

The Effect of Aerobic Power on Elite Youth Soccer Selection

A Thesis Submitted to the College
of Graduate Studies and Research in
Partial Fulfillment of the Requirements for
the Degree of Masters of Science in the
Department of Kinesiology
University of Saskatchewan
Saskatoon

By

Jessica Murphy

© Copyright, Jessica Murphy, April 2015. All Rights Reserved

Permission to Use

In presenting this thesis/dissertation in partial fulfillment of the requirements for a Postgraduate degree from the University of Saskatchewan, I agree that the Libraries of this University may make it freely available for inspection. I further agree that permission for copying of this thesis/dissertation in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis/dissertation work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis work was done. It is understood that any copying or publication or use of this thesis/dissertation or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to the University of Saskatchewan in any scholarly use which may be made of any material in my thesis/dissertation.

Requests for permission to copy or to make other uses of materials in this thesis/dissertation in whole or part should be addressed to:

Dean

College of Graduate Studies and Research

University of Saskatchewan

107 Administration Place

Saskatoon, Saskatchewan S7N 5A2

Canada

Abstract

Soccer is a multifaceted sport requiring game-specific intelligence and particular physiological and physical characteristics for success. Despite the wide variety of contributing factors, it has been reported that youth soccer players who are larger in size, more mature, and have superior aerobic power are favoured during team selection. The current investigation examined aerobic power and anthropometric size differences between selected and not selected elite youth soccer players; values were also compared between playing position and sexes. Twenty-three elite soccer players, 10 males and 13 females, with an average age of 14 years were recruited for the study; participants performed a graded treadmill test to exhaustion and a sport participation questionnaire. Aerobic power results from the treadmill test were expressed in absolute (l/min) and relative terms, to body mass and fat free mass (ml/kg/min & ml/kg FFM/min); values were compared between selection status, playing position and sex. No significant differences were detected for any measure of aerobic power or anthropometric size between selected and not selected athletes when sexes were combined or separated ($p>0.05$); males had significantly higher aerobic power levels compared to females despite scaling method ($p<0.05$). In females, goalkeepers had a significantly lower absolute aerobic power ($p<0.05$), differences were not detected when expressed relative to body mass or fat free mass ($p>0.05$). Males showed no significant difference between playing positions in any measurement of aerobic power ($p>0.05$). It appears as though Saskatchewan coaches view attributes, other than physical size and aerobic fitness, as more beneficial for team success at this level. Results are encouraging as they suggest that size and aerobic power may not be the main influencing criteria for achieving success on an elite youth Saskatchewan soccer team.

Acknowledgements

First, I need to express my deepest appreciation towards my supervisor Dr. Adam Baxter-Jones, without him I would not be in the position I am today. I thank him for being a comedic relief in times of stress, teaching me to believe in myself, and reminding me that my academic journey meant more than just completing a final thesis. I am forever grateful for the amount of guidance, help and support that he has given me during my time at the University of Saskatchewan. The past two years have made me a better person, both professionally and personally, and I truly believe that his guidance significantly contributed to this.

I would like to thank my committee members, Marta Erlandson and Corey Tomczak; their advice, words of wisdom and hours of editing are appreciated beyond words. Their work ethic and dedication towards my thesis and their own research has inspired me to become a better academic. I thank both of them for being there to guide my research, include me in opportunities to broaden my academic career, and being a friendly face I could count on while away from home.

To my professors, I have all of you to thank, for without you I would not have the love for learning that I do today. Each and every one of you has allowed me to grow and develop skills in a different way. I feel that every experience in academia has led to me to this point, and without your guidance life may not have taken me down this path.

I would also like to thank my parents, siblings and fiancé, Dave; the strength and support that you give me cannot be put into words. You have kept me afloat, been my saving grace, and have loved me unconditionally regardless of my successes or failures. I thank you from the

bottom of my heart for accepting me during my brightest and darkest moments; your support is what has kept me going through the hardest points in my life.

Lastly, to my adopted family, while only being in my life for a short time you have made one of the largest impacts of all. Alex, Darcie and Megan, I truly can say that without you I would not be here today, or if I were, I definitely would not be looking back with a smile on my face. When away from your family, you make your own, and I am eternally grateful that I met each of you. The connections we made, and the experiences we had will forever be in my heart.

Table of Contents

Title Page.....	i
Permission to Use.....	i
Abstract.....	ii
Acknowledgements.....	iv
Table of Contents.....	v
List of Tables.....	vii
List of Figures.....	viii
1.0 Introduction.....	1
2.0 Literature Review.....	4
2.1 Aerobic Power.....	4
2.1.1 Scaling Aerobic Power.....	9
2.1.2 Association Between Aerobic Power and Health.....	11
2.2 Youth Physical Activity.....	12
2.2.1 Youth Sport Participation.....	14
2.3 Growth and Maturation.....	16
2.3.1 Growth.....	16
2.3.2 Maturation.....	23
2.3.3 Aerobic Power Development with Growth, Maturation and Aging.....	25
2.3.4 Comparison of Aerobic Power between Sexes.....	25
2.4 Aerobic Power and Training.....	31
2.4.1 Aerobic Power and Soccer.....	35
2.4.2 Aerobic Power by Playing Position in Soccer.....	36
2.5 Talent Identification in Sport.....	38
2.5.1 Relationship between Talent Identification and Aerobic Power.....	37
2.6 Summary.....	41
2.7 Purpose.....	42
2.8 Hypothesis.....	44
3.0 Methods.....	44
3.1 Study Design.....	44
3.2 Participants.....	43
3.3 Measurements.....	45
3.3.1 Anthropometry.....	45
3.3.2 Skinfold Thickness.....	47
3.3.3 Aerobic Power.....	47
3.3.4 Physical Activity Levels.....	48
3.4 Statistics.....	49

4.0 Results	50
4.1 Growth and Maturation	50
4.2 Aerobic Power	57
5.0 Discussion.....	65
5.1 Growth.....	66
5.2 Aerobic Power	69
5.3 Team Selection	72
5.4 Limitations.....	74
5.5 Future Directions	74
6.0 Conclusion.....	75
7.0 References	77
Appendices	
Appendix A Study Consent/Assent Form	84
Appendix B Bruce Protocol	92
Appendix C Physical Activity Questionnaire	93

List of Tables

Table 2.1.....
 Summary of VO₂max literature..... 39

Table 4.1.....
 Descriptive characteristics of male and female participants 54

Table 4.2.....
 Additional maximal testing results 60

Table 4.3.....
 Summary of aerobic power (ml/kg/min) by position 65

List of Figures

Figure 2.1	Effects of training on aerobic power (ml/kg/min) in adult males	8
Figure 2.2:	Effects of training on aerobic power (ml/kg/min) in adult females	9
Figure 2.3:	Scammon's systematic curves of growth	18
Figure 2.4:	Height and weight percentile chart for males age 2-20 years	21
Figure 2.5:	Height and weight percentile chart for females age 2-20 years	22
Figure 2.6:	Aerobic power percentile chart for males (chart A) and females (chart B)	23
Figure 2.7:	Average male and female aerobic power (l/min and ml/kg/min)	28
Figure 2.8:	Maximal absolute (l/min) and relative (ml/kg/min) aerobic power for male and female adults	30
Figure 3.1:	Recruitment and allocation process	46
Figure 4.1:	Plotted male anthropometry: percentile chart	55
Figure 4.2:	Plotted female anthropometry: percentile chart	56
Figure 4.3:	Plotted female (A) and male (B) aerobic power: percentile chart	57
Figure 4.4a:	VO ₂ peak (ml/kg/min) compared between sexes	61
Figure 4.4b:	VO ₂ peak (ml/kg FFM/min) compared between sexes	61
Figure 4.5:	Development of aerobic power (l/min and ml/kg/min) in males	62
Figure 4.6:	Development of aerobic power (l/min and ml/kg/min) in females	62
Figure 4.7a:	VO ₂ peak (ml/kg/min) compared between selection groups	63
Figure 4.7b:	VO ₂ peak (ml/kg FFM/min) compared between selection groups	64

1.0 Introduction

The ability to identify talent and predict the future potential of a young adolescent athlete is a complex and multifaceted task (Reilly, Williams, Nevill, & Franks, 2010). It is believed by many coaches that the ability to distinguish between players with differing levels of talent forms the foundation of a successful team (Abbott, Button, Pepping, & Collins, 2005). Varying methods of talent identification exist, the majority use easily measurable or observable physical characteristics such as speed, endurance (aerobic power), height and maturation (Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007). Past literature has indicated that athletes selected for elite youth soccer teams are, on average, taller, more mature and have superior aerobic power than those who are not selected (William & Reilly, 2000; Carling, Le Gall, & Malina, 2012). Aerobic power, the maximal amount of oxygen consumed during exercise, is seen as a beneficial characteristic in endurance sports as it allows for faster recovery from high intensity exercise and greater endurance, leading to increased playing time and scoring potential (Carling et al., 2012). In addition to physical characteristics, other factors such as personality and perceptuo-cognitive skills (anticipation, attention, decision making, game intelligence and creativity) have been identified as highly influential factors in youth sport selection (Reilly et al., 2010). Despite evidence to support the importance of these characteristics in sport, the dominating factors in elite soccer selection still appear to predominantly be physical and fitness characteristics (Carling et al., 2012).

The abbreviation VO_2 represents the volume of oxygen taken up into the body, while VO_{2max} (maximal oxygen uptake) represents the highest rate at which an individual can consume oxygen while performing exercise. This measure, VO_{2max} , describes aerobic power, the highest level of chemical energy that is aerobically transformed in the muscle mitochondria

(Malina, Bouchard, & Bar-Or, 2004). Aerobic power is often used interchangeably with aerobic capacity, however, aerobic capacity refers to the total chemical energy available to be transformed in the mitochondria (Malina et al., 2004a); this thesis will only describe aerobic power, as opposed to aerobic capacity. It has been suggested that aerobic power is crucial for success in both young and older soccer players, with contemporary elite male soccer players requiring a minimum relative aerobic power of 60-65 ml/kg/min (Gil et al., 2007; Reilly et al., 2010). Literature regarding female elite soccer is less available, however, it has been suggested that for the elite female athlete a $VO_2\text{max}$ of approximately 55 ml/kg/min is required (Haugen et al., 2014); while both values suggested are from elite male and female adult players, it has been suggested that relative exercise intensity and aerobic power is relatively equal between adult and adolescent soccer players (Stroyer et al., 2004). In addition to being a discriminating factor for selection, many studies have found a difference in $VO_2\text{max}$ levels between playing positions. While inconsistent, it has been reported that forwards and strikers have shown significantly greater $VO_2\text{max}$ levels as compared to goalkeepers of the same age, gender and caliber (Boone, Vaeyens, Steyaert, Vanden, Boosche, & Bourquois, 2012; Russell & Tooley, 2011; Stroyer, Hansen, & Klausen, 2004). The lower $VO_2\text{max}$ levels in goalkeepers has been suggested to be due to role differences of goalkeepers compared to outfield positions, in that the goalkeeper covers substantially less distance during a match, thereby possibly influencing aerobic power (Boone et al., 2012). While there is no denying the importance of aerobic fitness in a sport such as soccer, the use of this measurement when dealing with adolescent athletes can be unreliable as it is highly dependent on the individual's stage of growth and maturation (Cunha, Lorenzi, Sapata, Lopes, Gaya, & Oliveira, 2011; Armstrong, Barrett, & Welsman, 2007; Baquet, Van Praagh, & Berthoin, 2003; Rowland, 2005). Maturation, the progression into an adult state, is a

highly transitional time during adolescence where youth are growing and developing at different magnitudes as compared to their peers (Baxter-Jones & Maffulli, 2003). Due to the high dependence of aerobic power on growth and maturation, the use of this measure to identify a young athlete as talented may not be beneficial to future success of the team or athlete (Barreiros, Cote, & Fonseca, 2014).

The use of aerobic power during a highly transitional period, such as adolescence, often leads to late maturing but equally talented athletes being overlooked (Barreiros et al., 2014). When athletes who are more mature, and therefore have superior aerobic power, are chosen over those who are less mature, it puts equally talented, but less aerobically developed athletes at a disadvantage. Selected athletes are immersed in extensive training, while those who are not selected are removed from an environment that would foster further athletic development. While elimination is a part of competitive sport, studies have shown those who are eliminated from sport are more likely to discontinue participation in coach-based organized sport (Durant, Pendergrast, Donner, Seymore, & Gaillard, 1991). Therefore, aside from the frustration caused by being cut from a team, more serious implications arise, such as: unequal opportunities and increased drop-out rates for athletes who are not selected for elite level teams; this may lead to lower participation rates in sport.

The relationship between aerobic power, soccer selection and continued sport participation is an area that merits further research. It would be helpful to identify if using aerobic power as a method for talent identification is warranted in an adolescent population. Therefore, the primary objective of the current study is to determine if aerobic power is a discriminating factor in selection for elite youth soccer teams in Saskatchewan. Secondary objectives include identifying potential sex and playing position effects.

2.0 Literature Review

2.1 Aerobic Power

Aerobic fitness is an umbrella term encompassing aerobic power and aerobic capacity; it is the ability to deliver and utilize oxygen in the working muscles to generate energy during exercise (Armstrong, 2006). Maximal aerobic power, indexed as VO_2max , is the chemical energy that can be aerobically transformed, while aerobic capacity is the total chemical energy available to perform aerobic work (Malina et al., 2004a). While both aerobic power and aerobic capacity should be considered when analyzing maximal aerobic performance, aerobic power can be measured and expressed (VO_2max), while no single index has been identified to represent aerobic capacity (Malina et al., 2004a). VO_2max , the maximal amount of oxygen utilized by the body during exercise, is marked by a plateau in oxygen consumption of greater than or equal to 2 ml/kg/min despite and increase in exercise intensity (McArdle et al., 2010). In children, and in older individuals, a plateau is only seen in 20-60% of cases, and therefore, the term VO_2peak , the highest level of chemical energy aerobically transformed during an exercise session is often used (Baxter-Jones & Maffulli, 2003; Armstrong, Tomkinson, & Ekelund, 2011). Aerobic power is an indication of overall cardiovascular health, and is often used as an indication of performance in aerobically based sports such as soccer (McArdle et al., 2010).

While there are many methods used to elicit this marker of oxidative metabolism, such as step-tests and sport specific measures, the most common are cycle and treadmill ergometers (McArdle et al., 2010). When measuring aerobic power, treadmill and cycle ergometer tests are used to perform progressive exercise, or graded exercise tests, that increase intensity until volitional exhaustion of the participant (McArdle et al., 2010; Rowland 2005). The utilization of treadmill and/or cycle ergometers along with a metabolic cart allows for direct calorimetry, a

more precise option as compared to indirect, or predictive measures (Malina et al., 2004a). When selecting which ergometer to use it is important to consider the age, body composition and training of the participant (Malina et al., 2004a; Baquet et al., 2003). While treadmill or cycle ergometers can be used for children, cycle ergometers tend to elicit VO_2max values that are approximately 10% lower than that of a treadmill due to the whole-body muscle utilization required for treadmill tests (Malina et al., 2004a). It is also important that the testing method reflects the training modality and activity history of the participant in order to obtain the most accurate measure of aerobic power (Baquet et al., 2003).

While different methods are used depending on the age and overall health and fitness of the individual, all modalities aim to achieve the same common goal. Ultimately, an exercise test to exhaustion should result in the achievement of the main criteria of a VO_2max , a plateau in oxygen consumption of 2 ml/kg/min despite an increase in exercise intensity (McArdle et al., 2010). Following this plateau, any further energy required is supplied by anaerobic metabolism, which, quickly results in the accumulation of lactate and other byproducts leading to fatigue and termination of exercise (Rowland, 2005). In some cases, such as in children, a plateau may not be achieved and; therefore, other secondary criteria are used as indicators of maximal effort. These secondary criteria include, but are not limited to: (i) achievement of 85% of age predicted maximum heart rate ($220-\text{age}$), (ii) a respiratory exchange ratio (the ratio of carbon dioxide produced to oxygen consumed) exceeding 1-1.15, or (iii) signs of intense effort (McArdle et al., 2010; Baxter-Jones & Maffulli, 2003; Armstrong et al., 2011; Rowland, 2005). In the case where a plateau is not seen, but secondary criteria are achieved, the term VO_2peak , the highest value of oxygen consumption during a graded exercise test, is used (McArdle et al., 2010).

Research has indicated that measuring VO_2max in younger populations is difficult due to the fact that only 21-60% of children and adolescents achieve the main criteria of a plateau in VO_2 (Baxter-Jones & Maffulli, 2003; Armstrong et al., 2011). A study by Barker and associates (2011) found that only 30% of participants aged 8-10 were able to achieve a plateau in VO_2max upon testing using a cycle ergometer (Barker, Jones, Williams & Armstrong, 2011). Despite the lack of plateau in VO_2 seen in younger populations studies have found no significant differences between those who achieve a plateau and those who do not in maximal heart rate, respiratory exchange ratio, aerobic power, or nonaerobic factors (speed or strength) (Rowland & Cunningham, 1992). It has therefore been suggested that other factors, such as internal pH levels or running economy may be inhibiting the ability to achieve a VO_2 plateau in some young individuals (Rowland & Cunningham, 1992). Studies have questioned the validity of using graded exercise testing to achieve an accurate measure of adolescent VO_2max , as well as the secondary criteria used to identify maximal effort in the absence of a plateau (respiratory exchange ratio, heart rate, blood lactate levels) (Barker et al., 2011). In a study by Barker and associates (2011), it was found that the use of secondary criteria, such as RER or heart rate, can result in the acceptance of a sub-maximal VO_2 as the peak measurement, or the rejection of an individual's VO_2max . In addition, VO_2 levels attained during the ramp testing using a cycle ergometer were not significantly different than those attained when exercising at supra-maximal values (Barker et al., 2011). These results indicate that the use of secondary criteria may be problematic, that VO_2peak can be attained without a plateau, and that VO_2peak is a valid representation of VO_2max in younger populations (Barker et al., 2011).

