., Tan, F., Yeo, A., Teh, K.C. (2003). Physiological attributes of professional players in the Singapore soccer league. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April 2003*, p301. Madrid: Gymos Editorial Deportiva.

Baltzopoulos, V. & Brodie, D. (1989). Isokinetic dynamometry: applications and limitations. *Sports Medicine*, **8**, 101-116.

Bangsbo, J. (1994a). The physiology of soccer - with special reference to intense intermittent exercise. *Acta Physiologica Scandinavia*, 619 (Supp), 1-155.

Bangsbo, J. (1994b). *Fitness training in football – a scientific approach.* Bagsvaerd: HO & Storm.

Bangsbo, J. (1994c). Energy demands in competitive soccer. *Journal of Sports Sciences*, **12**, S5-12.

Bangsbo, J., Krustrup, P. & Mohr, M. (2003). Physical Capacity of High-level soccer players in relation to playing position. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April* 2003, p76. Madrid: Gymos Editorial Deportiva.

Bar-Or, O., Foreyt, J., Bouchard, C., Drownell, K.D., Deitz, W.H., Ravussin, E., Salbe, A.D., Schwenger, S., St. Jeor, S. & Torun, B. (1998). Physical activity, genetic, and nutritional considerations in childhood weight management. *Medicine and science in sports and exercise,* **30(1)**, 2-10.

Bell, W. (1988). Physiological Characteristics of 12 year old soccer players. In *Science and Football,* (edited by T, Reilly, A. Lees, K. Davids, & W.J. Murphy), pp175-80. London: E and FN Spon.

Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D. & Cirone, J. (1998). Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers. *British Journal of Sports Medicine*, **32**, 309-314.

Berg, A., Frey, I., Baumstark, M.W., Halle, M. & Keul, J. (1994). *Physical Activity & Lipoprotein lipid disorders.* Sports Medicine, **17**, 6-21.

Bernstein, M., Morabia, A. & Slouthis, D. (1999). Definition and Prevalence of Sedentarism in an urban population. *American Journal of Public Health,* **89(6)**, 862-867.

Biddle, S.J.H., & Mutrie, N. (2001). Psychology of physical activity: Determinants, well-being and interventions. London: Routledge.

Biddle, S.J.H., Gorely, T. & Stensel, D. (2004). Health enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of Sports Sciences,* **22**, 679-701.

Blair, S.N., Kampert, J.B., Kohl, H.W. 3rd, Barlow, C.E., Macera, C.A., Paffenbarger, R.S. Jr & Gibbons, L.W. (1995). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *Journal of the American Medical Association.* **276(3)**, 205-10.

Blair, S.N. & Brodney, S. (1999). Effects of physical inactivity and obesity on morbidity and mortality: Current evidence and research issues. *Medicine and Science in Sports and Exercise*, **31**, S646-662.

Blair, S.N. & Church, T.S. (2004). The fitness, obesity & health equation – is physical activity the common denominator? *Journal of the American Medical Association*, **292**, 1232-1234.

Brady, K., Maile, A. & Ewing, B. (1997). An investigation into the fitness of professional soccer players over 2 seasons. In *Science and Football III*, (edited by T. Reilly, J. Bangsbo, & M. Hughes), pp118-122. London: E and FN Spon.

Bray, K. & Kerwin, D. (2004) The unsavable zone. *The Guardian.* 24th June 2004.

Brick, N. & O'Donoghue, P. (2003). Fitness profiles of elite players in hurling and three football codes: soccer, rugby union and Gaelic football. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April 2003,* p79. Madrid: Gymos Editorial Deportiva.

British Heart Foundation. (2000). *Couch kids: The growing epidemic*. London: British Heart Foundation.

British Paediatric Association. (1992). *Guidelines for the Ethical Conduct of Medical Research involving Children*. London: BPA.

Buchfuhrer, M. J., Hansen, J. E., Robinson, T. E., Sue D. Y., Wasserman, K. & Whipp, B.J. (1983). Optimizing the exercise protocol for cardiopulmonary assessment. *Journal of Applied Physiology*, **55**, 1558-1564.

Burkett, L.N. (1970). Causative factors in hamstring strains. *Medicine and Science in Sports and Exercise*, **2**, 39-42.

Butler, G.E., Walker, R.F., Walker, R.V., Teague, P., Riad-Fahmy, D. & Ratcliffe, S.G. (1989). Salivary Testosterone Levels and the Progress of Puberty in the Normal Boy. *Clinial Endocrinology*, **30**, 587-596.

Campenella, B., Mattacola, C.G. & Kimura, I. (2000). Effect of visual feedback and verbal encouragement on concentric quadriceps and hamstrings peak torque of males and females. *Isokinetics and exercise science*, **8**, 1-6.

Carminati, I. (2004). http://www.TheFA.com. 18th June 2004

Casajus, J.A. (2001). Seasonal variation in fitness variables in professional soccer players. *Journal of Sports Medicine and Physical Fitness*, **41 (4)**, 463- 469.

Caspersen, C.J., Powell, K.E. & Christenson, G.M. (1985). Physical activity, exercise and physical fitness: Definitions and distinctions for health related research. *Public Health Reports*, **100**, 126-131.

Clark, D., McKeon, A., Sutton, M. & Wood, R. (2004). Healthy life expectancy in Scotland. On behalf of the HLE measuremtent in Scotland Steering group. Edinburgh, NHS.

Colliander, E.B. & Tesch, P.A. (1989). Bilateral eccentric and concentric torque of quadriceps and hamstring muscles in females and males. *European Journal of Applied Physiology*, **59**, 227-232.

Cometti, G., Maffiuletti, N.A., Pousson, M., Chatard, J.C. & Maffulli, N. (2001). Isokinetic strength and anaerobic power of elite, sub-elite and amateur French soccer players. *International Journal of Sports Medicine*, **22**, 45-51.

Coole, W.G. & Gieck, J.H. (1987). An analysis of hamstring strains and their rehabilitation. *Journal of Orthopaedic Sports Physical Therapy*, **9**, 77-85.

Coombs, R. & Garbutt, G. (2002). Developments in the use of the hamstring / quadriceps ratio for the assessment of muscle balance. *Journal of Sports Science and Medicine*, **1**, 56-62.

Cooper, D.M., Weiler-Ravell, D., Whipp, B.J. & Wasserman, K. (1984). Aerobic parameters of exercise as a function of body size during growth. *Journal of Applied Physiology*, **56**, 628-634.

Cunningham, D.A., MacFarlane, B., Waterschoot, V., Paterson, D.H., Lefcoe, M. & Sangal, S.P. (1977). Reliability and reproducibility of maximal oxygen uptake measurement in children. *Medicine and Science in Sports*, **9**, 104-108.

Davies, G.J., Heiderschiet, B., Brinks, K. (2000). Test interpretation. In: *Isokinetics and Human Performance.* (edited by E., Brown), 3-24. Illinois: Human Kinetics.

Davis, J.A. & Brewer, J. (1993). Applied physiology of female soccer players. *Sports Medicine,* **16 (3)**, 180-189.

Delecluse, C., Van Coppenolle, H., Willems, E., Van Leemputte, M., Diels, R. & Goris, M. (1995). Influence of high-resistance and high velocity training on sprint performance. *Medicine and Science in Sports and Exercise*, **27(8)**, 1203-1209.

DeProft, E., Cabri, J., Dufour, W. & Clarys, J.P. (1988a). Strength training and kick performance in soccer players. In *Science and Football* (edited by T.Reilly, A. Lees, K. Davids & W.J. Murphy), pp108-113. London: E and FN Spon.

DeProft, E., Clarys, J.P., Bollens, E., Cabri, J. & Dufour, W. (1988b). Muscle activity in the soccer kick. In *Science and Football* (edited by T.Reilly, A. Lees, K. Davids & W.J. Murphy), pp434-440. London: E and FN Spon.