The value achieved upon VO_2max testing, whether a plateau in oxygen consumption is achieved or not, is influenced by numerous factors including heredity, state of training, age,

maturation, gender, body size and composition (McArdle et al., 2010). The relationship between body mass and composition influences how aerobic power is expressed and scaled; absolute (l/min) or relative to body mass (ml/kg/min) or fat free mass (ml/kg fat free mass/min), section 2.1.1 elaborates on this further. When expressed in absolute terms (l/min); therefore not taking into consideration the body mass of an individual, males show a somewhat linear increase from the ages of 6-17 years (McArdle et al., 2010; Giethner et al., 2004; Armstrong, 2006). When aerobic power values are expressed relative to body mass (in kilograms) it appears that aerobic power values stay relatively consistent across the same ages (McArdle et al., 2010; Geithner et al., 2004; Armstrong 2006). The stability of aerobic power when scaled to body mass (ml/kg/min) may indicate that the increases seen in absolute aerobic power (l/min) could be attributed to increase in size with growth (McArdle et al., 2010; Geithner et al., 2004; Armstrong 2006). In females of the same age, absolute VO_2max (l/min) shows a less linear increase up until the approximate age of 13 years where a plateau is seen; when expressed relative to body mass (ml/kg/min) VO_2max levels show a steady decline from the ages of 6-17 years (McArdle et al., 2010; Geithner et al., 2004; Armstrong, 2006). The increase in absolute aerobic power (l/min) seen in males and females with age is impacted by many factors including sex, body composition, as well as growth (Kohl & Cook, 2013). With growth, there is a change in the structure and function of the lungs, heart, blood and vascular system, all of which impact overall aerobic fitness (Kohl & Cook, 2013); these changes will be addressed later on. After the age of 25 there is a consistent and steady decline of absolute VO_2max with age (l/min) of approximately 1% per year in both sexes; with the magnitude of decrease in aerobic power accelerating with age (McArdle et al., 2010; Wilson & Tanaka, 2000; Fitzgerald, Tanaka, Tran, & Seals, 1997; Loe, Rognum, Saltin, & Wisloff, 2013). Also effecting aerobic power is the physical activity

and/or the trained state of an individual; those who maintain a physically active lifestyle show slower decline in $\dot{V}O_2$ values as well as higher aerobic power throughout the lifespan (McArdle et al., 2010; Wilson & Tanaka, 2000; Fitzgerald, Tanaka, Tran, & Seals, 1997; Loe, Rognmo, Saltin, & Wisloff, 2013). Comparisons between older individuals with differing activity levels are seen in Figures 2.1 and 2.2 for men and women respectively. The connection of physical activity to aerobic power may be attributed to the effects of physical activity to maintain a certain body composition, specifically higher levels of muscle mass and lower levels of fat mass. Higher levels of muscle mass have been shown to be beneficial to aerobic power values as muscle facilitates utilization of oxygen during exercise (Armstrong et al., 2011; Rowland, 2005). This relationship between body size and composition on $\dot{V}O_2$ max performance has led to multiple methods of scaling in order to properly express, as well as compare $\dot{V}O_2$ max values between different sized populations.

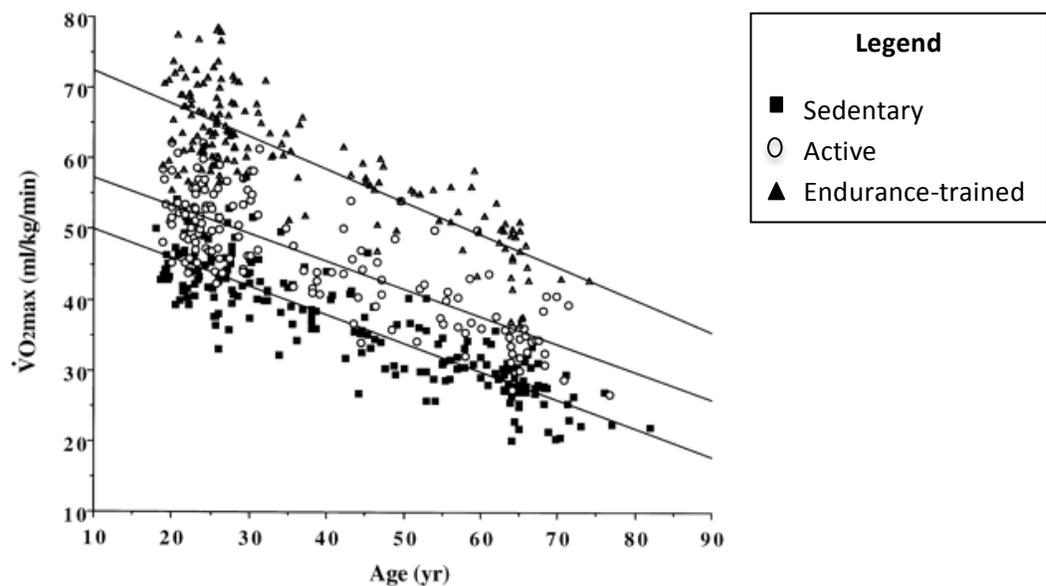


Figure 2.1 Effects of Training on Relative Aerobic Power (ml/kg/min) in Adult Males Adapted from “Meta-analysis of the age-associated decline in maximal aerobic capacity in men: Relation to training status,” by T.M. Wilson and H. Tanaka, 2000, *American Journal of Physiology Heart and Circulatory Physiology* 278, p. H831. Copyright 2000 by the American Physiological Society.

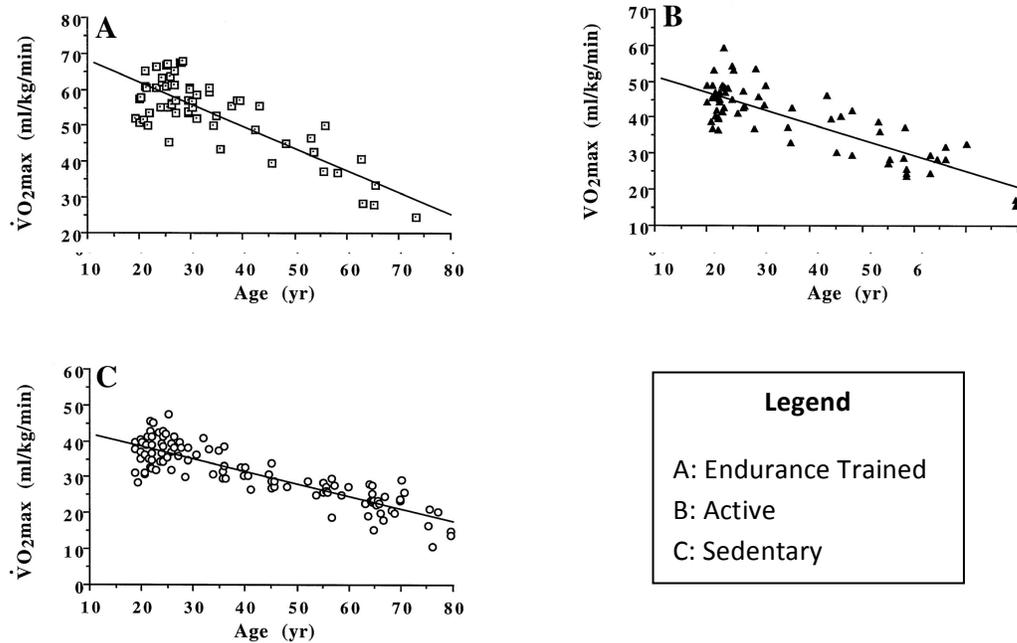


Figure 2.2 Effects of Training on Relative Aerobic Power (ml/kg/min) in Adult Females. Adapted from “Age-related declines in maximal aerobic capacity in regularly exercising vs sedentary women: A meta-analysis,” by M.D. Fitzgerald, H. Tanaka, Z.T. Tran, and D. R. Seals, 1997, *Journal of Applied Physiology* 83, p. 162. Copyright 1997 by the American Physiological Society.

2.1.1 Scaling Aerobic Power

Due to the high correlation between body mass, body composition and $\dot{V}O_{2\max}$, expressing aerobic power relative to body mass or fat free mass allows for a more accurate comparison between different sized individuals (Armstrong et al., 2011). As will be explained further later, the development of body composition is different between and within sexes, and therefore proper expression of aerobic power is crucial. Aerobic performance can be expressed in absolute terms (l/min), which does not take into consideration the size of the individual, or relative terms (ml/kg/min), which ratio scales $\dot{V}O_{2\max}$ to body mass or composition. Scaling $\dot{V}O_2$ relative to different characteristics of the body such as: body mass, fat free mass, leg length and other measures has been shown to significantly impact interpretation of final results.

Expressing this measure relative to different factors allows for not only comparisons between groups and to reference standards, but also allows for longitudinal tracking of physiological variables and performance throughout the lifespan (Armstrong & Welsman, 1997). Popular scaling methods include ratio standards, log-linear scaling, regression standards, and allometric modeling (Baxter-Jones & Maffulli, 2003; Cunha et al., 2011; Carling et al., 2012; Armstrong & Welsman, 1997). While many different methods can be used, ratio standards and allometric scaling are most commonly seen in the literature.

Ratio standards, the most commonly used method, expresses VO_2 relative to the body mass of the individual in kilograms (Armstrong & Welsman, 1997). This method assumes a linear relationship between body size and performance. In 1949 Tanner indicated this was not the case, as the ratio assumes that the velocity of growth in lung size (l) and body mass (kg) is 1:1. During growth this is not theoretically tenable as first there is an increase in size, followed by an increase in mass. If the ratio of the numerator and denominator are not 1:1 then this can lead to inappropriate interpretation. This potentially causes overestimation in those with lower body mass and underestimation in those with higher body mass (Armstrong & Welsman, 1997; Cunha et al., 2011). Furthermore, due to the fact that growth is not a linear process, and different areas increase in size at different times, scaling using body mass has its limitations in children (Baxter-Jones & Maffulli, 2003). Additionally, the use of body mass to scale aerobic power introduces further error, as it does not consider body composition. As earlier explained, there is a strong relationship between muscle mass and $\text{VO}_{2\text{max}}$, in that higher levels of muscle mass facilitate the utilization and delivery of oxygen to active muscles (Armstrong et al., 2011; Rowland, 2005). When comparing $\text{VO}_{2\text{max}}$ between genders, scaling to whole body fat free mass seems to elicit a decrease in percentage of difference between male and female aerobic power from 20% to 9%

(McArdle et al., 2010). Furthermore, studies have suggested that when VO_2max is scaled specifically to the muscle mass activated during exercise, such as percent muscle in the arm and lower leg for arm crank and cycle ergometers, respectively, the gender difference in VO_2max almost completely disappears (McArdle et al., 2010; Rowland & Cunningham, 1992).

Allometric scaling, a method using a co-efficient related to the body size of the sample, is used to reflect and control for the proportional adaptations in the body relative to changes in body size (Beunen, Baxter-Jones, Mirwald, Thomis, Malina & Bailey 2002). This form of scaling has been used in some pediatric and adolescent studies to scale VO_2peak according to the non-linear relationship to body size (Armstrong & Welsman, 1997). The use of allometric scaling, while becoming more popular, appears to be used less than the traditional ratio standards. A study by Nevill and associates (2004) showed that when measuring aerobic power in children playing weight bearing sports, such as soccer, the use of the ratio standard resulted in similar values as allometric scaling. Due to the use of ratio standards in the majority of literature, this thesis will be expressing VO_2max relative to body mass and fat free mass in order to maintain consistency and allow for comparisons to earlier literature. The term VO_2peak will also be used rather than VO_2max due to the ability to ensure that values detected represent a true VO_2max in the adolescent age group.

2.1.2 Association Between Aerobic Power and Health

Aerobic power has a number of health implications in both children and adults. Its natural decrease with age plays a significant role on longevity, quality of life and functional capacity (Canadian Heritage, 2013). It is purported that higher levels of aerobic power early in life may confer advantages to adult aerobic fitness. Studies have shown that having a low relative aerobic power (ml/kg/min) can be an indication of health risks, even in the absence of other health

related problems (Armstrong & Welsman, 1997). To maintain aerobic power, as well as other health benefits such as muscular strength, appropriate blood pressure and body fat levels, it is important to maintain involvement in sport and physical activity throughout the lifespan (Tremblay, LeBlanc, Kho, Saunders, Larouch, Colley, Goldfield, & Gorber, 2011). Both children and adults benefit from sport and physical activity with participation in an active lifestyle showing positive effects on obesity, metabolic disease and diabetes (Armstrong and Welsman, 1997; Janssen & LeBlanc, 2010).

2.2 Youth Physical Activity

Despite the known benefits of physical activity, Statistics Canada (2013) reported that only 6% of Canadian children and youth ages 5-17 accumulate the recommended 60 minutes of moderate to vigorous physical activity (MVPA) at least 6 times a week. Intensities are dependent on the individual's level of fitness and therefore are very individual (WHO, 2015). Performing an activity at MVPA requires a moderate to large amount of effort causing a noticeable increase in heart rate and breathing (WHO, 2015). Often the intensity of exercise is determined by using the percentage of an individual's maximal heart rate ($220 - \text{age}$); moderate intensity is considered 50-70%, while vigorous is considered 70-85% (CDC, 2015). Attaining this level of intensity is critical; studies have shown that health benefits, such as decrease in cardiovascular risks, are evident following 60 minutes of MVPA (Active Healthy Kids Canada, 2014). A minimum of 60 minutes of MVPA is recommended for children and adolescents due to these positive health effects. Janssen and LeBlanc (2010) found that the benefits of exercise are only seen after a minimum of 30 minutes; therefore, it is critical to keep physical activity levels up (Active Healthy Kids Canada, 2014).

Research has consistently shown that children and adults with higher levels of physical activity show a decreased prevalence of obesity, cardiovascular disease, high blood pressure and depression (Janssen & LeBlanc, 2010). Furthermore, a dose-response relationship between physical activity and health exists, indicating that increased activity, within healthy limits, is matched with increased health benefits (Janssen & LeBlanc, 2010). In response to the secular decline in physical activity levels The Canadian Physical Activity Guidelines recently suggested an increase in physical activity by 30-90 minutes a day regardless of current levels (Janssen & LeBlanc, 2010). The literature has also shown that sedentary time, which accounts for approximately 62% of waking hours in children, is independently correlated with increased cardio-metabolic disease, all-cause mortality and a number of physiological and psychological problems (Tremblay et al., 2011). A recent study by the Center for Disease Control (CDC) (2014) concluded that less than 48% and 29% of high school students attend physical activity classes weekly, and daily, respectively; therefore adolescents need additional physical activity outside of the school systems (CDC, 2014).

Physical activity in children and youth can be broken down into two main components: free play and sport involvement. It has been reported by parents that their children only receive approximately 4.1 hours of physical activity outside of school and organized sport per week (Active Healthy Kids Canada, 2014). The low levels of free play may be impacted by the amount of screen time, increased focus on work efficiency in society, and an increased reliance of parents on organized sport to get their children active (Active Healthy Kids Canada, 2014). It was reported that 75% of children between the ages of 5 and 19 years participate in organized physical activities or sport; these children are estimated to take, on average, about 1500 more steps a day as compared to those who do not participate in organized sport (Active Healthy Kids

Canada, 2014). Among those between the ages of 5 and 17 years that participate in sport, 46% do so year round, 26% participate for 8-11 months and 27% participate for less than 8 months (Active Healthy Kids Canada, 2014). While it is important for children to have free play involving physical activity, organized sport has been shown to play a beneficial role in children's lives; participation in organized sport, even once or twice a week, has shown to decrease the odds of children becoming overweight by almost 50% (Active Healthy Kids Canada, 2014).

The most frequently played organized sports in Canada have been identified as soccer (38%), hockey (24%), swimming (17%), basketball (13%) and baseball (10%); primarily all of these occur in private community facilities or sport clubs (Active Healthy Kids Canada, 2014). With regards to differences between sports, soccer appears to elicit the highest level of physical activity for children and adolescents; unfortunately, only 30% of the 50-minute soccer match provides the athlete with MVPA (Sacheck, Nelson, Ficker, Kafka, Kuder, & Economos, 2011). It has been found that while participation in organized sport is beneficial, it does not eliminate the decrease in physical activity seen with age throughout adolescence and into adulthood (Sacheck et al., 2011; Statistics Canada, 2013). Therefore, while organized sport definitely doesn't supply the full recommendation of daily physical activity, Sacheck and colleagues (2011) found that days containing the participation of organized sport showed higher amounts of physical activity scores than those days not containing the organized sport.

2.2.1 Youth Sports Participation

Despite the importance of sport involvement for activity levels, it has been reported that national sport participation rates are steadily decreasing, with a 17% decline seen between 1992 and 2010 (Canadian Heritage, 2013; Active Healthy Kids, 2014). In addition, it has been found that while there is an increase in attrition with increased age, the highest magnitude of decline in

participation rates is during adolescence (Canadian Heritage, 2013). Looking into the reason for attrition in sport, Durant and associates (1991) found that there are specific reasons why youth continue or discontinue participation in sport. In addition to lack of fun or playing time, being cut from a team had a large impact on continuation in that sport; in fact, being cut from a particular team was identified as the second reason, only behind injury, for stopping participation in a sport (Durant et al., 1991). Adolescent athletes cut from a team showed higher threat scores and emotional ill-being as well as lower levels of performance goals, self-esteem, and positive affect (Adie, Duda, & Ntoumanis, 2010). Those athletes cut from a team were also identified as being less likely to engage in future organized and/or coach-based sport; therefore, possibly contributing to the observed decrease in physical activity levels (Durant et al., 1991). While eliminating athletes is part of competitive sport, the bias towards selecting more mature individuals could cause equally talented but less mature athletes to be unfairly eliminated from sport (Viickberg, Purge, Jurimae, Saar, Latt, Maestu, & Jurimae, 2013).

The importance of childhood and adolescent involvement in sport is emphasized in a study by Perkins and associates (2004) focusing on the tendency for active children to be active adolescents and adults. While consensus in this area rarely supports the ability to track physical activity levels across the lifespan, it was found that less than 1% of individuals with no experience in organized sport in adolescence initiated participation in sport later in life. In comparison, 36% of people who participated in sport in childhood continued to participate through to young adulthood (Perkins, Jacobs, Barber, & Eccles, 2004). While physical activity levels cannot be tracked from childhood into adulthood, Perkins and associates (2004) suggested that adolescent sport participation was a mediator between child and adulthood sport participation and physical fitness. It was found that continued sport participation in adolescence

had the ability to explain sport participation, and partially explain physical fitness activities in adulthood (Perkins et al., 2004). Overall, they suggested that sport participation during the early years of adolescence was likely to lead to greater rates of sport participation during adulthood (Perkins et al., 2004). Given the connection between sport participation and increased physical and mental well-being it is clear that the continuation of sport from childhood through adolescence and into adulthood is critical to lifelong health benefits.

2.3 Growth and Maturation

Before discussing the changes of aerobic power throughout the lifespan, it is important to understand the role of normal growth and maturation on the development of aerobic power. The process of growth and maturation during childhood and adolescence has vast effects on the body, including effects on characteristics identified as beneficial in athlete selection, such as aerobic power development (Tanner, 1978).

2.3.1 Growth

Growth, often measured as height, in children is an organized but complex process that dominates the first two decades of life and results in increases in size of the body and its tissues (Kohl & Cook, 2013). Maturation, which is defined as the progression into the adult state (Baxter-Jones, Eisenman, & Sherar, 2005; Malina et al., 2004a), includes the transitional period of puberty marked by the appearance of secondary sex characteristics, the adolescent growth spurt, and development of the reproductive system (Malina et al., 2004a). The first documented measurement of growth was by Count Philibert Gueneau in 1759, during the time of enlightenment; Gueneau measured the height of his son at each age and created a growth chart (Tanner, 1978). Now such growth charts are used in hospitals around the world in order to determine optimal development of children (Tanner, 1978).

The tracking of height in 1759 led to the creation of the curves of systematic growth first created in 1923 (Malina et al., 2004a). These growth curves, which describe the typical pattern of post-natal growth, are expressed as a percentage of growth attained from birth to 20 years of age, and are divided into general, lymphoid, neural and genital curves (Figure 2.3)(Malina et al., 2004a). The general curve describes the pattern of growth for the body as a whole, as well as most of its parts, including weight and height (Tanner, 1978; Malina et al., 2004a). While the pattern of growth, as described by Scammon's curves are relatively similar between males and females, females progress through growth approximately two years ahead of males, therefore, females are always closer to their mature state (Tanner, 1978). The average height growth curve in females shows a growth 'spurt' beginning around the age of 10.5 years, and reaching its peak in velocity (growth per year) at the age of 12 years. This peak in the amount of growth attained per year is named the adolescent growth spurt or peak height velocity (PHV). PHV is a measure of somatic maturity (Tanner, 1978). In males the initiation of and peak in velocity of growth (PHV) occurs approximately two years later than females, at approximately 12 and 14 years of age, respectively (Tanner, 1978). Despite the later observed growth found in males compared to females, adult males are, on average, taller than females due to a longer period of growth and higher velocities of growth at PHV (Tanner, 1978). It is important to remember that all healthy individuals follow the same pattern of growth but that the timing and tempo of growth at various maturity milestones differs not only between the sexes but also within the sexes. Absolute aerobic power ($\text{VO}_{2\text{max}}$ l/min) also follows the general curve of growth, although patterns are different when expressed relative to body mass ($\text{VO}_{2\text{max}}$ ml/kg/min)

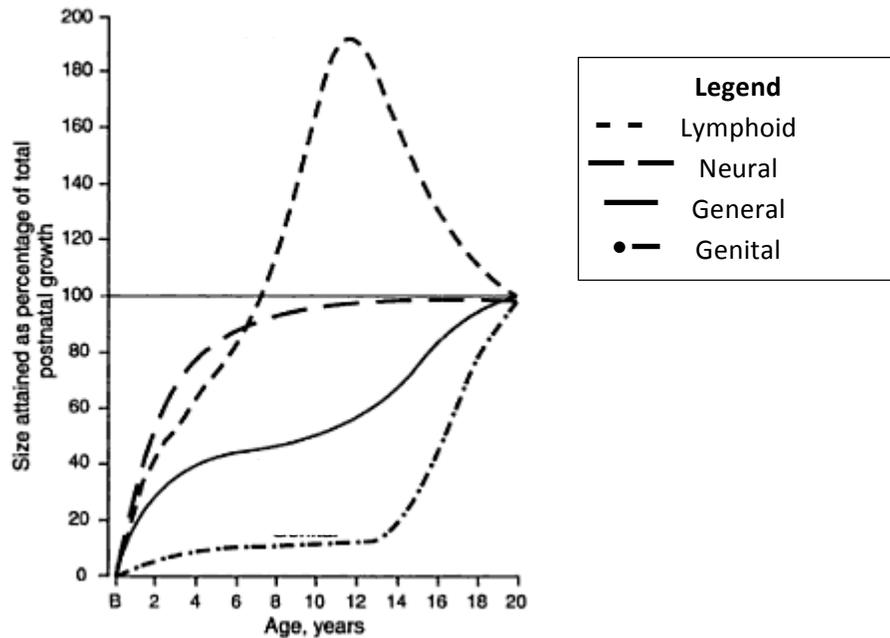


Figure 2.3 Scammon’s Systematic Curves of Growth Adapted from “Introductory Concepts” by R. M. Malina, C. Bouchard and O. Bar-Or, 2004, In *Growth Maturation and Physical Activity*, p. 13. Copyright 2004 by Robert M. Malina, Claude Bouchard, and Oded Bar-Or.

Males and females also differ in body composition development. For example, after the age of 8 years the difference in body fat between males and females diverges, with females having higher limb and total body fat (Tanner, 1978). During maturation females show a plateau and an incline in limb and body fat, respectively, until adulthood; an opposing trend is seen in males who experience a decline and a plateau in limb and body fat, respectively (Tanner, 1978). In females between the ages of 5 and 17 years, there is an increase in relative muscle mass of 40-45%; this later decreases as the percentage of relative fat mass increases, often reaching 25% (Armstrong, McManus & Welsman, 2008). In males of the same age range maturation causes an increase in relative muscle mass of 42-53% accompanied by a decrease of relative body fat of 12-14%; this lower fat mass as compared to females remains throughout the lifespan (Armstrong

et al., 2008). Higher relative muscle mass found in males when compared to females is believed to be the main influencing factor for the age-related sex differences of absolute aerobic power (l/min) (McArdle et al., 2010; Armstrong et al., 2011; Rowland, 2005; Armstrong & Welsman, 2000)(Figures 2.1, 2.2 and 2.6). Muscle mass has been shown to facilitate the use of oxygen during exercise, as well as increase venous return, thereby increasing the amount of blood pumped from the heart, and subsequently, oxygen carrying capacity (Armstrong & Welsman, 2000). Therefore, the lower level of muscle mass in females implies that females have a smaller capacity for facilitating oxygen, as well as venous return to increase circulation of oxygen. Furthermore, $VO_2\max$ is highly reliant on the amount of muscle activated during exercise; therefore, the lower aerobic power in females may be due to the fact that females have less muscle mass to activate when compared to males (McArdle et al., 2010).

Due to the variation of growth and development seen between individuals, percentile charts have been used to track both height and the velocity of change in height of children by chronological age (Tanner, 1978)(Figure 2.4 & 2.5). Percentiles (between 3 and 97%) represent the standards for height and weight at varying ages; the use of percentiles allows comparison between individuals to determine whether optimal development is occurring (Tanner, 1978). The use of percentiles can be explained using a hypothetical male subject aged 14 years, if this individual's height is 163 cm than he would be placed on the 50th percentile for his age group (Figure 2.4). This indicates 50% of the population at the same age has a height above his and 50% have a height below his; assuming the tempo of maturation is also average. Essentially, percentiles represent where one individual ranks in comparison to another of that sex, and age. Reading and expression of percentiles can be explained by the following situation; if there were 100 males, all of the same age, 10 males would fall below the 10th percentile, 25 below the 25th

percentile, and approximately 50 below the 50th percentile (Tanner, 1978). Furthermore, 97 males would fall below the 97th percentile, and only 3 would fall above; those three who fell above the 97th percentile would be considered very tall for their age and sex group (Tanner, 1978). Percentiles can be used in order to identify individuals who may be growing in an abnormal fashion as compared to their peers; for example, if a male fell under the 3rd percentile for height, it could be an indication of stunting or inhibition of proper development (Tanner, 1978). Percentile charts for height and weight for both males (Figure 2.4) and females (Figure 2.5), between the ages of 2 and 20 years of age, are included for reference. Using percentile charts, z-scores for height and weight can also be calculated in order to compare values to the mean of a population (the 50th percentile). In addition to growth characteristics, percentile charts can also be used to compare and track other measures such as aerobic power; VO₂max percentile charts for both males and females have also been developed (Figure 2.6). These charts, similar to the height and weight percentile charts in Figures 2.4 and 2.5, allow comparison between individuals and to illustrate where an individual falls in comparison to the general population of that age and sex. As will be seen in Figure 2.6, the 50th percentile (approximate median) for relative aerobic power in the female population remains near 39-40 ml/kg/min from the ages of 12-18 years, however, in males of the same age it increases from approximately 42-46 ml/kg/min (Eisenmann, Laurson, & Welk 2011).

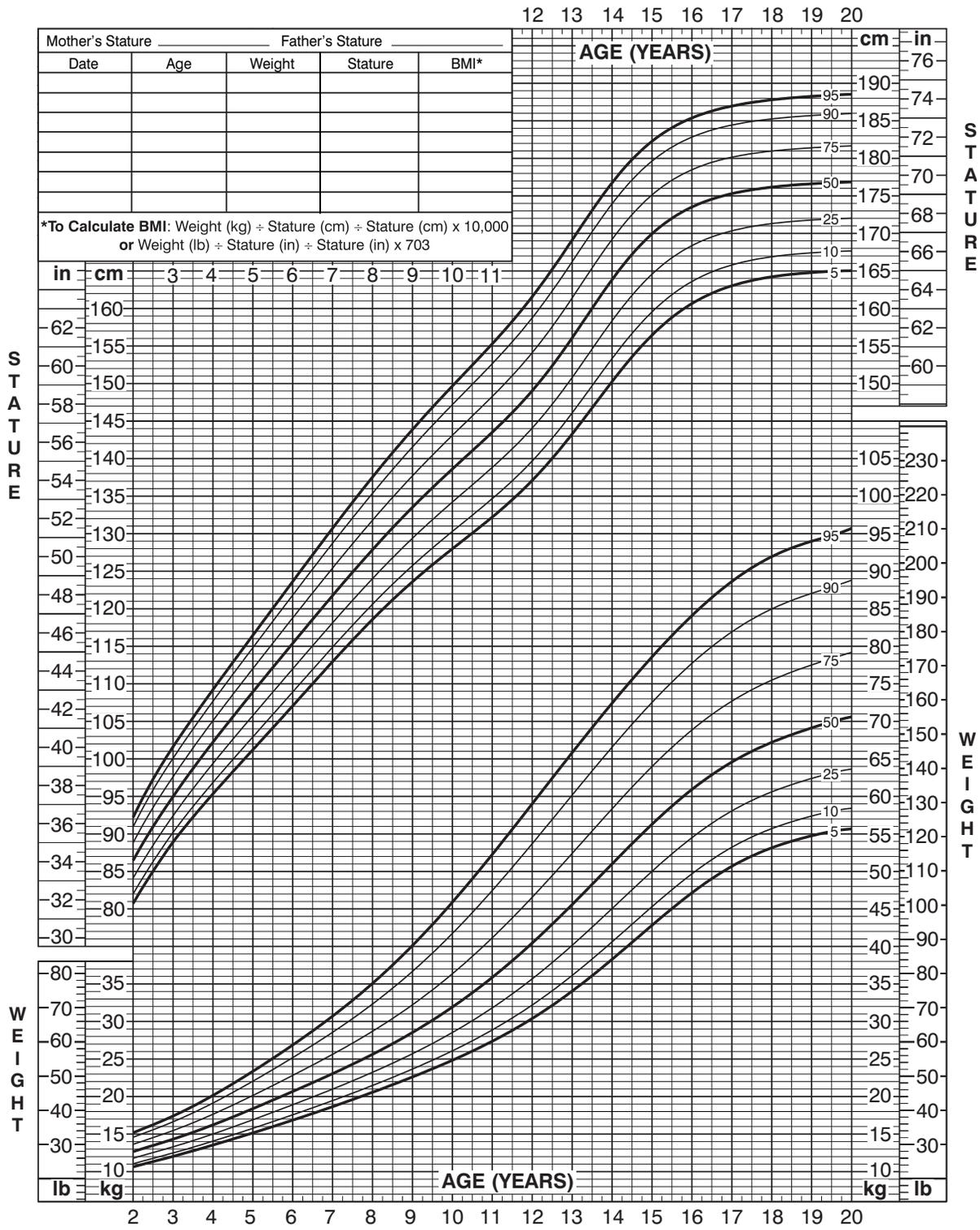


Figure 2.4: Height and weight percentiles for males aged 2-20 years old. From Clinical Growth Charts by Centers for Disease Control and Prevention (CDC), 2009, Retrieved from http://www.cdc.gov/growthcharts/clinical_charts.htm#Set2. Copyright 2009 by CDC.

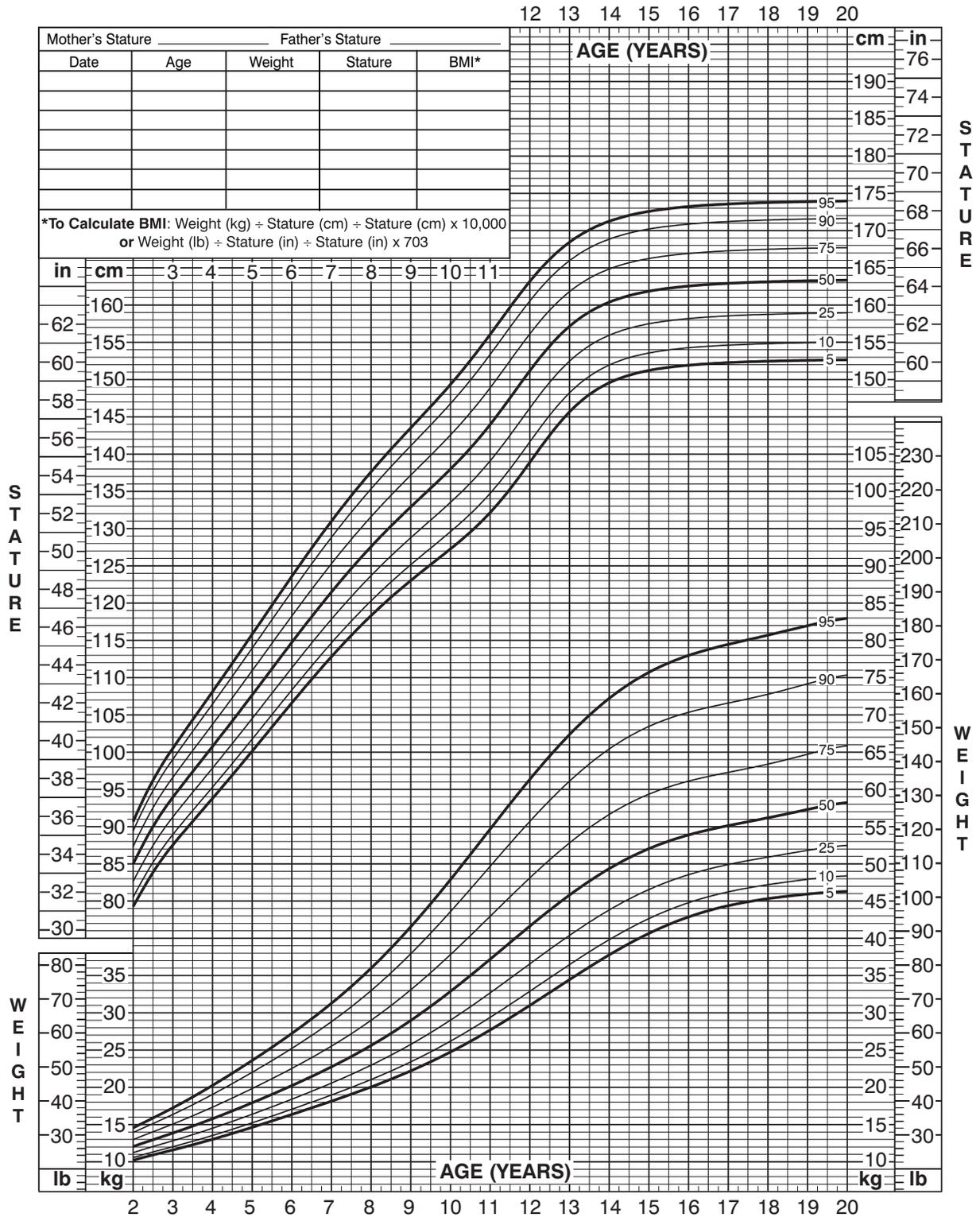


Figure 2.5 Height and weight percentiles for females aged 2-20 years old. From Clinical Growth Charts by Centers for Disease Control and Prevention (CDC), 2009, Retrieved from http://www.cdc.gov/growthcharts/clinical_charts.htm#Set2. Copyright 2009 by CDC

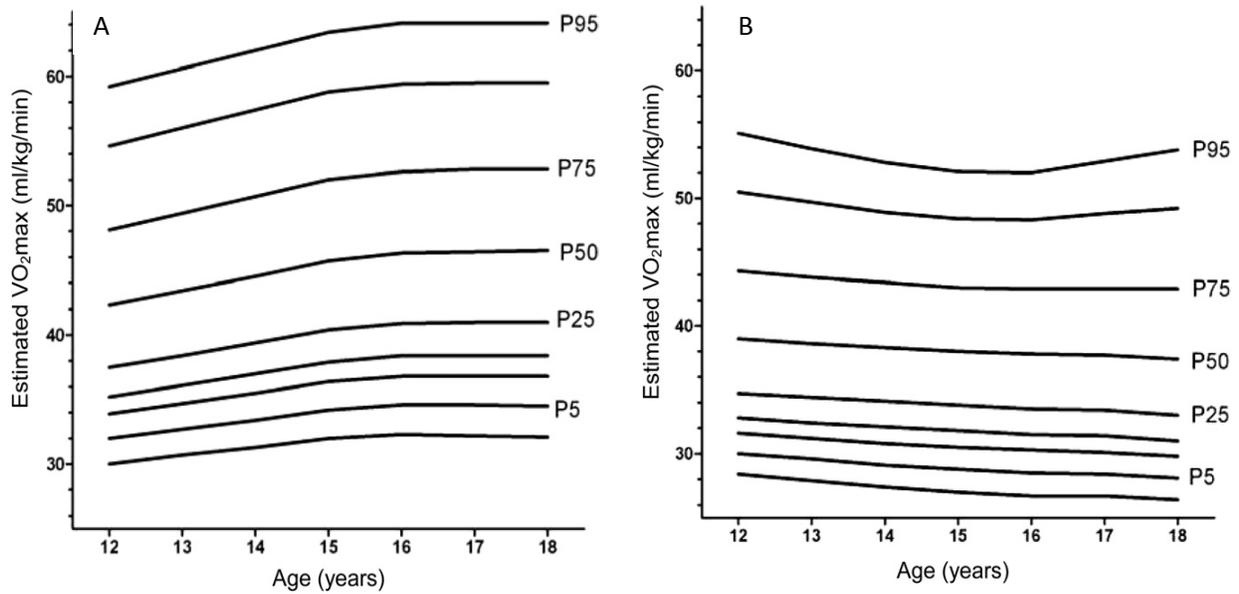


Figure 2.6 Relative aerobic power (ml/kg/min) percentiles for males (A) and females (B) by age. Adapted from "Aerobic fitness percentiles for U.S. adolescents," by J.C. Eisenmann, K. R. Laurson and G. J. Welk, 2011, *American Journal of Preventative Medicine* 41, p. S108. Copyright 2011 American Journal of Preventive Medicine

2.3.2 Maturation

As already discussed, there are wide variations in height and the rate of growth in height during the adolescent period between males and females. There are also wide ranges of maturational development (timing and tempo) within the sexes. The measurement of maturation can be performed using many different markers, such as: skeletal age, somatic maturity (e.g. PHV), secondary sexual characteristics, and dental age. The timing and tempo of maturation is different among all individuals and allows for the classification of adolescents into the categories of early, average or advanced maturation for their chronological age (Malina et al., 2004a). An individual who is advanced in maturation would have a higher skeletal age (SA) or biological age (BA) as compared to their chronological age (CA); average maturation is seen when SA and/or BA match CA, and those with CA greater than SA or BA are thought to mature later than

the general population (Carling et al., 2012; Malina et al., 2004a). In males, the beginning of puberty, which is marked by the beginning of testicular enlargement, can begin anywhere from 10-14 years of age depending on if the male is an early (age 10), average (age 12) or late (age 14) maturing individual (Tanner, 1978). In relation to height, the time of maximal growth (PHV) generally occurs approximately one year after the initiation of puberty (Tanner, 1978).