DiGiuiseppi, C., Roberts, I. & Li, L. (1997). Influence of changing travel patterns on child death rates from injury: trend analysis. *British Medical Journal*, **314**, 710.

Dunbar, G.M.J. & Power, K. (1995). Fitness profiles of English professional and semi-professional soccer players using a battery of field tests. *Journal of Sports Sciences*, **13**, 501-502.

Dunbar, G.M.J. & Treasure, D. (2003). An analysis of fitness profiles as a function of playing position and playing level in three English premier league soccer clubs. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April 2003*, p186. Madrid: Gymos Editorial Deportiva.

Duncan, P.W., Chandler, J.M., Cavanagh, D.K, Johnson, K.R. & Buehler, A.G. (1989). Mode and speed specificity of eccentric and concentric exercise training. *Journal of Orthopaedic Sports Physical Therapy*, **11**, 70-75.

Durnin, J.V.G.A. (1992). Physical activity levels past and present. In: *Physical Activity and Health* (edited by N.Morgan), pp20-27. Cambridge: Cambridge University Press.

Durnin, J.V.G.A. & Rahaman, M.M. (1967). The assessment of the amount of fat in the human body from measurements of skinfold thickness. *British Journal of Nutrition*, **21**, 681-689.

Durnin, J.V.G.A. & Womersley, J. (1974). Body fat assessed from total body density and it estimation from skinfold thickness: Measurements from 481 men and women aged from 16 to 72 years. *British Journal of Nutrition*, **32**, *77-97.*

Doherty, M., Dunbar, J., Collins, D.J., McInnis, G. & Faulmann, L.K. (1991). Optimal recovery from an endurance task prior to the Wingate anaerobic test. *Journal of Sports Sciences*, **9**, 413.

Dowson, M.N., Cronin, J.B. & Presland, J.D. (2002). Anthropometric and Physiological Differences between gender and age groups of New Zealand National Soccer Players. In *Science and Football IV*. (edited by W. Spinks, T. Reilly & A. Murphy), pp 63-71. London: Routledge.

Eisenmann, J.C. (2002). Blood lipids and lipoproteins in child and adolescent athletes. *Sports Medicine*, **32(5)**, 297-307.

Ekblom, B. (1986). Applied physiology of soccer. *Sports Medicine*, **3**, 50-60.

Ekstrand, J. (1982). Soccer injuries and their prevention. Doctoral thesis, Linkoping University.

Erith, S.J. (2004). An overview of fitness testing within English professional football clubs. *Journal of Sports Sciences*, **22(3)**, 247-8.

European Commission (2003) Physical Activity. Special Eurobarometer 183-6/ Wave 58.2- European Opinion Research Group EEIG.
http://europa.eu.int/comm/public_opinion/archives/ebs/ebs_183_6_en.pdf

Evans, A., Tolonen, H., Hense, H.W., Ferrario, M., Sans, S., Kuulasmaa, K., for the WHO MONICA Project (2001) Trends in coronary risk factors in the WHO Monica Project. *International Journal of Epidemiology*, **30**, S35-S40.

Foxdal, P., Sjodin, A. & Sojdin, B. (1995). Comparison of blood lactate concentrations obtained during incremental and constant intensity exercise. *International Journal of Sports Medicine*, **17**, 360-365.

Franks, A.M., Williams, A.M., Reilly, T. & Nevill, A. (1999). Talent identification in elite youth soccer players: Physical and Physiological Characteristics. *Journal of Sports Sciences*, **17**, 812.

Franks, A.M., Williams, A.M., Reilly, T. & Nevill, A.M. (2002). Talent identification in elite youth soccer players: Physical and Physiological Characteristics. In *Science and Football IV*. (edited by W. Spinks, T. Reilly & A. Murphy), pp265-270. London: Routledge.

Graham-Smith, P. & Lees, A. (2002). Risk assessment of hamstring injury in rugby union place kicking. In *Science and Football IV* (edited by W. Spinks, T. Reilly & A. Murphy), pp183-189. London: Routledge.

Hamzeh, M. & Head, A. (2004). Isokinetic hamstrings and quadriceps evaluation of professional soccer players. *Journal of Sports Sciences*, **22(3)**, 265-266.

Hanten, W.P. & Ramberg, C.L. (1998). Effect of stabilization ion maximal isokinetic torque of the quadriceps femoris muscle during concentric and eccentric contraction. *Physical Therapy*, **61**, 64-67.

Hawley, J.A. (1999). Guidelines for laboratory and field testing of athletic potential and performance. In *Basic and Applied Sciences for Sports Medicine.* (edited by R.J. Maughan), p314. Oxford: Butterworth-Heinemann.

HEBS (1997) Physical Activity: A strategic statement, HEBS, Edinburgh

Heiser, T.M., Weber, J, Sullivan, G., Clare, P. & Jacobs, R.R. (1984). Prophylaxis and management of hamstring muscle injuries in intercollegiate football players. *American Journal of Sports Medicine*, **12**, 368-370.

Helgerud, J., Engen, L.C., Wisloff, U. & Hoff, J. (2001). Aerobic training improves soccer performance. *Medicine and Science in Sports and Exercise*, **33**, 1925-31.

Hergenroeder, A.C. & Klish, W.J. (1990). Body composition in adolescent athletes. *Paediatric Clinics of North America*, **37(5)**, 1057-1083.

Hill, A.V., London, C.N.H. & Lupton, H. (1924). Muscular exercise, lactic acid and the supply and utilization of oxygen. Parts IV – VIII. *Proceedings of the Royal Society of London*, **B97**, 84-138, 155-176.

Hood, P., Barnes, C. & Atkinson, G. (2003). Age and seasonal variation in the soccer-specific performance of English youth academy players. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April 2003*, p149. Madrid: Gymos Editorial Deportiva.

Hrysomallis, C., Koski, R., McCoy, M. & Wrigley, T. (2002). Correlations between field and laboratory test of strength, power and muscular endurance for elite Australian rules footballers. In *Science and Football IV* (edited by W. Spinks, T. Reilly & A. Murphy), pp81-85. London: Routledge.

Hugg, P.J. (1994). The selection of Australian youth soccer players based on physical and physiological characteristics. *Unpublished masters thesis*, University of Canberra.

Institute of European Food Studies, Trinity College Dublin (1999) A Pan-EU Survey on Consumer Attitudes to Physical Activity, Body-weight and Health. IEFS.

Jago, R. & Bailey, R. (2001). Ethics and paediatric exercise science: Issues and making a submission to a local ethics and research committee. *Journal of Sports Sciences*, **19**, 527-535.

Jankovic, S., Heimer, N. and Matkovic, B.R. (1993). Physiological profile of prospective soccer players. In *Science and Football II* (edited by T. Reilly, J. Clarys and A. Stibbe), pp. 295-297. London: E & FN Spon.

Jankovic, S., Matkovic, B.R. & Matkovic, B. (1997). Functional abilities and process of selection in soccer. Communication to the 9th European Congress of Sports Medicine, Porto, Portugal, 23-26 September.

Jones, A.D.G. and Helms, P. (1993). Cardiorespiratory fitness in young British soccer players. In *Science and Football II* (edited by T. Reilly, J. Clarys and A. Stibbe), pp. 298-303. London: E & FN Spon.

Kannus, P. (1994). Isokinetic evaluation of muscular performance: Implications for muscle testing and rehabilitation. *International Journal of Sports Medicine*, **15** suppl 1, 11-15.

Keating, J.L. & Matyas, T.A. (1996). The influence of subject and test design on dynamometric measurements of extremity muscles. *Physical Therapy*, **76**, 866-889.

Kellis, S., Gerodimos, V., Kellis, E. & Manou, V. (2001). Bilateral isokinetic concentric and eccentric strength profiles of the knee extensors and flexors in young soccer players. *Isokinetic Exercise Science*, **9**, 31-39.