Progression of maturation is highly variable among individuals; it has been reported that some males can move through all 5 stages of secondary sexual characteristics (pubic hair or genitalia growth) within two years, while others can develop much slower (Tanner, 1978). In females, while maturation occurs earlier than in males, the variation of the tempo in the development of secondary sexual characteristics, (breast and pubic hair development) also occurs at different rates for each individual (Tanner, 1978). Early maturing females could start puberty as early as 9 years of age, while late maturing females may not start puberty until around the age of 13; the average age of maturation in females, as indicated by breast development, is approximately 11 years old (Tanner, 1978). Menstruation, which, on average, begins between the ages of 12.8 – 13.2 years, occurs when the velocity of height starts to decline at its fastest rate (Tanner, 1978). With regards to height, females experience PHV much earlier in maturation than in males; therefore, while PHV marks the beginning of puberty for males, it often marks the end for females (Tanner, 1978).

The use of PHV as a maturational indicator is the most used method in longitudinal studies (Baxter-Jones et al., 2005). In longitudinal studies, PHV is measured using whole year height velocities or changes in height per year (cm/year). These values are plotted on curves and mathematical procedures are utilized in order to identify the age at which the maximum velocity in height occurred (Baxter-Jones et al., 2005). The use of a longitudinal study to identify the age

at which maximal velocity of height occurs requires longitudinal based studies where the same individuals can be followed for a long period of time. Unfortunately, such studies can be difficult to operate, expensive and time consuming. To address this problem, a multiple regression equation, using measurements that can be taken during a cross-sectional study was developed (Mirwald, Baxter-Jones, Bailey & Beunen, 2002). This equation uses segmental growth patterns by utilizing height, trunk length and leg length measurements, along with chronological age and body mass to predict age of peak height velocity (aPHV), which can further calculate maturity offset.

Age at peak height velocity (aPHV) is a measure of somatic maturity that indicates the time of greatest velocity in growth during adolescents (Mirwald et al, 2002). This formula was adapted using Saskatchewan youth, and has shown to estimate maturity status to within +/- 1.18 years, 95% of the time in boys and 1.14 years, 95% of the time in girls (Mirwald et al., 2002; Baxter-Jones et al., 2005). This equation was been used in pediatric populations, and was developed using Saskatchewan children and adolescents; therefore the sample from which this equation was created was similar and applicable to the current cohort (Mirwald et al., 2002). Following the calculation of aPHV, maturity offset can be predicted using the following equation: $MaturityOffset = aPHV - CA$ where CA represents chronological age at test. Maturity offset, the number of years from, or past, aPHV can be used as a categorical term to place individuals into early, average, or late maturing categories or as a continuous measure of maturity (Baxter-Jones et al., 2005).

2.3.3 Aerobic power development with growth, maturation and aging

Development, an umbrella term for growth and maturation can refer to the refinement of biological systems, or behaviors such as motor competencies (Kohl & Cook, 2013). Growth and maturation, which were discussed earlier, result in increased size of the body and its tissues progressing the individual closer to their biologically developed, adult state (Kohl & Cook, 2013; Baxter-Jones et al., 2005; Malina et al., 2004a; Cunha et al., 2011). While past literature has shown that height, age and mass explain large amounts of variance in aerobic fitness, it has also been shown that Tanner stages of maturation have a positive relationship with VO_2 values (Armstrong & Welsman, 2000). Tanner stages, which range from 1 (child-like) to 5 (adult-like), are ratings for sex-maturity that are used to predict physical changes such as the adolescent growth spurt, menarche and the first release of sperm (Boltin, 2001). In females, progression from Tanner stage 1 to stage 2 is marked by the development of breasts, occurring at the average age of 11 years; menarche generally begins at stage 4 or 5 (Boltin, 2001). In males, the growth of the testicles indicates the onset of puberty; spermarche, or the first release of spermatozoa occurs before stage 3 and pubic hair occurs at stage 4 (Boltin, 2001). Studies using multiple regression analysis have shown that aerobic power is significantly increased with maturation in both sexes, after controlling for body mass. The independent effect of maturation in addition to growth indicates that maturation has a unique effect on aerobic power in developing youth (Armstrong et al., 2011; Armstrong & Welsman, 2000).

From a physiological perspective, the increase in aerobic power seen with maturation is attributed to increased size of the heart and lungs, subsequently increasing stroke volume, cardiac output, and ventilation volume (Kohl & Cook, 2013). Increased stroke volume, the

amount of blood pumped per minute, and cardiac output, the amount of blood pumped per heartbeat, allows for an increase in blood flow from the heart despite an age related decrease in heart rate (Kohl & Cook, 2013). During this time there is also an increase in red blood cell and hematocrit levels, thereby increasing hemoglobin, which, is responsible for transporting oxygen to the tissues (Kohl & Cook, 2013). Beneficial increases due to maturation are evident until the third decade of life where a decline in maximal relative aerobic power of approximately 5-10% per decade is seen; this decline has a larger magnitude in males (McArdle et al., 2010; Hawkins & Wiswell, 2003). This secular decline in relative aerobic power is related to the decrease in heart rate (3-5% per decade), this causes a decreases in stroke volume and cardiac output, thereby decreasing oxygen carrying capacity and subsequently, aerobic power (McArdle et al., 2010; Hawkins & Wiswell, 2003). The decline in maximal heart rate is positively affected by a physically active lifestyle; however, is unavoidable and has been shown to reduce cardiac output anywhere from 40-100% (McArdle et al., 2010; Hawkins & Wiswell, 2003). While these decreases occur in all individuals, the decline occurs almost twice as fast in sedentary as compared to active individuals (McArdle et al., 2010)

2.3.4 Comparison of Aerobic Power between Sexes

Beneficial changes that occur during maturation, such as increased hemoglobin and red blood cells, however, are more evident in males. It has been reported that upon the initiation of puberty, marked differences in physiological development and aerobic power can be detected between sexes (McArdle et al., 2010). With aging, growth and maturation, there is an increase in absolute aerobic power (l/min) of 150% and 80% between the ages of 8 and 16 for males and females, respectively (Armstrong et al., 2008; Armstrong et al., 2011). While maturation causes an increase in VO_2 peak (l/min) in both sexes, males tend to increase in a more linear and

consistent pattern up until the age of 16, while females plateau at the age of 14 (Figure 2.7) (Kohl & Cook, 2013; Rowland, 2005; Armstrong et al., 2008; McArdle et al., 2010). In males, it appears that the greatest magnitude of change in aerobic power appears upon the attainment of PHV, however, others have reported maximum magnitude anywhere from 3 years before to 2 years after PHV (Armstrong et al., 2008). This larger increase in aerobic power in males as compared to female's results in consistently higher values across the lifespan with differences measured at 200 ml/kg/min before puberty, and increasing with maturation (Rowland, 2005; Armstrong et al., 2011). While data is less available for females, Armstrong and Welsman (2000) identified that the largest increase in $\dot{V}O_{2\text{peak}}$ occurs between the ages of twelve and thirteen.

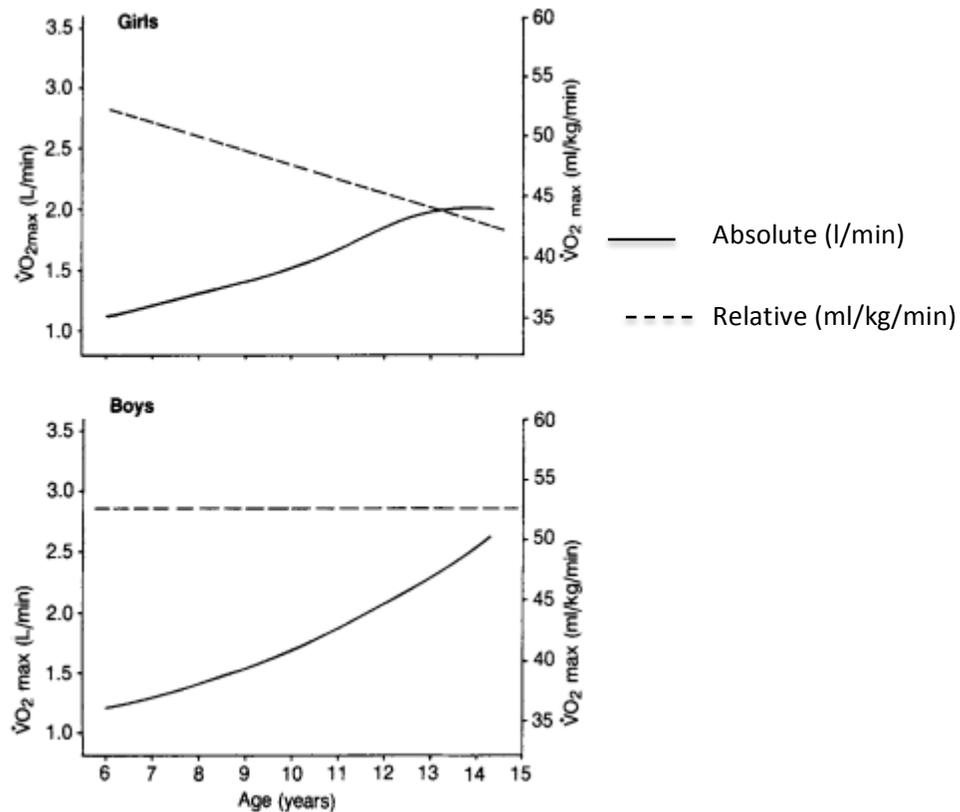


Figure 2.7 Average absolute (l/min) and relative (ml/kg/min) aerobic power for males (top) and females (bottom) Adapted from "Aerobic fitness" by Rowland, T. W. 2005, In *Children's Exercise Physiology*. Copyright Human Kinetics

The difference in aerobic power between sexes is dependent on the way in which values are expressed. In absolute terms (l/min), male and female values remain somewhat similar with only a 10% difference in VO_2 (l/min) until the age of 12 (McArdle et al., 2010; Armstrong, 2011). By the ages of 14 and 16, however, these differences in aerobic power increase to 25% and 50% or more, respectively (McArdle et al., 2010). These sex differences have been attributed to the larger relative muscle mass levels seen in males, as well as possibly higher physical activity levels, as compared to females (McArdle et al., 2010). When analyzed in relative values (ml/kg/min), there is a 36% increase in males and only a 10% increase in females between the ages of 5 and 13; when relative VO_2 values are analyzed in males and females between the ages of 12 and 19 years there is a smaller increase of 6.7% in males and a decrease of 5.5% in females (Helmantel, Elferink-Gernser & Visscher, 2009). Research in this area has found that there is a peak in aerobic power in females around the age of 14 years followed by a progressive decline reaching approximately 40 ml/kg/min by the age of 16 years (McArdle et al., 2010). In males, aerobic power stays relatively consistent from the ages of 6-16 years at approximately 52 ml/kg/min; male values at 16 years of age are approximately 32% greater than female values (McArdle et al., 2010). Differences in VO_2 peak between sexes have been suggested to be due to the large amount of changes that occur during puberty, including: changes in body composition, hemoglobin and hormone levels, as well as physical activity (Rowland, 2005; Baxter-Jones & Maffulli, 2003; Armstrong, et al., 2011). During maturation, hemoglobin levels increase in males, but plateau in females, these differences have been attributed to increased testosterone levels in males at this time (McArdle et al., 2010; Armstrong et al., 2008). Such changes seen with maturation result in males having, on average, hemoglobin concentrations 10-14% greater

than seen in females, allowing for greater oxygen-carrying capacity enabling larger amounts of oxygen to be circulated during exercise (McArdle et al., 2010).

The lower aerobic power values seen in adolescent females have been shown to continue across the lifespan with older females having lower aerobic power values than older males (Figure 2.8). The reasons for these sex differences are similar to the reasons for sex differences during adolescents, including body fat and hemoglobin levels, as well as heart size (Woo, Derleth, Stratton, & Levy, 2005). A review by Woo and associates (2005) attributed the lower resting and peak oxygen uptake levels in women to their lower maximal stroke volume. Females have a stroke volume that is approximately 5% lower than males; this lower value has been attributed to lower relative heart size, vascular resistance, hormone response and skeletal muscle pump function (Armstrong et al., 2008). While there is lack of evidence to suggest the ability of habitual physical activity to effect aerobic power values, it has been suggested that higher physical activity levels in adult males may contribute to higher aerobic power values as compared to females (Armstrong, 2011; Armstrong et al., 2008). Given the lack of evidence to support habitual physical activity effects on aerobic power, the sex differences seen during adolescence and adulthood is most likely due to maximal heart size, stroke volume and oxygen extraction in the peripheral limbs (Woo et al., 2005). Aerobic power (l/min and ml/kg/min) changes from the ages of 20 to 70+ years for both males and females are shown in Figure 2.8.

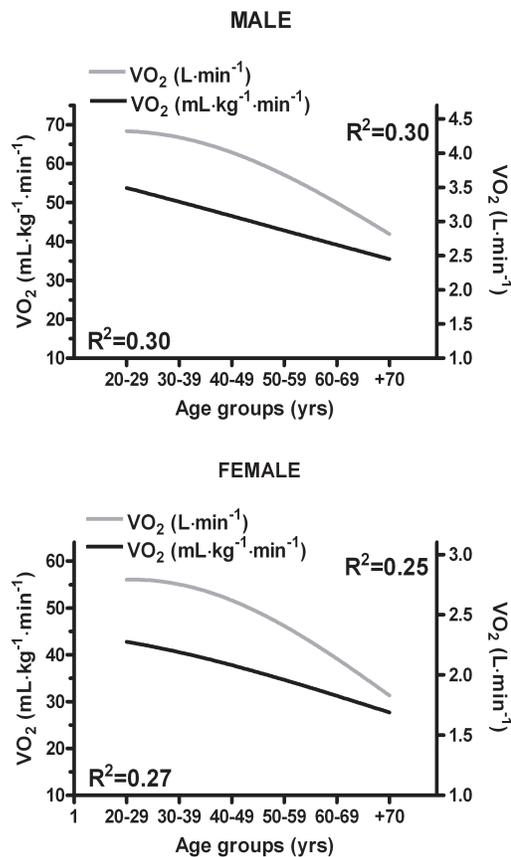


Figure 2.8 Average absolute and relative aerobic power for adult males (top) and females (bottom). Adapted from “Aerobic capacity reference data in 3816 healthy men and women 20-90 years,” by H. Loe, O. Rognmo, O. Saltin, and U. Wisloff (Loe, Rognmo, Saltin, & Wisloff, 2013, *PLoS One* 8, p. 9. Copyright 2013 Henrik Loe et al.

2.4 Aerobic Power and Training

Aerobic power is often used as an indication of performance in sports dominated by running and endurance abilities (Baquet et al., 2003). VO₂peak is an important criterion in sport, and can be incredibly helpful when predicting talent, and comparing competition level and training regimes of athletes (Cunha et al., 2011; Armstrong et al., 2011). With popularity of competitive sport increasing among younger populations, research into the ability and effects of aerobic training on VO₂peak in younger individuals is vast. Thus far, it has been shown that there is a positive relationship between VO₂peak, age, height and weight; in addition there is a

connection between VO_2peak , maturation and sport-specific training (Baquet et al., 2003; Baxter-Jones & Maffulli, 2003; Armstrong et al., 2007; Helmantel et al., 2009; Baxter-Jones, Goldstein, & Helms, 1993). Research has shown a relationship between stage of puberty and aerobic power development for male with a statistically significant increase in aerobic power appearing during pubertal development for males (Baxter-Jones et al., 1993). The increase in aerobic power in males during puberty is not seen in females; this lack of development in aerobic power in females is, as stated previously, impacted by increased relative fat mass acquired during puberty in females (Armstrong et al., 2008; Baxter-Jones et al., 1993). In addition to puberty, training regime also has a significant impact on aerobic power of youth athletes with swimmers, of both genders, showing superior aerobic power as compared to soccer players, gymnasts and tennis players (Baxter-Jones et al., 1993). Therefore, while there was no significant relationship between pubertal development and aerobic power in females, it does appear that training has a significant effect on the development of female aerobic power (Baxter-Jones et al., 1993). These results indicate that there is a significant effect of pubertal development on aerobic power in males, and training regime on both males and females during puberty (Baxter-Jones et al., 1993).

While there is a significant effect of pubertal development on aerobic power in males, and training regime on both males and females during puberty, young athletes do not show the same magnitude of effects as adults (Helmantel et al., 2009). In general, it has been shown in numerous studies that trained children and adolescents of both genders have superior VO_2max values when compared to their non-trained, age-matched counterparts (Baquet et al., 2003; Baxter-Jones & Maffulli, 2003; Armstrong et al., 2007; Helmantel et al., 2009). These studies have shown that trained youth have higher maximal cardiac output, blood and plasma volume, hemoglobin levels and myocardial mass and heart volume (Armstrong et al., 2007). These

factors, as well as lower heart rate with concomitant higher stroke volume during submaximal exercise indicate training adaptations of the cardiovascular system (Armstrong et al., 2007). The ability of young athletes to benefit from aerobic training has been shown in review articles summarizing that more mature athletes show no advantage in the ability to increase aerobic power with training (Armstrong et al., 2007). Such results provide evidence against the maturational threshold, and critical period theories by showing athletes under the age of 11 are just as likely to show beneficial adaptations due to exercise as those over 11 years of age (Armstrong et al., 2007; Baquet et al., 2003). Therefore, while there are studies arguing the ability of younger athletes to show advantageous changes in aerobic power, it is most likely that the lack of adaptation in such studies is due to inadequate intensity of the exercise (Baquet et al., 2003).

While changes in aerobic power during youth can be attributed to genetic, environmental or endocrine factors, the point that trained adolescents have super aerobic power is evidence that training adaptations exist (Armstrong et al., 2011). Physically active and trained male youth have displayed values greater than 60 ml/kg/min and females have been shown to have VO_{2peak} values of greater than 50 ml/kg/min (Armstrong et al., 2011). As compared to their age-matched, untrained peers showing average VO_{2peak} values of 35.2-48.0 ml/kg/min and 35.8-41.7 ml/kg/min in males and females, respectively, the trained adolescence are at an obvious advantage (Helmantel et al., 2009). Evidence supporting the ability of prepubescent populations to increase aerobic function with training have been seen in studies with athletes 8 years and older showing an increase of 5-6% in VO_2 values; when only those studies finding a significant training effect are included that rises to 8-10% (Baquet et al., 2003). Similarly, Armstrong and associates (2011) found that a 12 week training program induced, on average, an 8-9% increase

in VO₂peak values in youth athletes independently of sex, age and maturation. Furthermore, it was found that in male adolescents, both maturity and years of training explained a significant amount of variance; thus suggesting an independent role of training on aerobic power in male adolescents (Malina et al., 2004a).

The numerous studies that have shown increases in aerobic power in young males and females through interval and continuous training is extremely convincing (Helmantel et al., 2009). The ability of young children to show training adaptations is apparent in the review article by Helmantel and associates (2009) who divided children and adolescents into age and athletic focused categories. Athletes between the ages of 6 and 12 years were considered the “sampling” age who had high deliberate play and low deliberate practice; athletes who were 13 to 15 years old were in the “specialization” category had equal deliberate play and practice, and those 16 years and older were the “investment” category who had higher deliberate practice (Helmantel et al., 2009). This review found that the sampling and investment groups (6-12 and 16+ years) showed overwhelming evidence that training using dance, running, swimming, and other sports had the ability to increase aerobic power (Helmantel et al., 2009). Studies looking at the 13-15 year old age groups, in males and females, found no significant difference in aerobic power between those who were trained and not trained, however, these studies either used low duration training, or already highly trained athletes (Helmantel et al., 2009). It is important to note that the studies looking at this age group failed to provide adequate details regarding training, and therefore it is difficult to draw a final conclusions (Helmantel et al., 2009; Baquet et al., 2003). However, due to the success of the older and younger groups, it can be suggested that training can have a beneficial effect on aerobic power despite level of maturation (Helmantel et al., 2009).

Discrepancies between studies analyzing the ability of prepubescent athletes to show aerobic adaptations from training may be due to testing procedures or volume of training (intensity and duration) (Baxter-Jones & Maffulli, 2003; Armstrong et al., 2011; Baquet et al., 2003). Baquet and associates (2003) performed a review of all studies that looked at the effect of training to adapt the aerobic power of young athletes and found that the most important aspect of fitness leading to adaptations was intensity. Many studies that did not find a positive effect of training in young athletes did not appear to use adequate intensity in order to cause these changes (Baquet et al., 2003). In addition to intensity it was found that a minimum of 12 weeks of training, at adequate intensity, must be performed in order to elicit any changes in aerobic power (Armstrong et al., 2011). Another large difference between studies is the training level of the adolescent athletes studied; literature that did not find a difference between intervention and the control groups often utilized two groups of highly trained or similarly trained young athletes (Baquet et al., 2003). It has been found that there is a negative relationship between high initial aerobic power, often found in well trained athletes, and effects of training; in that, those who have an initial high aerobic power are less susceptible to training adaptations (Baquet et al., 2003). Lastly, there were reports of studies using modes of training that differed from the mode of testing, for example, some studies used a physical education class for training that was highly focused on locomotor exercises, and then tested athletes using a cycle ergometer (Baquet et al., 2003). Similarly, there was a study where the athletes trained with cycling and then performed a treadmill running test in order to measure aerobic power (Baquet et al., 2003). These studies did not see a difference in the trained and untrained group, possibly due to the mismatch of methods used in training and testing (Baquet et al., 2003).

2.4.1. Aerobic Power and Soccer

While it has been suggested that talent in soccer is multifaceted, there is no denying the need for superior aerobic power in order to be successful in such a sport. Soccer requires high aerobic fitness in order to provide adequate energy during match play and to recover from the high intensity bursts during rest, or lower intensity exercise bouts (Dickau, 2006). Having an adequate aerobic system is crucial during match play, it is estimated that 8-12 kilometers are covered by outfield soccer positions during a single match; aerobic metabolism is believed to contribute approximately 90% of the energy needed (Cunha et al., 2011). A study by Carling and associates (2008) found that players with higher aerobic fitness levels covered more distance in games, were more able to maintain work rates near the end of match-play, and recovered from maximal exercise bouts faster than those with lower aerobic fitness. Mujika and associates (2009) reported the need for a high level of endurance and aerobic power with results that found elite level soccer players of both sexes had superior endurance levels. While players in this study were between the ages of 18 and 23 years, research by Stroyer and associates (2004) found that during match play, adult and child elite soccer players elicit similar level of maximal oxygen uptake (ml/kg/min); therefore results from older player could possibly also represent younger samples. While it has been shown that successful male soccer players, as measured by competitive level, have higher VO_2 values (ml/kg/min) it is unclear if this difference is due to superior aerobic power prior to selection, the training received due to selection status, or a combination of both (Armstrong 2013).

2.4.2 Aerobic Power by Playing Position in Soccer

Given the numerous factors that can affect VO_{2peak} , it is not surprising that comparison of this aerobic measure between soccer positions, and between teammates is incredibly complex and inconclusive. Studies comparing the aerobic power between positions: including forwards, defensemen and goalkeepers have all resulted in unclear relationships, except for when comparing goalkeepers to other players. These studies have consistently shown that there are significant differences between goalkeepers and those athletes who play positions out in the field; with goalkeepers consistently having lower aerobic power levels (Boone et al., 2012; Russell & Tooley, 2011; Stroyer et al., 2004). Aside from goalkeepers, center backs were reported to have the next lowest VO_2 , followed by strikers, and finally by midfielders and fullbacks, who reported the highest VO_2 values (Boone et al., 2012; Stroyer et al., 2004). Since positions differ by amount of distance covered per match, it was suggested that VO_2 values could be correlated with this factor; goalkeepers, who cover the least amount of ground, had an average VO_{2peak} of 52.1 ml/kg/min, while full backs, covering up to 11.4 km reported a mean value of 61.2 ml/kg/min (Boone et al., 2012). Studies detecting no difference in aerobic power between positions either included a homogenously trained sample group, or did not include goalkeepers in data analysis (Malina et al., 2004a; Dillern, Ingrebrigtsen & Shalfawi, 2011).

2.5 Talent Identification in Sport

While many factors need to be considered when identifying talented athletes for a team sport during the adolescent period there tends to be favoritism towards more mature athletes (Phillippaerts et al., 2007; Reilly et al., 2010). Favoritism towards larger, more mature athletes often starts to appear around the age of 13 years in males, and by the age of 14 years, those who

are advanced in maturation are over represented in youth soccer (Phillippaerts et al., 2007). During these adolescent years, those who are more mature show an advantage in size and aerobic power over those who are delayed in maturation (Phillippaerts et al., 2007). These advantages however, are transient and short lived as athletes who are delayed in maturation catch up and the differences in size and aerobic power disappear (Pearson, Naughton, & Torode, 2006; Stroyer et al., 2004; Phillippaerts et al., 2007; Cunha et al., 2011). Interestingly, there are studies which have suggested that those athletes who were previously cut from the team due to smaller size and lower aerobic power later outperform those who were selected at the junior level (Barreiros et al., 2014). A study by Barreiros and associates (2014) found that only one-third of athletes selected at an early age were selected at the senior level; furthermore, those cut at the junior level who continued to play were selected at a higher rate in senior leagues than those who were previously selected. The findings by Barreiros and associates (2014) supported those by Baxter-Jones and Rowley (1995), who examined physical, physiological, psychological and environmental characteristics of young athletes (Baxter-Jones & Rowley, 1995). In an attempt to identify factors that may predict successful athletes, it was found that amongst male soccer players, female gymnasts and both male and female swimmers, physical factors were seen as poor predictors of future outcome in that sport (Baxter-Jones & Rowley, 1995). Such results suggest that physical size may not be a major influencing factor on sport selection, future sporting success and that late maturing, smaller athletes should not be ignored during sport selection (Barreiros et al., 2014; Baxter-Jones & Rowley, 1995).

Selection onto elite youth soccer teams tends to favor characteristics found in more mature athletes such as superior height, weight and strength (Phillippaerts et al., 2007; Pearson et al., 2006; Carling et al., 2012; Cunha et al., 2011). Along with these observable differences, it

has been suggested that biological maturation has a positive effect on aerobic power due to increases in muscle mass as well as development of the cardiorespiratory system (Baxter-Jones et al., 2005; Malina et al., 2004a; Cunha et al., 2011). Therefore, despite the complex and multifaceted nature of talent identification, the larger size, and possible advantage in aerobic power seen in more mature athletes has led to an overrepresentation of these athletes in elite male adolescent soccer (Carling et al., 2012; Williams & Reilly, 2000).

2.5.1 Talent Identification and Aerobic Power

While the importance of aerobic power in match play has been shown, there is contradicting data regarding the true ability of VO_{2max} values to discriminate between competition levels (Dickau, 2006; Phillippaerts et al., 2007; Coelho e Silva et al., 2010; Russell & Tooley, 2011; Dillern et al., 2011). Differing results between studies when comparing aerobic power between elite and not elite players may be due to sampling and training habits of the athletes studied. Studies resulting in no difference between groups reported using high caliber athletes, all with above average aerobic power levels, or athletes from the same team with similar training protocols (Dillern et al., 2011; Malina et al., 2004a). VO_{2peak} has been shown the tendency to be unable to detect differences in aerobic power between two groups of highly trained athletes; therefore, the lack of differences detected could have been due to high aerobic fitness levels of the sample (Dillern et al., 2011; Malina et al., 2004a; Coelho e Silva et al., 2010). Lastly, it has been suggested that due to the substantial effect of puberty on aerobic power, if all athletes were in later stages of maturation then pubertal-related changes may have already occurred, making differences hard to detect (Malina et al., 2004a).

Table 1 illustrates a review of the literature used in this paper, and reported aerobic power of participants for the respective studies.

Table 2.1. Review of Literature: Aerobic power of male and female soccer players (1-9) and average male and female adolescent population (10-12)

Author, yr.	Method	Participant Information	Position	VO ₂ (ml/kg/min)	VO ₂ (other scaling methods)
1. Stroyer et al., 2004	Treadmill	Male			
		Age 12-14 year old			
		Non-Elite early puberty		58.7 ± 5.3	2.35 (l/min) ± .26
		Elite early puberty		58.6 ± 5.0	2.47 (l/min) ± .28
		Elite end puberty		63.7 ± 8.5	3.59 (l/min) ± .44
2. Carling et al., 2012	Track	Male		Average	
		Elite		58.0 ± 3.2	
		Average age of 13.5 ± 0.4	Goalie:	55.1 ± 3.2	
			Defender:	58.5 ± 3.0	
			Midfielder:	58.9 ± 3.0	

Forward: 58.1 ± 2.7

Future Pro: 58.6 2.9

Future Non- 57.6 3.3

3. Russell & Tooley, 2011	20 m Sprints	Male Youth		U 14: 54.6 ± 2.8
				U 16: 56.3 ± 4.1
				U 18: 59.2 ± 2.7

4. Dillern et al., 2012	Treadmill	Female	Average (all)	48.7-53.8
			Elite	Defenders: 52.1 ± 3.6
				Midfielders 53.8 ± 5.5
			Average age: 17.4 ± 2.4	Attackers 53.0 ± 5.0
				Goal Keeper 48.7 ± 4.6

5. Boone et al., 2012	Treadmill	Male Professional	All	57.7 ± 4.7
			Average age: 25.4 ± 4.9	Goalkeepers: 52.1 ± 5.0
				Center Backs: 55.6 ± 3.5
				Full Backs: 61.2 ± 2.7
				Midfielders: 60.4 ± 2.8
				Strikers: 56.8 ± 3.1

6. Haugen et al., 200	Treadmill	Females 199 - broad range of performance levels	Junior Elite) (17.5 ± 1.7)	3.23 L/min ± 0.38	
			Forward (21.4± 3.7)	3.46 L/min ± 0.41	
			Defenders (22.3 ± 3.4)	3.54 L/min ± 0.31	
			Midfielders (22.3 ± 4.3)	3.63 L/min ± 0.40	
			Goalkeepers (21.6 ± 5.2)	3.50 L/min ± 0.20	
7. Gil et al., 2007	Cycle	Male average age of 17.31 ± 2.64	Forwards	62.4 ± 10.76	4.37 (l/min) ± 1.09
			Midfielders	57.71 ± 9.91	4.28 (l/min) ± 0.99
			Defender	58.55± 9.48	4.13 (l/min) ± 0.97
			Goalkeepers	48.41 ± 11.10	3.63 (l/min) ± 0.92
8. Davis & Brewer, 1993	Review Article	Female	Canadian University Players	47.1	
			Australian University age	47.9	
			Italian Elite	53.3	
			Danish National	57.6	

9. Hoare & Warr, 2000	Multi-stage fitness test (CD)	Female Broad range of skill 15-19 years of age	Female 15-19 Elite Top-Class	39.4 48-50 55+	
10. Dencker et al., 2006	Cycle	Males and Females			
		137 males (9.9 years \pm 0.6)		41.4 \pm 7.2	54.5 ml/min/LBM \pm 7.0
		108 females (9.7 years \pm 0.6)		35.8 \pm 6.4	50.5 ml/min/LBM \pm 6.9
11. Van Oort et al., 2013	Treadmill	Males (14.2 \pm 1.1) Females (11.5 \pm 0.7)		53.6 \pm 7.8	
12. Eisenmann & Malina, 2002		1990's VO ₂ peak averages			
		Males (13.4 years)		53.4	2.74 L/min
		Females (13.1 years)		40.5	2.08 L/min

2.6 Summary

Physical activity, whether free play or organized sport, has been shown to be mentally and physically beneficial for older and younger populations. While levels of physical activity during free play appear to be effected by factors of society, it has been shown that reliance on organized sport to obtain adequate levels of physical activity has increased. Soccer, the most played sport in Canada among children and teenagers has been shown to provide moderate to vigorous levels of physical activity for participants, positively contributing to the daily-recommended level. While levels of physical activity continue to decline, it is crucial to promote the initiation and continuation of such activities in children, youth and adults to foster better health. Given the popularity of soccer in Canada, as well as the aerobic nature of the sport, it is critical to maintain or increase participation levels in soccer. Unfortunately, beliefs that only those individuals who are taller, stronger, larger in size, and superior in aerobic power, can be successful players, may be causing equally skilled but smaller athletes to be cut from elite level soccer teams. The process of recognizing athletes with the most potential, also known as talent identification, is not as simple as selecting athletes based on observable characteristics such as size and aerobic power; this process further complicates when considering adolescent athletes due to the highly transient time of life.

Identifying talent during the adolescent years is incredibly difficult due to the large variation in size and maturity of individuals. In addition, when attempting to identify talent in soccer, a multifaceted sport, the coach must consider characteristics that are not so observable such as tactical, cognitive and technical skills. Although it has been suggested that successful soccer players exhibit superior anticipation, attention, decision-making skills, game intelligence and creativity, it is common for more observable characteristics, such as physical characteristics

and endurance levels, to influence coaches during talent identification. Studies have reported a bias towards soccer players who are taller, heavier and more mature during try-outs for elite youth soccer teams. The selection of these athletes who are believed to have more potential causes less mature but equally skilled athletes to be eliminated from a positive sporting environment. The exclusion of these athletes from sport and physical activity during a time that is crucial for physical and psychological development could be detrimental to future physical activity levels and concomitant health.

2.7 Purpose

The primary purpose of the current study is to compare aerobic power of youth soccer players selected onto an elite Saskatchewan soccer team to those who were not selected; differences in aerobic power will also be compared between playing positions. Secondary purposes include comparing anthropometry between selection status, and aerobic power between sexes.

2.8 Hypothesis

It is hypothesized that selected athletes will have superior aerobic power, measured by VO_2 peak, as well as greater anthropometric measurements as compared to those who were not selected. With regards to position it is hypothesized that goalkeepers will have the lowest aerobic power, as measured by VO_2 peak, as compared to peers in other positions. It is believed that the male sample will show greater aerobic power when compared to the female sample.

3.0 Methods

3.1 Study Design.

The current study utilized a cross-sectional design, and consisted of three separate measurements. Measurements occurred during one visit to either the University of Saskatchewan Exercise Physiology Lab, or the Dr. Paul Schwann Applied Health and Research Centre at the University of Regina. The three stages included: anthropometric measurements, including height, weight, sitting height and skin-fold thickness, followed by a progressive treadmill test to volitional exhaustion to measure aerobic power. Participants also filled out a physical activity questionnaire in order to determine physical activity levels.

3.2 Participants

137 youth participants from the Provincial Selects Program soccer tryouts, 63 females and 74 males, were contacted through telephone and email regarding the present study. Of those contacted, 23 athletes, 10 males and 13 females agreed to participate. 7 participants asked to be removed from the study due to scheduling and travel complications. Participants were a subgroup of participants who took part previously, or concurrently in a longitudinal study at the University of Saskatchewan entitled, "*The Sports Participation Research Initiative*". Participants played for various soccer clubs across Saskatchewan and were attending a weekend long try-out for the Saskatchewan Soccer Association Provincial Selects Program (PSP) in Moose Jaw Saskatchewan in March of 2014. This high performance team is designed to expose young soccer players to high quality training environments, coaching staff, athletic support and competition in order to prepare them to move further into Canada's National Team (Saskatchewan Soccer Association, 2014).

Rosters for the Provincial Selects Program (PSP) supplied by the coaching staff were used to group the 23 participating male and female soccer players into selection groups. Of the 13 females participating, approximately 80% were selected; of the 10 participating males, 40% were selected, therefore, a total of 14 selected and 9 not selected were analyzed for the current study. Participants were asked what position they most often played and were categorized into this position; one female participant reported playing all positions equally and was therefore excluded when comparing VO_2 peak between positions. Figure 3.1 illustrates the recruitment and grouping process.

All participants and their parents/guardians gave written informed consent (Appendix A); all procedures involved in the study were approved by the University of Saskatchewan Bio-Medical Research Ethics Board (Bio 14-252) (Appendix B).

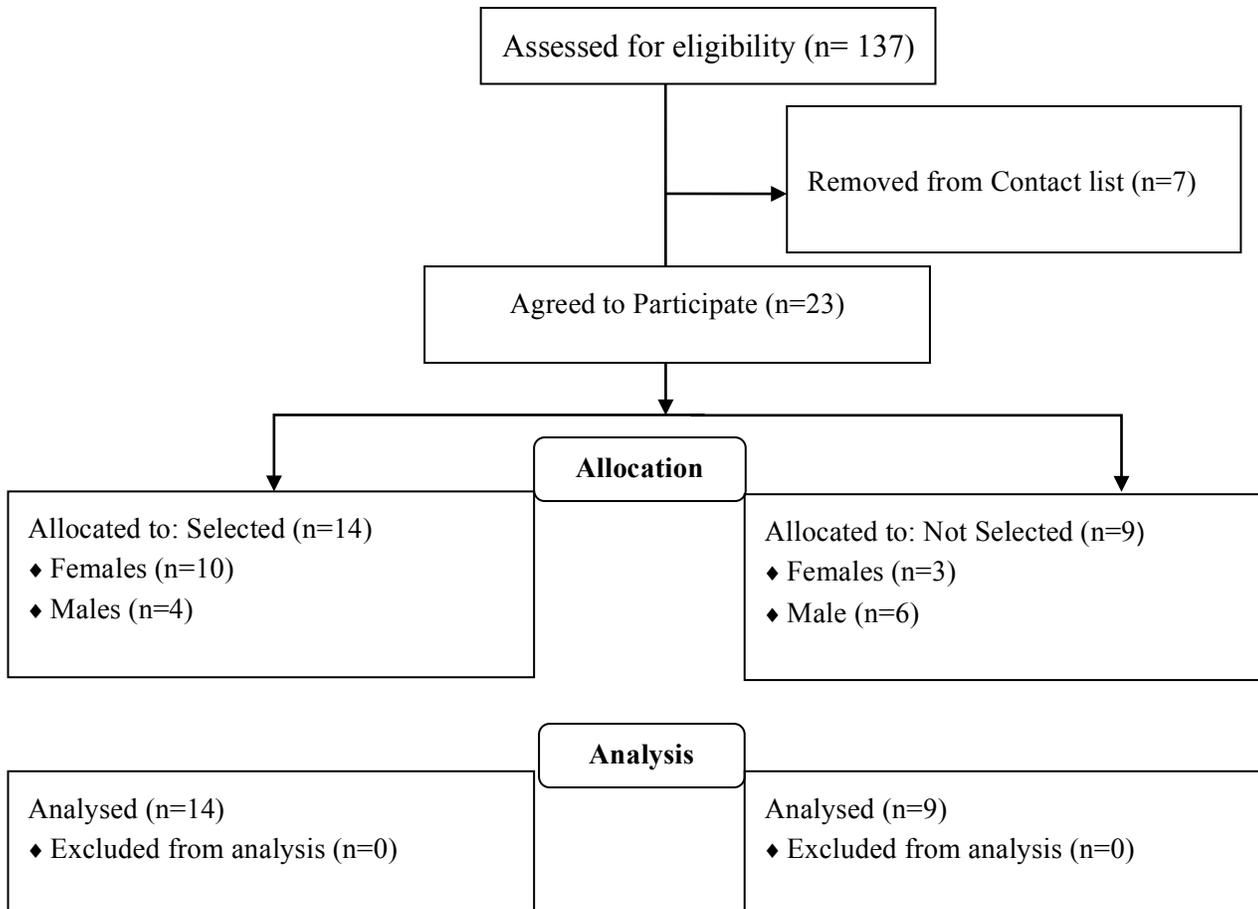


Figure 3.1 Recruitment and allocation process of 23 participants from possible 137.