Kemi, O.J., Hoff, J., Engen, L.C., Helgerud, J. & Wisloff, W. (2003). Soccer specific testing of maximal oxygen uptake. *Journal of Sports Medicine and Physical Fitness*, **43**, 139-44.

Kemper, H.C.G. (1994). Is leg muscle mass decisive in reaching a plateau in oxygen uptake during maximal treadmill running? Analysis of data from the Amsterdam Growth and Health Study. *American Journal of Human Biology*, **6**, 437-444.

Kirkendall, D.T. (2000). Physiology of Soccer. In: *Exercise & Sport Science*, (edited by, W.E. Garrett, D.T. Kirkendall), pp875-884. New York: Lippincott, Williams & Wilkins.

Knues, J.M., Rothstein, J.M., Lamb, R.L. (1992). Obtaining reliable measurements of knee extensor torque produced during maximal voluntary contractions: An experimental investigation. *Physical Therapy*, **72**, 429-501.

Kollath, E. & Quade, K. (1993). Measurement of sprinting speed of professional and amateur soccer players. In *Science and Football II*, (edited by T. Reilly, J. Clarys and A. Stibbe), pp31-36. London: E and FN Spon.

Kovaleski, J.E. & Heitman, R.E. (2000). Testing and training the upper extremity. In: *Isokinetics and Human Performance*, E. Brown (ed.), 171-195. Champaign, IL: Human Kinetics.

Kramer, W.J., Mazzetti, S.A., Ratamess, N.A. & Fleck, S.J. (2000). Specificity of training modes. In: *Isokinetics and Human Performance*, E. Brown (ed.), 25-41. Champaign, IL: Human Kinetics.

Leatt, P., Shephard, R.J. and Plyley, M.J. (1987). Specific muscular development in under-18 soccer players. *Journal of Sports Sciences*, **5**, 165-175.

Lee, C.D., Blair, S.N. & Jackson, A.S. (1999). Cardiorespiratory fitness, body composition and all-cause cardiovascular disease mortality in men. *American Journal of Clinical Nutrition*, **69**, 373-380.

Lee, I.M. & Paffenberger, J.R. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *American Journal of Epidemiology*, **151**, 293-299.

Lees, A. & Nolan, L. (2002). Three dimensional kinematic analysis of the instep kick under speed and accuracy conditions. In *Science and Football IV*, (edited by W. Spinks, T. Reilly & A. Murphy), pp16-21. London: Routledge.

LeMura, L.M., von Duvillard, S.P., Cohen, S.L., Root, C.J., Chelland, S.A., Andreacci, J., Hoover, J. & Weatherford, J. (2001). Treadmill and cycle ergometry testing in 5 to 6 year old children. *European Journal of Applied Physiology*, **85**, 472-478.

Lobstein, T., Baur, L., Uaoy, R. for IASO International Obesity Task Force. (2004). Obesity in children and young people: a crisis in public health. *Obesity Reviews*, **5**, 4-85.

Lourenco, L. (2004). Josĕ Mourinho: Made in Portugal. Stockport: Dewi Lewis Media. p23.

Lowther, M., Mutrie, N, Loughlan, C. & McFarlane, C. (1999). Development of a Scottish physical activity questionnaire: a tool for use in physical activity interventions. *British Journal of Sports Medicine*, **33**, 244–249.

M.R.C. (1991). *The Ethical Conduct of Research on Children.* London: MRC.

Malina, R.M. (2003). Growth and Maturity status of young soccer players. In *Science and Soccer (2nd Ed).* (edited by T. Reilly & A. Williams), pp287-306. London: Routledge.

Marcus, B.H., Rossi, J.S., Selby, V.C., *et al.* (1992). The stages and processes of exercise adoption and maintenance in a worksite sample. *Health Psychology*, **11**,386–95.

Marshall, S.I., Biddle, S.J.H., Murdey, I., Gorely, T.J. & Cameron, N. (2002a). Developing ecological self reports of sedentary behaviour and physical activity among youths: a momentary time-sampling approach. *Unpublished manuscript*, Loughborough University. Cited in: Biddle, S.J.H., Gorely, T. & Stensel, D. (2004). Health enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of Sports Sciences*, **22**, 679-701.

Marshall, S.I., Biddle, S.J.H., Sallis, J.F., McKenzie, T.L. & Conway, T.L. (2002b). Clustering of sedentary behaviours and physical activity among youth: a cross sectional study. *Paediatric Exercise Science*, **14**, 401-17.

Masuda, K., Kikuhara, N., Takahashi, H. & Yamanaka, K. (2003). The relationship between muscle cross-sectional area and strength in various isokinetic movements among soccer players. *Journal of Sports Sciences*, **21**, 851-858.

McArdle, W.D., Katch, F.I. & Katch, V.L. (2002). Essentials of exercise physiology 2nd ed. London: Lippincott Williams & Wilkins. 575.

McDevitt, B. (2004). Validity and reliability of the Glasgow Sports Medicine Fitness Test. *Unpublished manuscript*, Glasgow University.

McMillan, K., Macdonald, R., Newell, J. & Grant, S. (2002). Factor analysis of a fitness test battery for professional soccer players. *Journal of Sports Sciences,* **20 (1)**, 24-25.

Mercer, T.H., Gleeson, N.P. & Mitchell, J. (1995). Fitness profiles of professional soccer players before and after pre-season conditioning. *Journal of Sports Sciences*, **13**, 504-505.

More, R.C., Karras, B.T., Neiman, R., Fritschy, D & Woo, S.L. (1993). Hamstrings – an anteri- or cruciate ligament protagonist: an in vitro study. *American Journal of Sports Medicine*, **21**, 231-237.

Morris, J.N. (1994). Exercise in the Prevention of Coronary Heart Disease: today's best buy in public health. *Medicine and Science in Sport and Exercise,* **26**, 807-814.

Morris, J. (2003). Foreword. In: Physical Activity & Health: The evidence explained. Eds: A. Hardmann, & D. Stensel. Routledge: London.

Murray, A. (2004). The pro's and con's of fitness testing in soccer. Talk as part of Glasgow Rangers medical symposia. Murray Park, Glasgow, April 2004.

Murray, A., Aitchison, T.C., Ross, G., Sutherland, K., Watt, I., McLean, D. & Grant, S.J. (2005). The effect of towing a range of relative resistances on sprint performance. *Journal of Sports Sciences*, **23(9)**, 937-942.

Myers, J., Walsh, D., Sullivan, M. & Froelicher, V. (1990). Effect of sampling on variability and plateau in oxygen uptake. *Journal of Applied Physiology*, **68**, 404-410.

National Statistics (2004). Cited in: Business Life. British Airways, In flight magazine pp18-19.

Nicholson, R.N. (e.d.) (1986). *Medical Research with Children: Ethics, Law and Practice.* Oxford: Oxford University Press.

Noakes, T.D. (1988). Implications of exercise testing for prediction of athletic performance: a contemporary perspective. *Medicine and Science in Sports and Exercise*, **20**, 319-330.

Norton, K. & Olds, T. (2001). Morphological evolution of athletes over the 20th Century: causes and consequences. *Sports Medicine*, **31**, 763-783.

Nosse, L. (1982). Assessment of selected reports on the strength relationship of the knee musculature. *Journal of Orthopaedics and Sports Physical Therapy*, **4**, 78-85.

Oberg, B., Ekstrand, J., Moller, M. & Gillquist, J. (1984). Muscle strength and Flexibility in Different Positions of Soccer Players. *International Journal of Sports Medicine*, **5**, 213-216.

Oberg, B., Moller, M., Gillquist, J. & Ekstrand, J. (1986). Isokinetic torque levels for knee extensors and knee flexors in soccer players. *International Journal of Sports Medicine*, **7**, 50-53.

O'Connor, D. (1997). Fitness profile of professional rugby league players. In *Science and Football III* (edited by T. Reilly, J. Bangsbo, & M.Hughes), p176. London: E and FN Spon.