Note: allocated into selection group by coach-supplied roster

3.3 Measurements

3.3.1 Anthropometry

Height was measured using a permanent wall scale (University of Saskatchewan) and a Health-o-Meter 500KL Medical Scale (Balances, 2015) (University of Regina); participants were asked to stand with feet together and heels as close to the wall or back of the scale as possible. If standing in such a way created an arch in the back then feet were moved away from the wall.

Sitting height was measured using the same scales; participants sat up straight on a box or bench; for the wall mounted scale, height of the bench was subtracted from the total value, the medical

scale was placed on top of the bench and distance was measured from the top of the bench to the top of the head. Both height and sitting height were measured twice to the nearest 0.1 cm; if values differed by greater than 0.4 cm, a third measurement was taken. The average of the two closest values was used as the final height and sitting height value. Body mass was measured using an electronic Toledo digital scale at the University of Saskatchewan, and the Health-o-Meter 500KL Medical Scale at the University of Regina; the two scales were checked for consistency by using a set weight. Similar to height, two measures for body mass were taken, if these values differed by greater than 0.4 kg than a third measure was performed; the average of the two closest values was used as the final body mass. Leg length of each participant was calculated by subtracting sitting height from height.

The anthropometric measures attained were compared between selection status and position, but were also entered along with age into a multiple regression equation created by Mirwald and associates (2002). This equation, is gender specific and uses the interaction of anthropometric measurements and age to predict age at peak height velocity (aPHV), the time during adolescents where the largest velocity of growth (Mirwald et al., 2002). Using the estimated aPHV and chronological age at test, maturity offset, the years from or past aPHV can be calculated and used to classify individuals as early, average or later maturers. Maturity offset and aPHV will be compared to determine if level of maturation, or the time at which an individual differs between those selected and not selected. The equation for boys is: $\leq -9.235 + 0.0002708 \times \text{Leg Length and Sitting Height Interaction} - 0.001663 \times \text{Age and Leg Length Interaction} + 0.007216 \times \text{Age and Sitting Height Interaction} + 0.002292 \times \text{Weight by Height Ratio}$. The female equation is: $-9.376 + 0.0001882 \times \text{Leg Length and Sitting Height Interaction} + 0.0022 \times \text{Age and Leg Length Interaction} + 0.005841 \times \text{Age and Sitting Height}$

Interaction $-0.002658 \times \text{Age}$ and Weight Interaction $+0.07693 \times \text{Weight by Height Ratio}$. These equations have been predicted to be able to predict aPHV within ± 1 year 95% of the time and it has been suggested that this equation is appropriate for use in individuals ± 4 years from aPHV (Mirwald et al., 2002).

3.3.2 Skinfold Thickness

Skinfolds were taken from the right triceps and the medial side of the right calf.

Landmarks were measured and marked. Skinfolds were taken using harpenden calipers (Baty International, 2007) at the appropriate landmark sights identified as: the halfway point between the elbow and the acromion process for the triceps, and the location of the widest girth of the calf as measured by a measuring tap. Landmarks were then marked and measurements were taken at the respective sites. Two measurements were performed at each site and a third measurement was completed if the first two values differed by more than 0.4mm.

3.3.3 Body Composition

Skinfold values were entered into the Slaughter-Lohman skinfold formula, and were used in order to predict percent body fat of each participant (Slaughter, et al., 1988). The equation for body fat prediction using the Slaughter method is: $\%fat = 0.75 \times SF + 1.0$ for males, and $\%fat = 0.610 \times SF + 5.0$ for females (where SF represents sum of skinfolds); these equations are appropriate for all ages (Ehrman, Gordon, Visich, & Keteyian, 2009). The Slaughter skinfold method is one of the most used equations for predicting percent body fat in pediatric populations, and was developed from African American and Caucasian children 8-17 years of age, therefore are appropriate for the current sample; however, it has been reported that this prediction may not be as accurate in Chinese children (Yeung & Hui, 2010). Fat mass in kilograms was measured by multiplying weight in kilograms by the percentage of fat from the Slaughter-Lohman equation.

In order to calculate fat free mass in kilograms, the total amount of fat (kg) was subtracted by the total weight of the individual.

3.3.4 Aerobic Power

Aerobic power was measured using a Runrace treadmill from Technogym (Model Number D140) with the preprogrammed Bruce Protocol at the University of Saskatchewan. Testing at the University of Regina was done with an electronic treadmill; trained laboratory technicians adjusted speed and gradient manually. Testing results from the University of Saskatchewan measured heart rate, time to end of test, respiratory quotient and VCO_2 levels; however, at the University of Regina, system errors limited measurements to heart rate, final VO_2 , and time to end of test. Therefore, not all males in the current study were able to have measurement values for all variables listed in the results section (Table 4.2). The Bruce protocol was developed in the 1960's and is a commonly used protocol in order to measure maximum aerobic power (American College of Sports Medicine (ACSM), 2008). The Bruce Protocol starts at a low speed of 1.7 m/h (2.7 km/h) and a grade of 10%; the speed and grade increase every 3 minutes, for a total of 6 stages, an outline of this protocol can be found in Appendix C (ACSM, 2008). A 3-minute warm up at 3.5 km/h was performed prior to each test; following this warm-up, each participant was fitted with a Polar T31-CODED (Polar, 2015) heart rate monitor worn under the skin. It is important to note that not all heart rates could be measured; due to the small size of the participants heart rate monitors were unable to stay in the correct spot to monitor heart rate throughout the test. Each participant was then fitted with a mouthpiece that was secured using a headpiece fitted to the appropriate size of each participant; a nose clip was also worn in order to ensure no breathing could be performed through the nose. Using a Vmax Metabolic Cart (87659) equipped with Vmax29c software from Summit volumes of oxygen consumed and

carbon dioxide produced was measured. Prior to testing the Vmax Metabolic Cart warmed up for 30 minutes and a new flow-sensor was changed and re-calibrated. Calibration was performed to system instructions using a 3-litre syringe to manually pump air into the system to calibrate the flow sensor for both low and high low rates. Reference gases were then use in order to confirm the system's ability to measure air quality and mixture. Each participant had the protocol as well as hand signals explained to him or her prior to the test, and had the chance to ask any questions. The Bruce Protocol was completed until volitional exhaustion and gas exchange data was recorded every 20 seconds. Standard VO_2 peak criteria were used including: a respiratory exchange ratio (RER) of greater than 1.0, signs of intense effort from the participant, and/or the achievement of age-predicted maximal heart rate (220 beats per minute – age in years) (Rowland, 2005). Intense effort was identified by asking the participant how they were feeling; which was responded to using hand signals (thumbs up, thumbs down), as well as sweating, heavy breathing, redness in the face, and obvious fatigue marked by change in posture and running efficiency. If criteria, such as RER, signs of intense effort and maximal heart rate were seen, the highest 20-second average recorded by the VMax system was used as the participant's VO_2 peak. In the current study, there was no individuals who did not reach maximal predicted heart rate, an RER greater than 1.0 or show signs of intense effort; therefore, it is believed all achieved a VO_2 peak.

Absolute aerobic power (l/min) was scaled to body mass (ml/kg/min) and fat free mass (ml/kg FFM/min) for each participant by dividing absolute aerobic power by the appropriate value. The calculation of z-scores was accomplished by using the LMS (L=skewness, M=median and S= coefficient of variation) statistical procedure modified by Eisenmann and associates (2011). The LMS method summarizes the changing distributions of the data through

three curves representing the median, skewness and coefficient of variation (Eisenmann et al., 2011). Data represented by these curves, along with the observed measurement of aerobic power of the sampled athletes were entered into the following equation in order to calculate z-scores specific to gender and age: $\frac{\left[\left(\frac{\text{measurement}^L}{M}\right)-1\right]}{(L \times S)}$. The measurement was the VO₂peak value observed in the participants, M is the median, L is the skewness and S is the coefficient of variation; median, skewness and coefficient of variation values were all attained from the Eisenmann and associates study (2011). Relative aerobic power (ml/kg/min) values from the current study were also plotted onto the percentile charts created by Eisenmann and associates (2011) in order to show how the current sample compares to the 50th percentile of adolescents of the same age and sex group.

3.3.5 Physical Activity Questionnaire

A Physical Activity Questionnaire for Adolescents (PAQ-A) (Appendix D) (Kowalski, Crocker, & Donen, 2004) was also completed. This questionnaire was developed out of the University of Saskatchewan and is the high-school version of the Physical Activity Questionnaire for Older Children (Kowalski et al., 2004). The PAQ-A is a self-reported, 7-day physical activity recall questionnaire that consists of 8 questions, each scored on a five-point scale (Kowalski et al., 2004); Physical Activity is reported as 1 (low) to 5 (high). This questionnaire is a quick and inexpensive way to gather an idea of the general physical activity of adolescents, and has been shown to be a reliable representation of physical activity within this cohort (Kowalski et al., 2004).

3.4 Statistics

Mean and standard deviations were calculated and reported for VO₂peak values (L/min,

ml/kg/min, ml/kg FFM/min), anthropometric measures, age, and physical activity levels for all participants. All independent variables were checked for normality using Shapiro-Wilk; weight violated assumptions of normality and was transformed using Log¹⁰, upon which normality was achieved. Independent t-tests were performed to determine significant differences of anthropometric measurements, aerobic power aerobic power (l/min, ml/kg/min and ml/kg FFM/min), as well as time to exhaustion, maximal heart rate, VCO₂ and respiratory quotient between sexes and between selection groups. Maturity offset and aPHV were calculated for all participants; all individuals were past their aPHV and all matured at the average age for their sex; no significant differences were detected between aPHV and maturity offset between selection groups. Analysis of variance (ANOVA) was used in order to compare aerobic power (l/min, ml/kg/min and ml/kg FFM/min) between playing positions. Pearson correlation was used to establish relationships between VO₂peak (l/min) and height, weight, fat free and fat mass, age and sex. These variables were then used as covariates in an analysis of covariance (ANCOVA) with absolute VO₂peak as the dependent variable and selection group as the fixed factor. Differences in aPHV and maturity offset between participants were not found to be significant; therefore, aPHV was not added as a covariate. Additional assumptions required for ANCOVA were tested using an ANOVA with a customized model in order to test the interaction between the covariates and the independent variable, with no significant interactions detected; lastly an independent t-test was performed in order to ensure no covariate differed across selection group. All statistical analyses were performed using SPSS Statistical Package 22 (IBM, 2014); graphs were prepared using GraphPad Prism 6 Software (GraphPad Software Inc, 2015). The alpha level for significance was set as $p < 0.05$.

4.0 Results

4.1 Growth and Maturation

The average height of all soccer players tested was 164.50 cm ($SD = 6.59$); those selected players had an average height of 162.86 cm ($SD = 4.87$) while those who were not selected averaged 167.04 cm ($SD = 8.30$). When analyzing weight, the average of all players was 56.43 kg ($SD = 12.02$), while those who were selected and not selected averaged 54.73 kg ($SD = 12.48$) and 59.08 kg ($SD = 11.46$), respectively. Height and weight of male and female participants are plotted on growth charts in Figures 4.1 and 4.2 respectively. As a whole, the average height of all males sampled ($M = 167.14\text{cm}$, $SD = 7.93$), represented by the blue dot, fell approximately at the 50th percentile (approximately 168 cm) for their age and sex; for weight, the average of all males sampled ($M = 58.05\text{kg}$, $SD = 11.95$) fell in between the 50th (approximately 54kg) and 75th (approximately 61kg) percentiles. This indicates that as a whole, the current male sample was heavier than average but was of average height. In the female sample, illustrated in Figure 4.2, the average height of all females sampled ($M = 162.46\text{cm}$, $SD = 4.70$), represented by the blue dot, fell in between the 50th (approximately 160 cm) and 75th (approximately 164 cm) percentiles; for weight, the females average ($M = 55.19\text{kg}$, $SD = 12.41$) illustrated the same trend, falling in between the 50th and 75th percentiles, approximately 48 kg and 55 kg, respectively. Such findings indicate that the female sample, as a whole, was on average taller and heavier than the average female of this age.

The average height and weight for each sex, by selection group, is also illustrated on Figures 4.1 and 4.2. The average height of the selected males ($M = 164.81\text{cm}$, $SD = 3.97$) fell slightly below the 50th percentile (approximately 166 cm), while those who were not selected ($M = 168.7\text{ cm}$, $SD = 9.82$) fell slightly above the 50th percentile (approximately 168 cm) for their

average age. A similar trend was seen in weight as the selected males ($M = 50.83\text{kg}$, $SD = 7.19$) fell below the 50th percentile (approximately 53 kg) and the not selected males ($M = 62.9$ kg, $SD = 12.52$), fell above the 75th percentile (approximately 62 kg). In the female group, the average height of those selected ($M = 162.1$ cm, $SD = 1.63$) and of those not selected ($M = 163.7\text{cm}$, $SD = 3.10$) fell slightly above the 50th and 75th percentile, respectively (approximately 160cm ad 159 cm respectively) cm respectively. In regards to the average weight for the selected females ($M = 56.29\text{kg}$, $SD = 14.08$) and for not selected females ($M = 51.53\text{kg}$, $SD = 2.40$), a similar trend was detected in that the selected females fell above the 50th percentile (approximately 51 kg) and the not selected fell above the 75th percentile (approximately 51 kg) for their respected age groups.

Table 4.1 shows age, height, weight and body composition by selection status and sex. When comparing between selection status, including both sexes, there was no significant differences detected in any variable including height [$t(21) = 1.53$, $p > 0.05$], weight [$t(21) = 0.99$, $p > 0.05$], percent body fat [$t(21) = -1.75$, $p > 0.05$], fat free mass [$t(21) = 1.02$, $p > 0.05$] age [$t(11) = 0.01$, $p > 0.05$], or aPHV [$t(21) = 0.49$, $p > 0.05$]. Similar trends were found when separating by sex; in the male sample no significant differences were found between selection status for height [$t(8) = 0.74$, $p > 0.05$], weight [$t(8) = 1.78$, $p > 0.05$], percent body fat [$t(8) = 1.11$, $p > 0.05$], fat free mass [$t(8) = 1.70$, $p > 0.05$], age [$t(8) = 0.11$, $p > 0.05$], or aPHV [$t(8) = -1.48$, $p > 0.05$]. In females, there were not significant differences between selection groups for height [$t(11) = 0.25$, $p > 0.05$], weight [$t(11) = 0.49$, $p > 0.05$], percent body fat [$t(11) = -1.20$, $p > 0.05$], or fat free mass [$t(11) = -0.57$, $p > 0.05$], however, there was a significant difference detected in age [$t(11) = -2.51$, $p < 0.05$] and aPHV [$t(11) = -2.58$, $p < 0.05$]; selected females were older in chronological age and had an older aPHV. Comparisons of variables were also made between sexes, without considering selection group; a significant difference in percent

body fat [$t(21) = 57.16, p < 0.01$], age [$t(21) = -2.63, p < 0.05$], and aPHV [$t(21) = -8.84, p < 0.01$]. It was found that males had significantly lower percent body fat compared to females, and females were significantly younger with a lower aPHV when compared to males.