Orchard, J., Marsden, J., Lord, S. & Garlick, D. (1997). Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *The American Journal of Sports Medicine*, **25**, 81-85.

Ozcakar, L., Kunduracyoolu, B., Cetin, A., Ülkar, B., Guner, R. & Hascelik, Z. (2003). Comprehensive isokinetic knee measurements and quadriceps tendon evaluations in footballers for assessing functional performance. *British Journal of Sports Medicine*, 37, 507-510.

Park, D.H. & Ransome, J.W. (2003). Effects of submaximal exercise on HDL-Cholesterol subfractions. *International Journal of Sports Medicine,* **24(4)**, 245-51.

Pate, R.R., Pratt, M., Blair, S.N., Haskell, W.L., Macera, C.A., Bouchard, C., Buchner, D., Ettinger, W., Heath, G.W., King, A.C., *et al.* (1995). Physical activity and public health. *Journal of the American Medical Association*, **273**, 402-407.

Perrin, D.H. (1993). *Isokinetic exercise and assessment.* Champaign, IL: Human Kinetics.

Petersen, S., Peto, V., Rayner, M., Lead, J., Luengo-Fernandez, R. & Gray, A. (2005). European cardiovascular disease statistics: 2005 edition. European Heart Network & British Heart Foundation.

Pincivero, D.M., Lephart, S.M. & Karunakara, R.A. (1997). Reliability and precision of isokinetic strength and musclar endurance for the quadriceps and hamstrings. *International Journal of Sports Medicine*, **18**, 113-117.

Pincivero, D.M. & Heller, B.M. (2002). The effects of ACL injury on quadriceps and hamstring torque work and power. *Journal of Sports Sciences,* **20(9)**, 689-697.

Prentice, A.M. & Jebb, S.A. (1995). Obesity in Britain: Gluttony or Sloth? *British Medical Journal,* **311**, 437-339.

Public Health Institute of Scotland (2001). Chasing the Scottish Effect. November 2001.

Ramsden, J. (2000). Isokinetic profiling of youth professional soccer players. *Unpublished manuscript*, Glasgow University.

Read, M.T.F. & Bellamy, M.J. (1990). Comparison of hamstring/quadriceps isokinetic strength ratios and power in tennis, squash and track athletes. *British Journal of Sports Medicine*, **24**, 178-182.

Reilly, J.J. (2005). Fat or fiction? The truth about our chubby children. *The Scotsman*, 17th February.

Reilly, J.J. & McDowell, Z.C. (2003). Physical activity interventions in the prevention and treatment of paediatric obesity: systematic review and critical appraisal. *Proceedings of the Nutrition Society*, **62**, 611-619.

Reilly, J.J., Jackson, D.M., Montgomery, C., Kelly, L.A., Slater, C., Grant, S., Paton, J.Y. (2004). Total energy expenditure and physical activity in young Scottish children: Mixed longitudinal study. *Lancet*, **363** (9404), 211-212.

Reilly, T. (1979). *What Research Tells the Coach about Soccer*. Washington DC: American Alliance for Health, Physical Education, Recreation and Dance.

Reilly, T. (1994a). Physiological aspects of soccer. *Biology of Sport*, **11(1)**, 3-20.

Reilly, T. (1994b). Motion characteristics. In: B. Ekblom (ed.). Football (Soccer). Blackwell Scientific publications, 78-95.

Reilly,T. (2003). Different populations. In *Science and Soccer (2nd Ed)*, (edited by T. Reilly & A. Williams), p99. London: Routledge.

Reilly, T. & Doran, D. (2003). Fitness Assessment. In *Science and Soccer (2nd Ed)*, (edited by T. Reilly & A. Williams), p21. London: Routledge.

Reilly, T. & Gilbourne, D. (2003). Science and football: a review of applied research in the football codes. *Journal of Sports Sciences*, **21**, *693-705*.

Reilly, T. & Thomas, T. (1976). A motion analysis of work rate in different positional roles in professional football match play. *Journal of Human Movement Studies*, **2**, 87-97.

Reilly, T. & Williams, A.M. (2003). Science and Soccer. *2nd ed*. Routledge, London.

Reilly, T., Bangsbo, J. & Franks, A. (2000a). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, **18**, 669-83.

Reilly, T., Williams, A.M., Nevill, A. & Franks, A. (2000b). A Multidisciplinary Approach to Talent Identification in Soccer. *Journal of Sports Sciences*, **18**, 695-702.

Rico-Sanz, J., Frontera, W.R., Mole, P.A., Rivera, M.A., Rivera-Brown, A. & Meredith, C.N. (1998). Dietary and performance assessment of elite soccer players during a period of intense training. *International Journal of Sports Nutrition*, **8**, 230-40.

Rico-Sanz, J., Zehnder, M., Buchli, R., Kuhne, G. & Boutellier, U. (1999). Non-invasive measurement of muscle high-energy phosphates and glycogen concentrations in elite soccer players by ^{31}P and ^{13}C-MRS. *Medicine and Science in Sports and Exercise*, **31**, 1587-93.

Ritmeester, J.W., Kemper, H.C.G. & Verschuur, R. (1985). Is a levelling-off criterion in oxygen uptake a prerequsisite for a maximal performance in teengagers? In *Children and Exercise XI* (Edited by R.A., Binkhorst, H.C.G., Kemper, and W.H.M. Saris) pp161-169. Champaign, Illinois: Human Kinetics.

Rivera-Brown, A.M., Rivera, M.A. & Frontera, W.R. (1994). Achievement of VO2 max criteria in adolescent runners; a comparison between plateau achievers and nonachievers. *Pediatric Exercise Science*, **7**, 203-210.

Roberts, D., Foehr, U., Rideout, V. & Brodie, M. (1999). Kids and media at the New Millennium. Menlo Park, CA: The Henry J. Kaiser Family Foundation.

Rochongar, P., Morvan, R., Jan, J., Dassonville, J. & Beillot, J. (1988). Isokinetic investigation of knee extensors and knee flexors in young French soccer players. *International Journal of Sports Medicine*, **9**, 448-450.

Rowland, T. (1996). *Developmental Exercise Physiology*. Champaign, IL: Human Kinetics.

Ryan, L.M., Magidow, P.S. & Duncan, P.W. (1991). Velocity specific and mode-specific effects of eccentric isokinetic training of the hamstrings. *Journal of Orthopaedics and Sports Physical Therapy*, **13**, 33-39.

Sallis, J.F., Simons-Morton, B.G., Stone, E.J. *et al.* (1992). Determinants of physical activity and interventions in youth. *Medicine and Science in Sports and Exercise*, **24(S6)**, S248-257.

Schramm, W., Lyle, J. & Parker, E. (1961). *Television in the lives of our children.* Stanford, CA: Stanford University Press.

Scottish Executive Health Department (1998) *Scottish Health Survey, Volume 1,* Scottish Executive, Edinburgh.

Scottish Executive (1998) *Towards a Healthier Scotland, A White Paper on Health.*

Scoville, C.R., Arciero, R.A., Taylor, D.C. & Stoneman, P.D. (1997). End range eccentric agonist / concentric agonist strength ratios: A new perspective in shoulder strength assessment. *Journal of Sports Physical Therapy*, **25**, 203-207.

Seger, J.Y., Arvidsson, B. & Thorstensson, A. (1998). Specific effects of eccentric and concentric training on muscle strength and morphology in humans. *European Journal of Applied Physiology and Occupational Physiology*, **79**, 49-57.

Shepard, R.J. (1999). Biology & medicine of soccer: an update. *Journal of Sports Sciences,* **17**, 757-786.

SIRC. (2005). *Obesity and the facts: An analysis of data from the Health Survey for England 2003.*

Smaros, G. (1980). Energy usage during a football match. In: *Proceedings of the First International Congress on Sports Medicine Applied to Football.* Rome: L Vecchiet, 1980: 795–801.