Table 4.1 Descriptive characteristics of male and female participants by respective sex and selection group

Variable	Selected Average (SD)		Not Selected Average (SD)	
	Male (4)	Female (10)	Male (6)	Female (3)
Gender (n)				
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	14.4 (0.6)	13.8 (.87)	14.7 (1.2)	12.5 (0.3)*
aPHV (years)	14.1 (0.4)	12.09 (0.4)	13.6 (0.6)	11.5 (0.2)*
Height (cm)	164.8 (4.0)	162.1 (5.2)	168.7 (9.8)	163.7 (3.1)
Weight (kg)	50.8 (7.0)	56.3 (14.0)	62.9 (12.5)	51.5 (2.4)
Body Fat (%)	2.6 (.03)	6.4 (.04)	2.8 (0.3)	6.4 (.01)
PAQ-A	3.3 (0.6)	3.3 (.40)	3.4 (0.6)	3.5 (0.2)

Note

* represents a significant difference compared to selected females ($p < 0.05$)

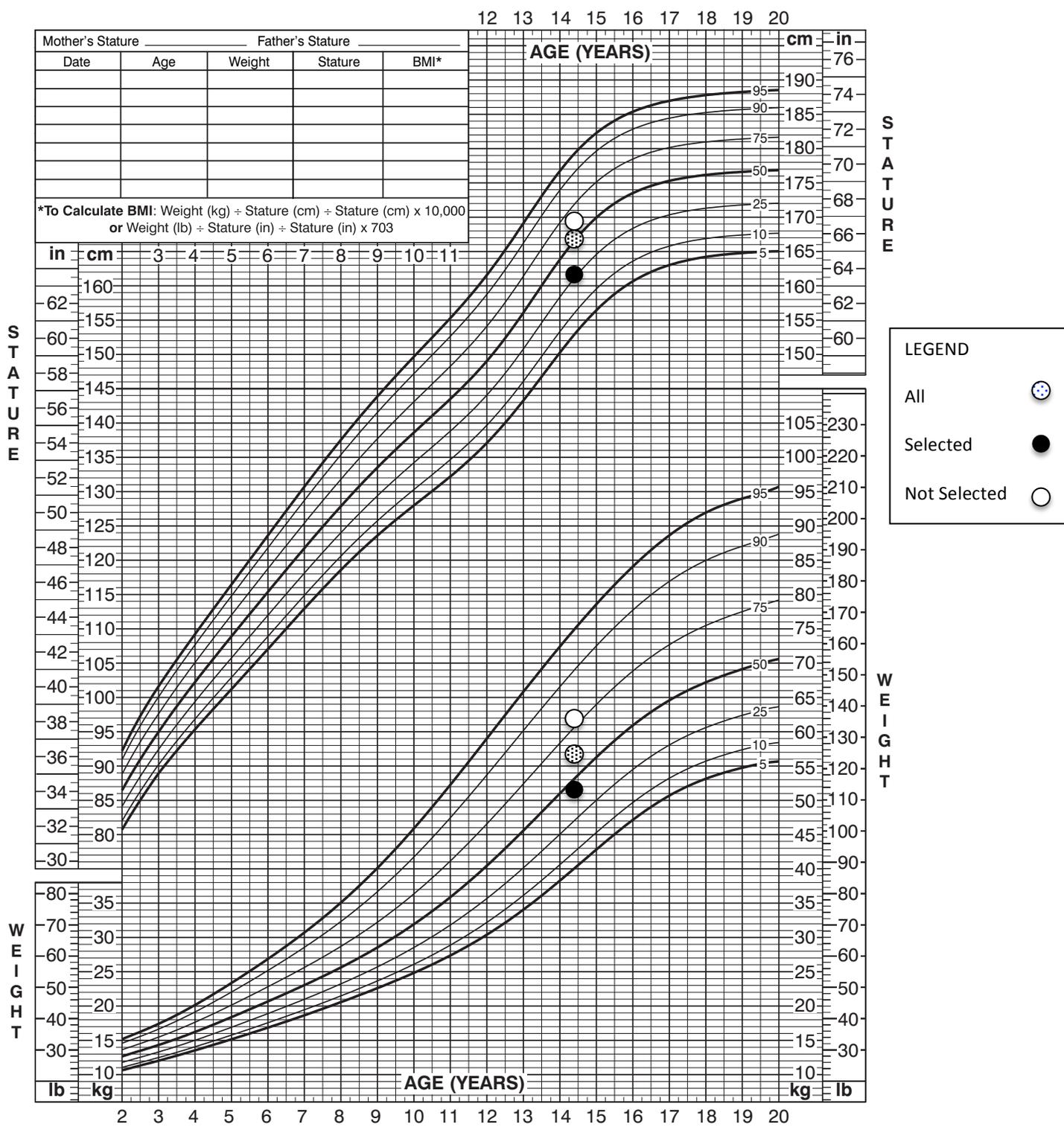


Figure 4.1 Male height and weight percentiles with plotted height and weight averages for all, selected, and not selected male participants

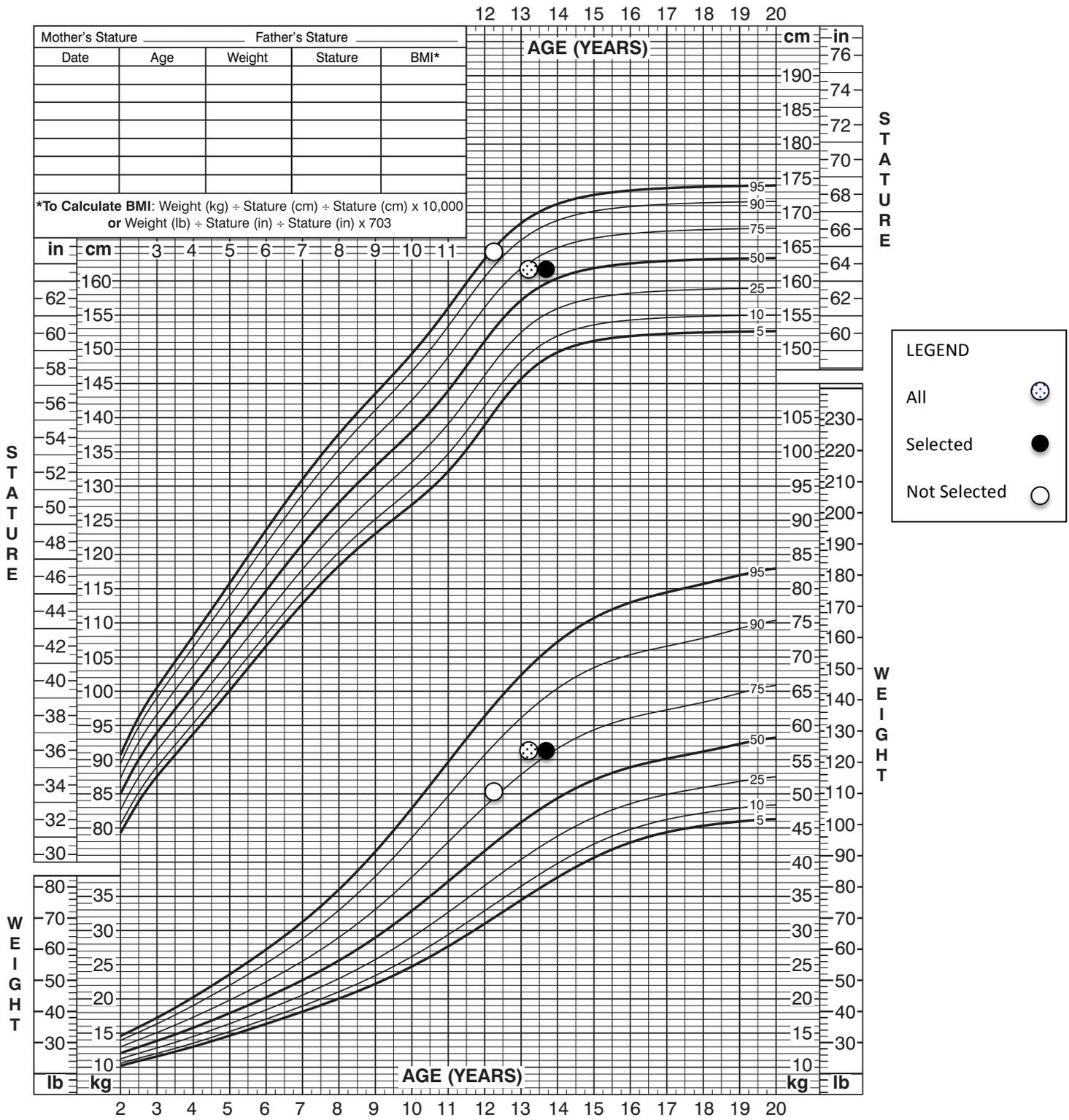


Figure 4.2 Female height and weight percentiles with plotted height and weight averages for all, selected, and not selected male participants

4.2. Aerobic power

The average aerobic power, indexed by VO_2peak (ml/kg/min) of all soccer players tested was 55.59 ml/kg/min ($SD = 8.56$); those selected players had an average aerobic power of 54.94 ml/kg/min ($SD = 9.25$) while those who were not selected averaged 56.59 ml/kg/min ($SD = 7.79$). Figure 4.3 illustrate the average aerobic power (ml/kg/min) of all males (Graph B) and females (Graph A), as well as the average for selected and not selected males and females. As a whole, the average aerobic power (ml/kg/min) of all males sampled ($M = 60.82$ ml/kg/min, $SD = 8.45$), represented by the blue dot, fell above the 90th percentile for this age and sex (58.5 ml/kg/min) (Eisenmann et al., 2011). The average relative aerobic power (ml/kg/min) of the selected males ($M = 64.88$ ml/kg/min, $SD = 6.28$) as well as the not selected males ($M = 58.12$ ml/kg/min, $SD = 9.10$), represented by the green and red dots, respectively, fell above the 95th (63.0 ml/kg/min) and fell approximately on the 90th percentile, respectively. In the female sample, the average aerobic power (ml/kg/min) of all females sampled ($M = 51.56$ ml/kg/min, $SD = 6.36$), represented by the blue dot, also fell above the 90th percentile for this age group and sex (48.7 ml/kg/min). Those females selected, represented by the green dot, averaged an aerobic power value of 50.97 ml/kg/min ($SD = 7.00$) while those females not selected, represented by the red dot, averaged 53.53 ml/kg/min ($SD = 3.85$). These values, as seen in Figure 4.3 illustrate that the selected and not selected females both fall above the 90th percentile, with those not selected falling much closer to the 95th percentile (53.9 ml/kg/min) for the appropriate age and sex. When analyzing aerobic power relative to fat free mass (FFM) (not illustrated in Figure 4.3), the average of all players was 59.15 ml/kg FFM/min ($SD = 10.60$), while those who were selected

and not selected averaged 59.38 ml/kg FFM/min ($SD = 12.40$) and 58.80 ml/kg FFM/min ($SD = 7.68$), respectively.

Utilizing data and equations supplied by Eisenmann and associates (2011), Z-scores were calculated using male and female VO_{2peak} (ml/kg/min) averages and comparing those values to the averages for the appropriate age group and sex found by Eisenmann and associates (2011). The calculation supplied in the Eisenmann and associates paper (2011) used the LMS statistical procedure in order to calculate an appropriate z-score for the male and female participants in the current study. The z-score for females was calculated as 1.54, using the z-score table it was found that approximately 94% of values for this sex and age group would fall below this score. For males, the z-score was calculated as 1.44, using the z-score table, this indicated that that approximately 93% of values for this age and sex group would fall below this value. In regards to those selected, the z-score for males and females was 1.75 and 1.47, respectively, indicating the 96% and 93% of aerobic power (ml/kg/min) values for the respective sex and age groups would fall below averages measured in the current study. The average aerobic power of males and females who were not selected resulted in a z-scores of 1.29 and 1.70, respectively; when analyzed in the z-score table it was found that 90% and 96% of values for the respective age and sex groups would fell below the averages found in the current study.

Table 4.2 illustrates additional data attained from the maximal exercise test including time to end of test, highest heart rate (if attained), highest VCO_2 value and highest respiratory exchange ratio. The highest values attained were often measured right before the participant reached volitional exhaustion or 20-40 seconds prior. Heart rates could not be measured for all

participants as the heart rate monitors often fell down during the testing due to the small size of the athletes. No significant differences in any of the displayed averages were detected between selection groups in females, however, in the male group, the selected males had significantly lower VCO_2 values when compared to those who were selected [$t(4) = 2.78, p = 0.05$]. When analyzing between selection groups, not considering gender, there was not significant differences detected

Table 4.2. Summary of relevant measures attained from Bruce Protocol maximal exercise testing

		Maximal Heart Rate (bpm)		Time to End of Test Selected (mm:ss)		Maximal Respiratory Quotient		Maximal VCO_2 (l/min)	
		N	M (SD)	N	M (SD)	N	M (SD)	N	M (SD)
Selected	All	10	181.30 (± 14)	14	12:31 (1.81)	13	1.13 (0.05)	13	3.34 (0.68)
	Male	4	193.25 (± 8)	4	14:10	3	1.12 (0.04)	3	4.08 (0.49)
	Female	6	173.33 (± 12)	10	12:16 (1:56)	10	1.13 (0.05)	10	3.14 (0.58)
Not Selected	All	8	189.13 (± 12)	9	13:22 (2.14)	6	1.14 (0.04)	6	4.08 (1.16)
	Male	5	187.40 (± 11)	6	13:17 (1.78)	3	1.14 (0.05)	3	5.11 (0.41)*
	Female	3	192 (± 15)	3	12:03 (2.19)	3	1.13 (0.02)	3	3.05 (0.10)

* Represents a significant difference compared to selected males ($p \leq 0.05$).

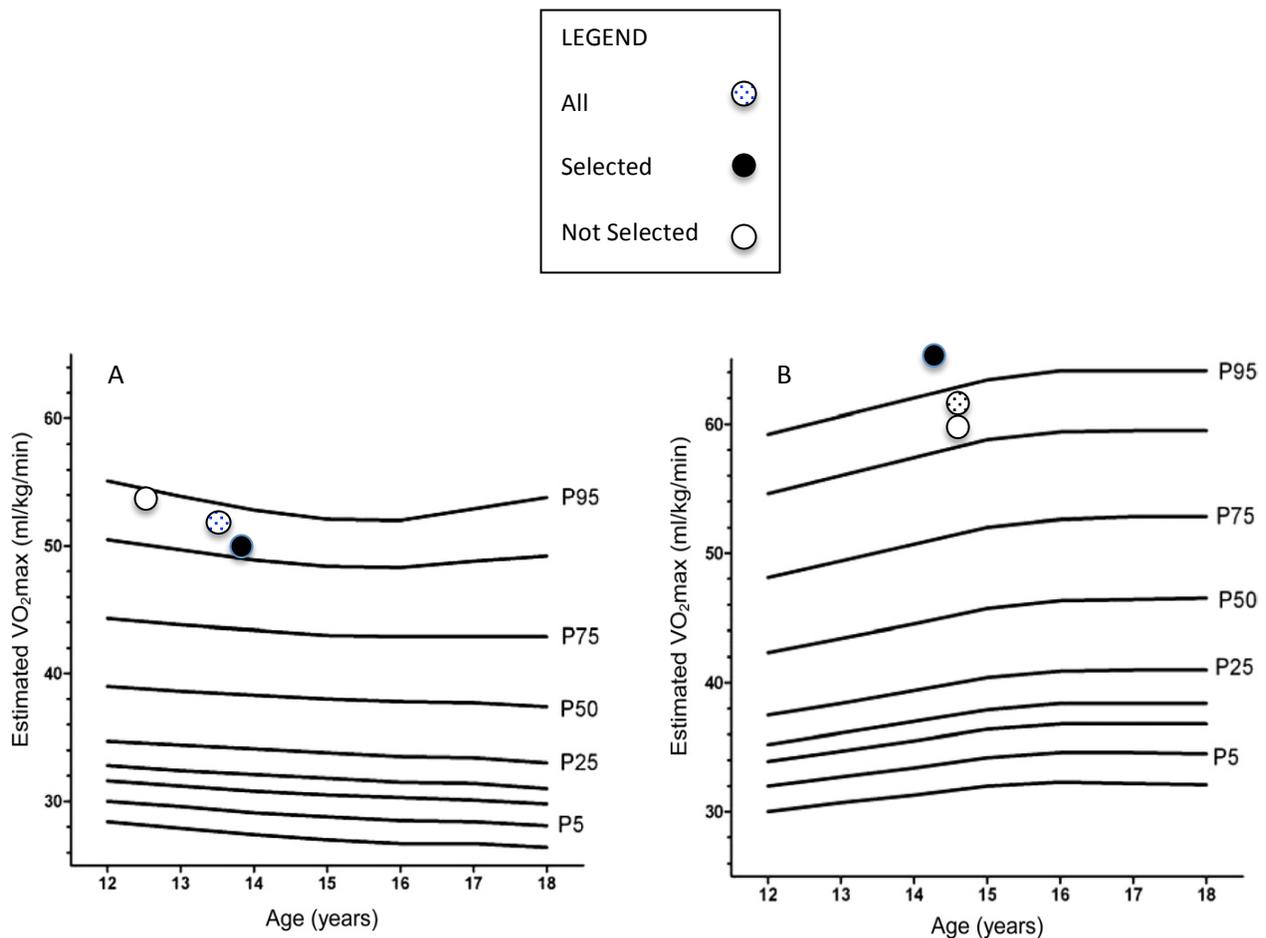


Figure 4.3 Relative aerobic power (ml/kg/min) values for male (A) and female (B) participants. Adapted from “Aerobic fitness percentiles for U.S. adolescents,” by J.C. Eisenmann, K. R. Laurson and G. J. Welk, 2011, *American Journal of Preventative Medicine* 41, p. S108. Copyright 2011 American Journal of Preventive

Relative aerobic power (ml/kg/min) was compared between male and female participants; males were found to have significantly higher aerobic power than females [$t(21)=-3.0, p < 0.01$]. This significantly greater value in males was also seen when aerobic power, expressed relative to fat free mass, was compared between males and females [$t(21) = -2.30, p < 0.05$]. These aerobic power values (ml/kg/min and ml/kg FFM/min) are illustrated in Figure 4.4a and 4.4b.

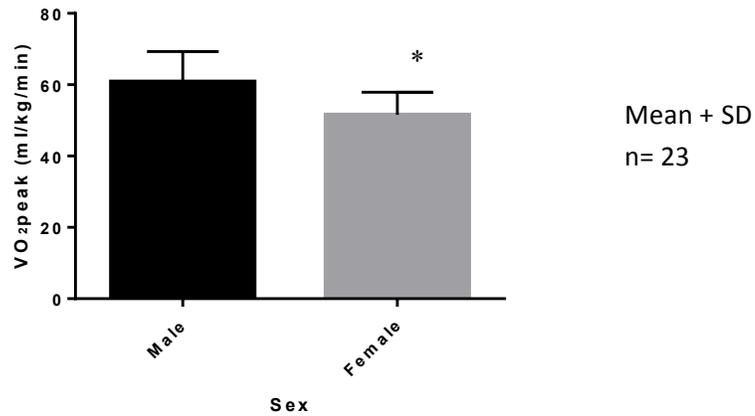


Figure 4.4a Comparison of VO₂peak (ml/kg/min) between sexes.
 * Represents a significant lower value compared to males ($p < 0.05$)
 n=23; 10 (male), 13 (female)

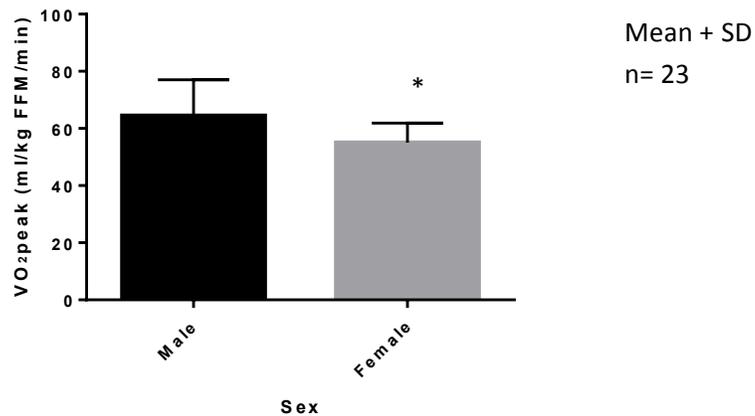


Figure 4.4b Comparison of VO₂peak (ml/kg FFM/min) between sexes.
 * Represents a significant lower value compared to males ($p < 0.05$)
 n= 23; 10 (male), 13 (females)

Average relative (ml/kg/min) and absolute (l/min) aerobic power by age group, in males and females are illustrated in Figure 4.5 and 4.6. In the male sample, the highest absolute aerobic power was seen in the 15 year old age group, while the highest relative aerobic power was measured in the 14 year group. In the females, similarly to the males, the highest absolute

aerobic power was measured in the 15 year old group, while the highest relative aerobic power was measured in the 13 year old group.