Smith, A. (2004). England clear losers in the fitness guessing game. *The Daily Telegraph.* 28/06/04.

Steindler, A. (1955). *Kinesiology of the Human Body under Normal and Pathological conditions.* Charles C Thomas Publisher: Springfield, IL.

Suurorg, L. & Tur, I. (2001). The main determinants of blood pressure in schoolchildren were body weight and height. *Papers on Anthropology,* **10**, 288-299.

Thoden, J.S. (1991). Testing aerobic power. In *Physiological Testing of the High-Performance Athlete.* (edited by J.D., MacDougall, H.A., Wenger & H.J. Green) pp107-174. Champaign, Illinois, Human Kinetics.

Togari, H., Ohashi, J. & Ogushi, T. (1998). Isokinetic muscle strength of soccer players. In: *Science and Football,* (edited by T., Reilly, A., Lees, K., Davids & W.J., Murphy.), 181-184. London: F&N Spon.

Tomlinson, A. (1999). *The Games Up: Essays in the Cultural Analysis of Sport, Leisure and Popular Culture.* Basingstoke: Arena Ashgate.

Tschopp, M., Held, T. & Marti, B. (2003). Four year development of physiological factors of junior elite soccer players aged between 15-19 years. In *Book of Abstracts of 5th World Congress on Science and Football, Portugal 11th-15th April 2003*, p307. Madrid: Gymos Editorial Deportiva.

Tumilty, D. (1993). The relationship between physiological characteristics of junior soccer players and performance in a game situation. In *Science and Football II* (edited by T. Reilly, J. Clarys and A. Stibbe), pp. 281-286. London: E & FN Spon.

United States. Public Health Service. Office of the Surgeon General. *"Physical Activity and Health: A Report of the Surgeon General".* National Centre for Chronic Disease Prevention and Health Promotion (U.S.). 1996. Official Report.

Van Gool, D., Van Gerven, D. & Boutmans, J. (1988). Physiological load imposed on soccer players during real match-play. In *Science and Football* (edited by T.Reilly, A. Lees, K. Davids & W.J. Murphy), p51-59. London: E and FN Spon.

Valquer, W., Barros, T.L. & Sant'anna, M. (1998). High intensity motion pattern analyses of Brazilian elite soccer players. In: *IV World Congress of Notational Analysis of Sport,* 80. Porto: HM Tavares Fernanado.

Varo, J.J., Martinez-Gonzalez, M.A.M., de Irala-Estevez, J., Kearney, J., Gibney, M. & Martinez, J.A. (2003). Distribution and determinants of sedentary lifestyles in the European Union. *International Journal of Epidemiology*, **32**, 138-146.

Walker, R.F., Wilson, D.W., Read, G.F. & Riad-Fahmy, D. (1980). Assessment of Testicular function by the radioimmunoassay of testosterone in saliva. *International Journal of Andrology*, **3**, 105-120.

Welsman, J., Armstrong, N. & Kirby, B.J. (1994). Serum testosterone is not related to peak VO2 and submaximal blood lactate responses in 12 to 16 year old males. *Pediatric Exercise Sciences*, **6**, 120-127.

Westing, S.H., Seger, J.Y. & Karlsen, E. (1988). Eccentric and concentric torque velocity characteristics of the quadricep femoris in man. *European Journal of Applied Physiology*, **58**, 100-104.

Whelton, P.K. (1994). Epidemiology of hypertension. *The Lancet,* **344** (8915), 9 July, 101-106.

Wilk, K.E., Romaniello, W.T., Socia, S.M., Arrigo, C.A. & Andrews, J.R. (1994). The relationship between subjective knee scores, isokinetic testing and functional testing in the ACL reconstructed knee. *Journal of Orthopaedic Sports Physical Therapy,* **20**, 60-73.

Williams, M., Borrie, A., Cable, T., Gilbourne, D., Lees, A., Maclaren, D. & Reilly, T. (1997). *Umbro® Conditioning for Football.* London: Ebury Press.

Wisloff, U., Helegrud, J. & Hoff, J. (1998). Strength & endurance of elite soccer players. *Medicine and Science in Sports and Exercise*, **30**, 462-467.

Wisloff, U., Castagna, C., Helgerud, J., Jones, R. & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump in elite soccer players. *British Journal of Sports Medicine,* **38**, 285-288.

Withers, R.T., Maricic, Z., Wasilewski, S. & Kelly, L. (1982). Match analysis of Australian professional soccer players. *Journal of Human movement studies,* **8**, 159-176.

Wrigley, T.V. (2000). Correlations with athletic performance. In: *Isokinetic Performance Enhancement.* (edited by L. Brown). Champaign, Illinois: Human Kinetics.

Young, W. & Pryor, J. (2001). Resistance Training for Short Sprints and Maximum-speed sprints. *National Strength and Conditioning Association.* **23**, 7-13.

13.0 Appendices

<u>APPENDIX 1:</u> Physical Activity questionnaire

The following questionnaire is a simple way of measuring your physical activity (PA) over the past week. It is strictly confidential and so try and answer all the questions as honestly as you can. The overall accuracy will depend on the accuracy of your individual answers. This is not a test, there is no pass or fail.

Regular PA relates to;

Exercise e.g. weight training, aerobics etc. 2-3 times per week *or*
Sport e.g. golf, hockey, football, netball etc. 2-3 times per week *or*
General Activity e.g. walking, gardening, etc. accumulating at least 30 minutes, 4-5 times per week

Do you consider yourself to be regularly physically active? YES ☐ NO ☐

(tick one box)

If YES go to question 2. If NO, were you regularly physically active;

3 months ago? YES ☐ NO ☐
6 months ago? YES ☐ NO ☐
(tick one box)

Please read through the categories listed below and tick ONE box to describe how physically active you have been over the last six months;

(i) I am not regularly physically active and do not intend to be so in the next 6 months ☐
(ii) I am not regularly physically active but am thinking about starting to do so in the next 6 months ☐
(iii) I do some PA but not enough to meet the description of regular PA given above ☐
(iv) I am regularly physically active but only began in the last 6 months ☐
(v) I am regularly physically active have and have been so for longer than 6 months ☐

The following questions relate to your physical activity over the previous 7 days. Please try and think carefully and be as accurate as possible with your answers. For example you may have spent 4 hours at the disco but actually only spent half that time dancing. Be careful not to count the same activity twice. For example if you have spent time in the last week hill walking be careful only to include this in either the walking or the leisure section and not both.

Only include activities of either moderate or vigorous intensity.

X LIGHT INTENSITY - Your heart rate and breathing rate are no different from what they are when you are standing, sitting etc

☐ MODERATE INTENSITY - Your heart rate and breathing rate are faster than normal. You may also sweat a little. Brisk walking or sweeping and mopping are good examples of how you might feel

☐ VIGOROUS INTENSITY - Your heart rate is much faster and you have to breathe deeper and faster than normal. You will probably sweat. Playing football or squash are good examples of how you might feel

In the past 7-days how many minutes did you spend each day;	MON	TUE	WED	THUR	FRI	SAT	SUN	TOTAL
Walking at school/ work? e.g. up/down stairs, to/from your desk, between drills at training, etc.								
Walking outwith school /work? e.g. to the shops, to school, up/down stairs etc.								
Manual labour at work / school? INCLUDE; e.g. lifting, stacking shelves, climbing ladders etc. DON'T INCLUDE e.g. sitting, operating check out etc.								
Manual labour outwith school/work? INCLUDE; e.g. cutting grass, washing car, paper round etc DON'T INCLUDE; e.g. weeding, answering phone etc								
Doing active housework? INCLUDE; e.g. hoovering, bed making, hang out washing etc DON'T INCLUDE; e.g. dusting, wash dishes, food prep etc								
Dancing? E.g. disco, line, country								
Cycling for pleasure or to work?								
Participating in a sport, leisure activity or training? INCLUDE; e.g. classes, football, golf, jogging etc DON'T INCLUDE; e.g. darts, pool, playing instrument etc								
Other Physical Activity if not already covered? Please specify								

Was last week typical of the amount of physical activity you usually do?

YES ☐ **(tick one box)**

NO – I usually do more ☐ **Normally how much more?** ☐ **Of** ☐

NO – I usually do less ☐ **Normally how much less?** ☐ **Of** ☐

APPENDIX 2a
CONSENT FORM

1. I have read and had explained to me by a member of the University staff the accompanying information sheets relating to the project entitled Physiological monitoring of youth male soccer players and age matched control groups.
2. I understand that the participation of my child is entirely voluntary and that I and / or my child have the right to withdraw from the project at any time and that this will be without detriment to any care or services I may be receiving or receive in the future.
3. I understand the associated risks and benefits.
4. I confirm that I have completed a health-screening questionnaire with my child and that he/she is in a fit condition to undertake the required exercise.
5. I have received a copy of this consent form and a copy of the accompanying information sheet.
6. I confirm that the results of the current test can be used for academic purposes.

Name of child ____________________ (Print please)
Name of Parent / Guardian ____________________ (Print please)
Signature ____________________
Exercise Physiologist ____________________
Date ____________________

APPENDIX 2b
ASSENT FORM

NAME : ______________________

I am happy to take part in your research project, which is looking at the physiology of youth soccer players and age matched control groups. I have had the project explained to me by Andrew Murray.

I understand that I will be asked to perform a range of exercise including a maximum effort on the treadmill and I am happy to do this.

I understand that if I am unhappy about anything that I am being asked to do, I can say so and if I want to I can stop taking part.

If I am not sure of anything then I can ask Andrew Murray and he will explain it to me.

Signed: ______________________

Date: ______________________

Investigator: ______________________

APPENDIX 3a
University of Glasgow
Institute of Biomedical and Life Sciences

INFORMATION SHEET

TITLE: **Physiological monitoring of young male soccer players and age matched control groups**

You have been invited to take part in a research study monitoring the physiological characteristics of youth soccer players and non-soccer players of the same age through a battery of fitness tests. In order to help you to understand what the investigation is about, please read the following information carefully. If there are any points that need further explanation, please ask a member of the research team. It is important that you understand what you are volunteering to do and are completely happy with all the information before you sign this form.

What is the purpose of the study? There is a lack of data available on the fitness of Scottish footballers, especially at a youth level. This study aims to eliminate this lack of information by asking twenty elite footballers to complete an array of tests. These will be compared to two other groups (recreationally active and sedentary individuals) of the same size to evaluate any differences between soccer players and non-soccer players. The results obtained could be important to aid sporting performance and to assess the health benefits of repeated exercise.

Why have I been chosen? You have been selected as a possible participant in this investigation because of your age, sex and current health status. Before you become a subject, you will complete a medical questionnaire. People who have asthma, heart-related and/or circulatory problems, hypertension or any other contraindicated condition will not be allowed to take part in the study.

Do I have to take part? It is up to you to decide whether or not to take part. If you decide to take part, you will be given this information sheet to keep and you will be asked to sign an assent form while your parents will have to sign a consent form to show that they are happy for you to participate. If you decide to take part, you are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part? You will be asked to visit the laboratory within the Sports Medicine Centre at Hampden Park on two occasions. The first visit will involve testing for a period of around 90 minutes, while the second, (up to a week later) will take just one hour.

During your visit, you will be introduced to the laboratory personnel and familiarised with all the equipment used. You will be asked to complete three confidential questionnaires: the first will allow us to obtain information related to your general health; the second will allow us to quantify your past exercise/activity involvement and the third will record any injuries you have experienced in the past. Your height, weight and body fat will then be taken along with a pinprick of blood from your thumb to measure the cholesterol in your blood. Your blood pressure will be measured. Body fat is assessed using the thickness of selected skinfolds; you will then complete a series of sprints to assess your speed.

You will then be asked to perform a test to assess the flexibility of the muscles in your upper leg and lower back. You will be required to reach, in a seated position, as far as possible, if you have a history of lower back or hamstring problems you may have difficulty doing this. Then you will complete a test of strength in the legs and ankles. This test will involve various movements of your leg and a series of efforts from you, ranging from moderate to the greatest possible effort you can give.

You will then be asked to perform what is called a "maximal exercise test" on a treadmill. The treadmill speed will start at a very low level and the speed and gradient will be increased during the test. The idea is that you keep going until you can do no more. The test will be stopped when you decide you can go no longer. In this test we will ask you to breath through a "snorkel" type mouthpiece with a noseclip in place. This is so we can monitor the air you breathe in and out.

You will be asked to perform a test to assess the strength in various ways of your lower limbs. This will involve you resisting against computerized machinery to test the strength of your quadriceps and hamstrings and the muscles around your ankle joint at different speeds and angles of your leg. You will also be asked to perform 3 twenty-metre sprints as fast as you can in a straight line.

You will also be asked to maintain a stable position on a platform, which tilts slightly. You will carry out tests on both legs and your right and left legs. The three tests will last for 30 seconds each.

Finally, you will not be able to consume any alcohol 48 hours prior to each lab visit. You will be excluded from participating in this study if you take drugs (recreational or performance-enhancing drugs).

When will these tests occur? On day 1 you will perform the sprints, the flexibility, a practice of the lower limb strength test along with measurement of ankle strength and the maximal exercise test. On day 2 the tests of height, weight and body fat will be taken along with the blood sample, and the actual test of the lower limb strength.

What are the side effects of taking part? There are none.

What are the possible disadvantages and risks of taking part? Exercise has a negligible risk in healthy children, although maximal exercise does carry a small risk of reducing the blood supply to the heart, which can cause chest pain on exertion and in extreme circumstances a heart attack. If you experience any unusual sensations in your chest during the experiment, you should cease exercising immediately. Your heart rate will be monitored via a heart rate monitor placed around the chest. In the unlikely event you experience serious problems during the exercise, medically qualified personnel are on call at all times during the test and approved emergency procedures are in place.

At the end of the maximal test you will be very tired (exhausted), your legs will be very heavy and you will be out of breath. It is also not uncommon to feel a little light-headed and sometimes nauseous.

You may experience difficulty swallowing while breathing through a mouthpiece and wearing a noseclip; this is due to a slight but transient pressure build up in your ears. Also, some subjects produce more saliva while breathing through a mouthpiece.

During the sprint tests there is a slight risk of falling, but no more than when running normally in everyday life.

What are the possible benefits of taking part? The results from the exercise tests will give you a good idea of how fit you are. The research team will take the time to explain these results to you. The information from these tests will provide us with valuable information on the current state of young males in Scotland.

What if something goes wrong? If taking part in this research project harms you, there are no compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. At least one investigator has been trained in Life Support and attended an advisory defibrillation workshop. In the event of an untoward incident, basic life support including chest compressions and ventilation will be applied. An advisory defibrillator will be used (if necessary) until emergency medical staff are on hand.

Will my taking part in this study be kept confidential? All information that is collected about you during the course of the research will be kept strictly confidential.

What will happen to the results of the research study? Results will be published in an established scientific journal once the study is completed. You will automatically be sent a copy of the full publication. You will not be identified in any publication.

If you are worried about any unwanted side effects from any of the above procedures, you should contact:

Dr Stan Grant
West Medical Building,
University of Glasgow,
Glasgow G12 8QQ
Phone: 0141 330 6490
e-mail: s.grant@bio.gla.ac.uk

APPENDIX 3b
UNIVERSITY OF GLASGOW
INSTITUTE OF BIOMEDICAL AND LIFE SCIENCES
SUBJECT QUESTIONNAIRE AND ASSENT FORM FOR HIGH INTENSITY EXERCISE TESTING

If you feel unwell on the day of a proposed test, or have been feeling poorly within the last two weeks, you are excluded from taking part in an exercise test. The considerations that follow apply to people who have been feeling well for the preceding two weeks.

NAME ....

SEX: M/F AGE: .... (yr) HEIGHT: .... (m) WEIGHT: ...... (kg)
Last sport played & when:......................... Hours of training per week:..........
Regular position at soccer:....................... Games per week: ....
Years in sport / sedentary:...............................
Level of experience (i.e. national, regional, international, recreational):.....................

Details of last medical examination (where appropriate):
Date: .... Location:...
(day/mo/yr)

Exercise lifestyle:
What kind(s) of exercise do you regularly do (20 min or more per session), and how often? (*Please circle the number of times per average week*):

Walking	1	2	3	4	5
Running	1	2	3	4	5
Cycling	1	2	3	4	5
Swimming	1	2	3	4	5
Skiing	1	2	3	4	5
Rowing	1	2	3	4	5
Gymnastics	1	2	3	4	5
Martial Arts	1	2	3	4	5
Tune Up	1	2	3	4	5
Popmobility	1	2	3	4	5
Sweat Session	1	2	3	4	5
Weight Training	1	2	3	4	5
Field Athletics	1	2	3	4	5
Racket Sports	1	2	3	4	5
Rugby/soccer/hockey	1	2	3	4	5
Others*	1	2	3	4	5

*(*Please specify*)
....

How long have you been exercising at least twice/week for at least 20 min/session?
.........years

Smoking: (*Please tick one*) Never smoked .... Not for > 6 months ......
Smoke < 10 per day .... Smoke > 10 per day .....

Illnesses: Have you ever had any of the following? (*Please circle NO or YES*)

Anaemia (low blood count)	NO/YES	Asthma	NO/YES
Diabetes	NO/YES	Epilepsy	NO/YES
Heart Disease	NO/YES	High Blood Pressure	NO/YES
Other*	NO/YES		

*(*Please specify*)..

Symptoms:

Have you ever had any of the following symptoms to a significant degree ***at rest or during exercise***? That is, have you had to consult a physician relating to any of the following?

	Rest	*Exercise*
Breathlessness	NO/YES	NO/YES
Chest Pain	NO/YES	NO/YES
Dizzy Fits/Fainting	NO/YES	NO/YES
Heart Murmurs	NO/YES	NO/YES
Palpitations	NO/YES	NO/YES
Tightness in chest, jaw or arm	NO/YES	NO/YES
Other*	NO/YES	

*(*Please specify*)..

Muscle or joint injury:

Do you have/or have had any muscle or joint injury, which could affect your safety in performing exercise ***(e.g. cycling or running),*** strength testing or strength training?

NO/YES*

*(*Please specify*)..

Medication:

Are you currently taking any medication? NO/YES*

*(*Please specify*)..

Family History of Sudden Death:

Is there a history of sudden death in people under 40 years in your family? NO/YES*

Can you think of any other reason why you should not take part in our tests?

(*Please specify*) ....

The following exclusion and inclusion criteria will apply to this study:

Exclusion Criteria

If you have any of the following, you will be excluded from the study:

(a) Asthma, diabetes, epilepsy, heart disease, a family history of sudden death at a young age, fainting bouts, high blood pressure, anaemia (low blood count) and muscle or joint injury.

(b) If you are taking any medication that may adversely affect your performance or health in this study, you will not be allowed to take part in the study.

(c) If you take recreational drugs, you will not be allowed to take part in the study.

(d) If you have ingested alcoholic drinks in the previous 48 hours, you will not be allowed to take part in the study.

Inclusion Criteria

(a) Male or female subject aged at least 16 years and ***normally no more than*** 35 years.

(b) In good health at the time of testing.

Signature ....Date ....

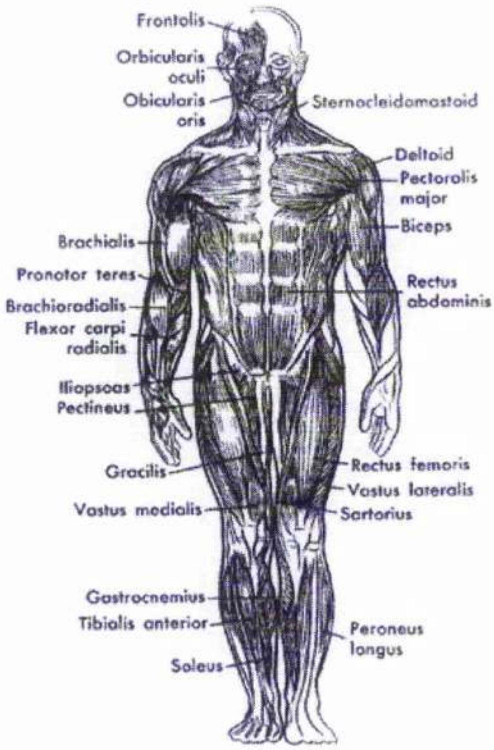
Body Weight and Blood Pressure:

Body Weight: ....Height: ....

BP (Resting) ....

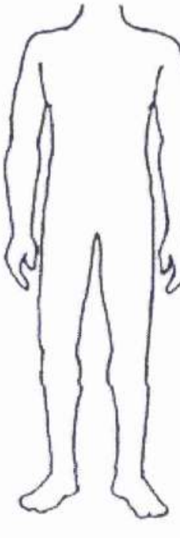
Screened by: .... Date:.................................

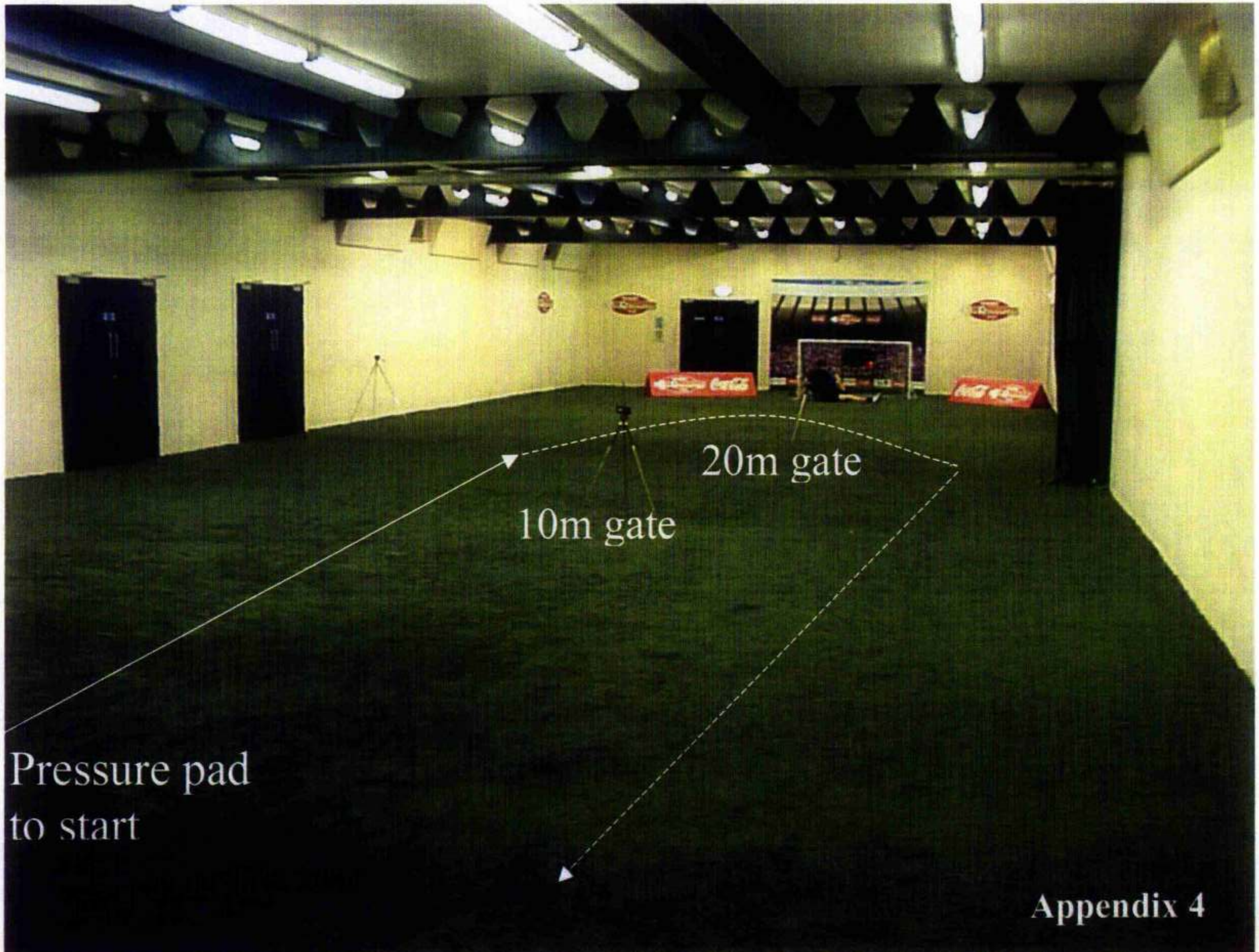
APPENDIX 3c
Previous Injury Questionnaire



Using the anatomical model opposite for guidance please note any previous injuries that you have experienced below and the time that they occurred (i.e. month and year) – noting their location on the blank outline on the correct side.

This will help us to assign more relevance to your results from the strength tests. Include all injuries that you have had **especially** those in the *lower body*.




20m gate
10m gate
Pressure pad
to start
Appendix 4

APPENDIX 5

Boys to men; comparison of $\dot{V}O_{2max}$ to elite males

Over the course of this study two senior squads also underwent testing of maximal aerobic fitness. The protocols used to assess each squad differed to each other and to that used to assess our youth subjects. If the criteria for achieving maximum oxygen uptake are achieved, it suggests that all subjects are pushed to their maximum. So should we be concerned about the method of obtaining the maximum value? Obviously if repeat testing was used then the same protocol would have to be utilized for consistency but as the comparison in this case is between elite youths and elite males, (different ages and therefore stages of development), the process of determination is not as relevant as it might be due to the inherent age and maturation differences.

The first senior population was a Premier division squad of 26 players (mean±s) (age; 22.8±4.9 years, height; 181.8±5.3 cm; mass; 77.8±5.8 kg) all of whom were current or former internationals at their respective age group. In this case the protocol used was that of Casajus *et al.* (2001) and saw an increase of speed every minute beginning at 9 $km.h^{-1}$ over a constant 3 % gradient.

The second senior population was a second division squad of 21 players (mean±s) (age; 24.1±4.6 years, height; 177.3±6.4 cm; mass; 74.5±7.9 kg). In this case the protocol used was that which determines the fitness of Scotland's grade 1 officials* annually, which has recently been validated in-house (McDevitt, 2004).

The hypothesis in this case was that the senior squads should have differing levels of fitness due to their different levels of performance and they should have a superior level of fitness to the youths involved due to their greater experience and maturational development. To allow a fair assessment of fitness analysis was carried out by position (Figure 14). Positionally, there is generally a difference in aerobic fitness with central midfielders generally having the highest $\dot{V}O_{2\,max}$, central defenders having the lowest and fullbacks and strikers having intermediate values (Reilly, 1979; Bangsbo 1994b; Wisloff *et al* 1998, Al-Hazzaa *et al*, 2001).

From the three plots in Figure 14, it is clear that the only 'obvious' difference is between the seniors and youths for defenders with youths 'substantially' lower in their average $\dot{V}O_{2\,peak}$.

Statistical limitations prevented an unbalanced two-way ANOVA so simply looking at the three comparisons between seniors and youths separately for each of the three positions, shows that the only difference between positions is for defenders where on average elite seniors have a maximal $\dot{V}O_2$ 0.82-7.23ml.kg^{-1}.min^{-1} higher than youths.

* The top referees and assistants in the country

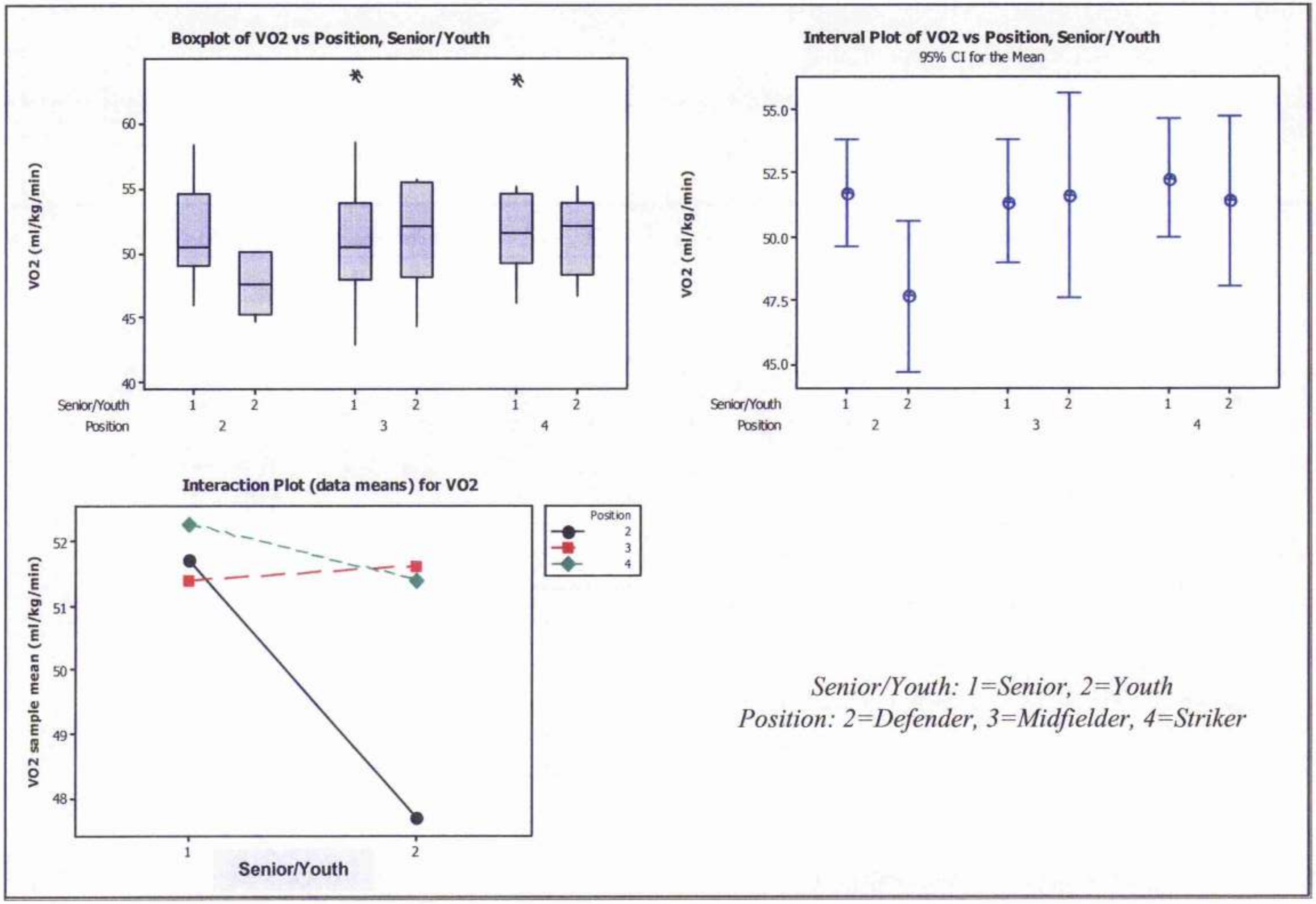


Figure 14: Analysis of elite seniors and elite youths by position