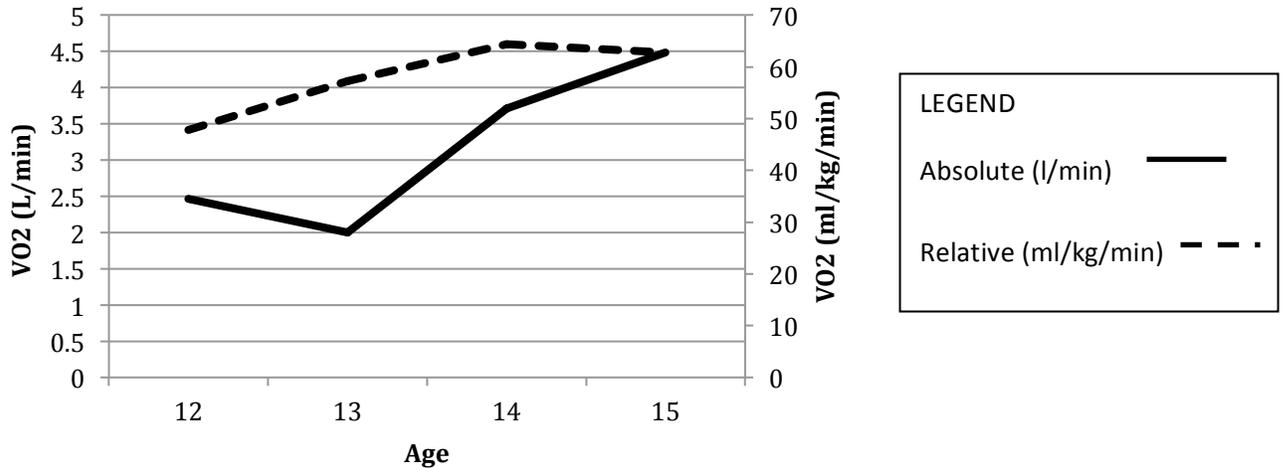


Figure 4.5 Male absolute (l/min) and relative (ml/kg/min) aerobic power by age

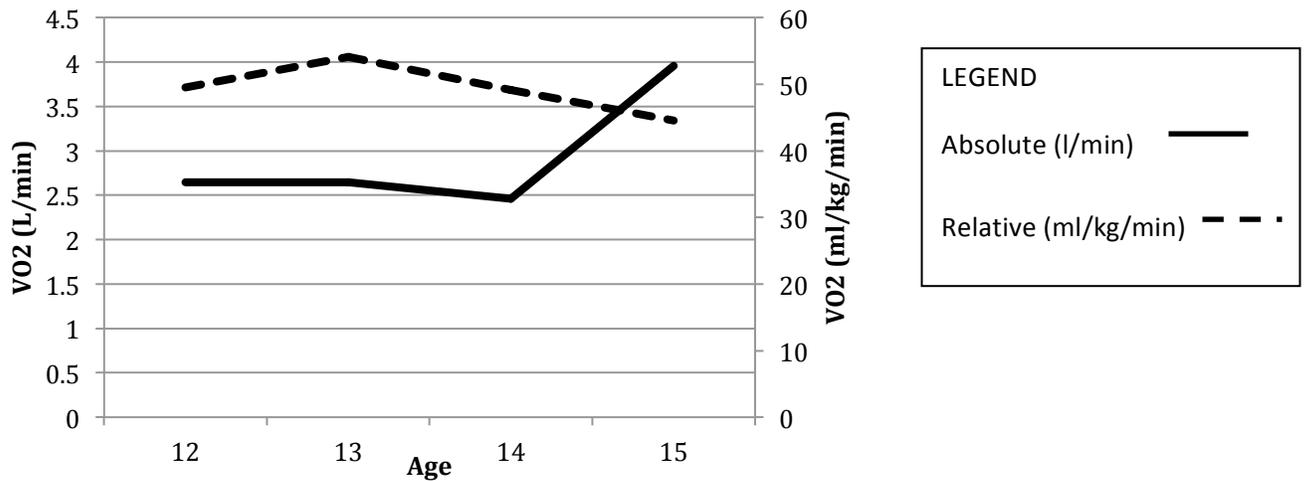


Figure 4.6 Female absolute (l/min) and relative (ml/kg/min) aerobic power by age

Results for relative aerobic power (ml/kg/min and ml/kg FFM/min), compared between selection groups are illustrated in Figure 4.7a and 4.7b, respectively. When comparing VO_2 peak (ml/kg/min) between selection groups, sexes combined, no significant differences were detected [$t(21) = .422, p > 0.05$]. When comparing between selection groups for relative aerobic power scaled to fat free mass (ml/kg FFM/min) there was also no significant difference detected [$t(21) = -.124, p > 0.05$]. When analysis was compared using sex as a covariate there was still no significant difference detected in aerobic power scaled to body mass [$F(1,20) = 0.41, p > 0.05$], or fat free mass [$F(1,20) = 1.18, p > 0.05$].

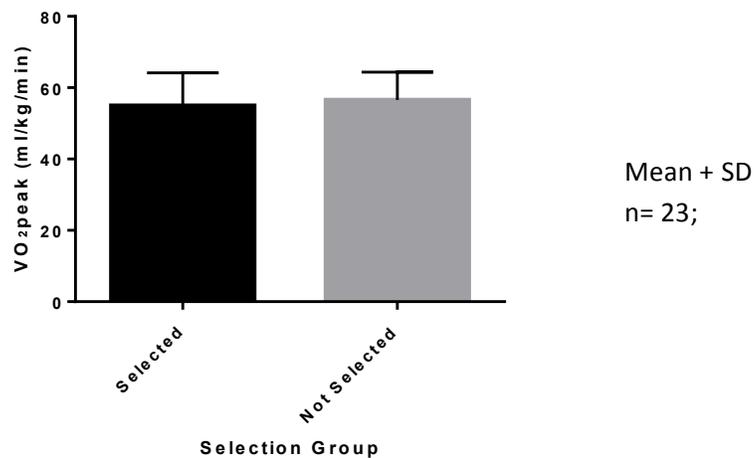


Figure 4.7a Comparison of VO_2 peak (ml/kg/min) between selection groups.
n= 23; 14 (selected), 9 (not selected)

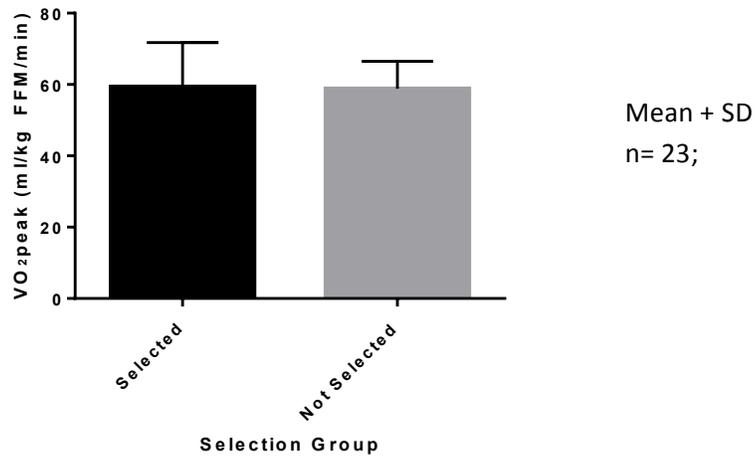


Figure 4.7b Comparison of VO₂ peak (ml/kg FFM/min) between selection groups.
n = 23; 14 (selected), 9 (not selected)

When comparing aerobic power scaled to body mass (ml/kg/min) between positions, with sexes combined, no significant differences were detected [$F(3,18) = 1.45, p > 0.05$]; a similar trend was seen when comparing absolute aerobic power (l/min) [$F(3,18) = .86, p > 0.05$] and when scaled to fat free mass [$F(3,18) = .83, p > 0.05$]. When comparing aerobic power between positions in males and females separately, it was found that the female goalkeepers had significantly lower absolute aerobic power (l/min) when compared to all other positions [$F(3,8) = 20.14, p < 0.01$]; no significant differences were found when aerobic power was scaled to body mass [$F(3,8) = 1.62, p > 0.05$] or body mass [$F(3,8) = 1.57, p > 0.05$]. In males, there was no significant differences between positions for absolute aerobic power (l/min) [$F(3,6) = 1.67, p > 0.05$] or when scaled to body mass (ml/kg/min) [$F(3,6) = .31, p > 0.05$] or fat free mass (ml/kg FFM/min) [$F(3,6) = .26, p > 0.05$]. Table 4.3 displays the average aerobic power values (ml/kg/min) for each position as a whole, and by gender.

Table 4.3. Summary of relative aerobic power (ml/kg/min) by sex and playing positions

Position	All Athletes		Males		Females	
	n	Mean (SD) (ml/kg/min)	n	Mean (SD) (ml/kg/min)	n	Mean (SD) (ml/kg/min)
Goalie	3	50.7 (6.5)	1	57.4 (-)	2	47.35 (4.0)
Forwards	6	55.2 (5.2)	3	58.3 (4.0)	3	52.07 (4.6)
Defenseemen	9	57.8 (9.8)	5	61.5 (11.4)	4	53.10 (5.6)
Midfielder	4	59.4 (6.3)	1	68.2 (-)	3	56.50 (2.7)

5.0 Discussion

Superior aerobic power has been shown to be a beneficial characteristic in youth soccer players, with those who have higher VO_2 peak (ml/kg/min) levels more likely to be selected than those with lower VO_2 peak (ml/kg/min) values (Vaeyens et al., 2006). Soccer has been identified as being multifaceted, meaning that true success is reliant on physiological, cognitive, technical and tactical skill development (Reilly et al., 2010). Despite the evidence supporting the need for a wide variety of skills, it has been shown that taller, heavier, more mature players, with superior aerobic power are often favored when it comes to selection onto elite youth soccer teams (Phillippaerts et al., 2007). The objective of the current study was to determine if aerobic power and anthropometric size was different between athletes who were selected and not selected for an

elite Saskatchewan soccer program. Results indicated that there was no significant difference between selection groups for absolute (l/min) or relative (ml/kg/min or ml/kg FFM/min) aerobic power. Similarly, there was no significant difference in anthropometric size between those selected and not selected. The secondary objective of this study was to determine if there were differences in aerobic power between playing position and sex. When comparing aerobic power, both absolute and relative, it was found that the males in the current sample had significantly higher aerobic power values when compared to females.

5.1 Growth

The current study found that there was no significant difference in height, weight, percent body fat or fat free mass between selection groups (sexes combined). The lack of significant difference in anthropometric size between selection groups agrees with findings of the Training of Young Athletes, which found that physical factors were poor predictors of future success in three out of four sports (Baxter-Jones & Rowley, 1995). The current study reports that there was no significant difference in size between selection groups; therefore anthropometric size does not appear to be a key factor in predicting future success, as marked by selection. While there was no significant difference in anthropometric size in either male or female athletes, the selected females in the current study were significantly older and had later age at PHV than the not selected. The older age at PHV in the selected females versus the not selected females may suggest that early maturation is not an advantage in female soccer. It is important to note that maturational status was consistent in all players, of both sexes, in that all matured at the average age for the respective sex. In addition, all athletes in the current study were past PHV and therefore the significant difference in PHV between female selection groups may not be as applicable in this sample as it may be in a younger cohort. In regards to male maturation and

soccer, the current study agreed with findings by Geithner and associates (2004) who found that average maturation in male youth soccer players, as measured by testicular volume, fell in the 50th percentile. While Geithner and associates (2004) did not study female maturation, and used a more invasive measure of maturation, the average maturing status of male soccer players detected agrees with the findings in the current study.

In order to compare size characteristics of the current sample to the average, age-matched population, height and weight have been marked on percentile charts in the Figures 4.1 and 4.1. It was found that as a whole, the male sample was average height and slightly above average in weight; the selected males however were below average for height and weight. This therefore may be an indication that size is not a large influencing factor for selection in the male sample. With regards to females, all those sampled were slightly above average for height and weight falling in between the 50th and 75th percentiles for both measures. Those females who were selected were above the 50th percentile for height and weight, however, those not selected were above the 75th percentile for both measures. Therefore, this is an indication that while the female sample as a whole was slightly above the 50th percentile, the not selected group fell into higher percentiles for both measures as compared to the selected females. Such results could suggest that the elite Saskatchewan coaches were not overly concerned with the height and weight of the selected soccer players, especially in the male sample.

When comparing anthropometric results of the current study to other literature in the area, the current results are similar to that of Malina and associates (2004b) who found that male Portuguese youth soccer players placed in higher percentiles for weight than height. The current results however conflict with those by Carling and associates (2011) who found that most of the male youth soccer players in their study fell near the 75th percentile for height and weight.

Discrepancies between studies could be due to differing averages in different areas, the current study uses percentiles from the United States while the others use Portuguese and French records, some of which from many years prior to the study. In regards to comparing height and weight percentiles of the females, it appears that when compared to the study by Dillern and associates (2011) the height and weight of the current females is similar. Dillern and associates (2011), while dealing with an older sample (average age 17 years) recorded values that would place their female soccer players in between the 50th and 75th percentiles. Similar to the current study, the athletes used in the Dillern et al., (2011) study were well-trained, elite athletes, and therefore, are comparable to the sample in the current study.

When comparing anthropometric measurements between selection groups no significant differences were detected. This finding contrasts those in other literature suggesting that selected male players are often taller than those who are not selected (Phillippaerts et al., 2007; Pearson et al., 2006; Carling et al., 2012; Cunha et al., 2011). However, the current findings do agree with that of Vaeyens et al., (2006) who found no significant difference between elite, sub-elite and non-elite male soccer players from under 14 to under 17 year old teams. In regard to females, data comparing elite and non-elite, or those who were selected or not selected is sparse, and often focused on older samples. A study by Dillern and associates (2012) focused on 17 year old female soccer players and found that the elite level players were just under the 75th percentile for their age group; these females were comparable in height to other elite female soccer players of the same age in different countries. The lack of significant difference in height between selection groups might suggest that height is not seen as an important quality when selecting elite youth soccer players, agreeing with results such as those in the TOYA Study (Baxter-Jones & Rowley, 1995). Furthermore, this lack of significant difference in height may be an indication of a similar

trend for aerobic power between selection groups as aerobic power is strongly influenced by growth (Armstrong et al., 2011; Armstrong et al., 2008; McArdle et al., 2010). Therefore this could indicate that size, and the possible concomitant increase in aerobic power seen with growth may not be a large concern when selecting elite youth soccer players.

5.2 Aerobic Power

Peak oxygen uptake values for males in the current study (61.1 ml/kg/min) agree with the range of values found in previous literature of 54-63 ml/kg/min. Similarly, the female average of 51.6 ml/kg/min also agrees with the range suggested by literature of 39-57.6 ml/kg/min. When comparing the aerobic power of males and females in the current study it was found that males had a significantly greater aerobic power than females, despite scaling method. While a significant difference between genders is to be expected, the males and females in the current study differed by more than the expected 10-35% that is usually seen with this age group (Rowland, 2005; Baxter-Jones & Maffulli, 2003; Armstrong, et al., 2011). Higher aerobic power in males was matched with greater fat free mass (kg), which, as previously explained helps to facilitate oxygen utilization during exercise (Armstrong et al., 2011; Rowland, 2005). The remained presence of a significant difference between male and female aerobic power once fat free mass was controlled for supports past literature (Santisteban, Impellizzeri & Castagna, 2009). Santisteban and associates (2009) illustrated the numerous physiological, behavioral and training differences between males and females have a unique effect on VO_{2peak} values in addition to the differences due to body composition. The significant difference in relative aerobic power remaining between sexes once body composition was controlled for supports the idea that there are multiple contributing factors to differing aerobic power levels between sexes.

The above average aerobic power values in the current sample are to be expected given the high caliber level of these adolescent athletes. The importance of a higher than average aerobic power for elite soccer performance has been emphasized in the literature with a minimum VO_2max value of 60-65 ml/kg/min being suggested for an outfield position (Hoare & Warr, 2000; Gil et al., 2007). Given the emphasized importance of aerobic power (ml/kg/min) in soccer, and results from past studies involving youth of the same age (Vaeyens et al., 2006), it was expected that a significant difference in VO_2peak would have been detected between selection groups. However, in the current study no significant difference was found when comparing the aerobic power levels between selection groups, despite scaling method, when sexes were combined or separated. Studies involving male youth soccer players have shown differences in aerobic power between elite, sub-elite and non-elite players, with elite having an advantage over the other two groups (Vaeyens et al, 2006). As previously stated, the literature comparing female elite and non-elite youth soccer players is sparse, however, Dillern et al., (2012) discussed the need of superior aerobic power in elite female soccer players.

The lack of significant difference between selection groups despite scaling method and sex as a covariate agrees with the TOYA study (Baxter-Jones & Rowley, 1995). Baxter-Jones and Rowley (1995) reported that there was no significant difference in aerobic power between high performance and lower performance athletes in six out of the seven sports. In the current study, the lack of significant difference in aerobic power in the female group could be due to the highly developed and trained anaerobic system that has been reported in some female athletes (Mujika et al., 2009). It was suggested by Mujika and associates (2009) that due to the tendency for female athletes to play at, and be trained by coaches, at a lower absolute intensity than their male counterparts, they tend to have a better-developed anaerobic system. As the anaerobic

system has been identified as an important part in soccer, and females have been known to cover less distance than males during match-play, it could be that in females, anaerobic power is more favored (Mujika et al., 2009). The lack of significant difference between selection groups in males may have been due to the insensitivity of VO_2peak to detect differences in two groups of highly trained athletes (Dillern et al., 2011; Malina et al., 2004a; Coelho e Silva et al., 2010). Lastly, as all athletes were approximately one year past their aPHV, and all matured at the average age for their sex, the substantial effect of puberty on aerobic power, it could be that drastic changes in VO_2peak may have occurred prior to testing making differences hard to detect (Malina et al., 2004a).

In addition to the impact of aerobic power on selection in previous literature, it has also been suggested that a relationship occurs between playing position and aerobic fitness (Boone et al., 2012; Russell & Tooley, 2011; Stroyer et al., 2004). It has been reported that goalkeepers have significantly lower aerobic power values as compared to those who play an outfield position (Boone et al., 2012; Russell & Tooley, 2011; Stroyer et al., 2004a). In the current study, there was no significant difference in VO_2peak levels, absolute (l/min) or relative (ml/kg/min or ml/kg FFM/min) between positions. When considering gender, the lack of significant differences between positions remained for males, however, in females, goalkeepers showed a significantly lower absolute VO_2peak (l/min); this difference disappeared when aerobic power was scaled to body mass and fat free mass. The lack of significant difference in VO_2peak (ml/kg/min and ml/kg FFM/min) between playing position is most likely due to the similar training regime of each player despite their playing position (Dillern et al., 2011). The athletes in the current sample reported that all players practiced together, and that goalkeepers were

occasionally separated for different practice sessions, therefore, the majority of training would be relatively similar between positions.

5.3 Team Selection

The present study set out to determine if those Saskatchewan youth athletes selected for the Provincial Selects Program had significantly greater aerobic power and size than those players not selected. Results show that there was no significant difference in VO_2 peak values or anthropometric measurements between the selection groups of those athletes sampled. This lack of significant difference in aerobic power and size of selected athletes could suggest many different outcomes: (i) that there was a previous form of selection prior to the try-out, (ii) that aerobic power was not seen as important for selection or (iii) a different set of criteria are used when selecting elite youth athletes. For example, given the high level of aerobic power of all athletes in the study, as well as similar maturational status between all players, it could be that there was a form of selection that occurred prior to the try-out. It is possible that the athletes that attended the try-out were encouraged by coaches or parents who recognized their superior skill level; likewise, those athletes who are viewed as less skilled due to a lower aerobic power, size or maturity status may have been discouraged from attending. This all around elite level of skill and game experience may have contributed to, or caused the lack of differences between aerobic power, size and maturation. Similar cases have been seen in past literature, it has been reported that when comparing elite to non-elite players there is a marked difference in aerobic power, however, when the two groups are both highly trained there is a less consistent ability of aerobic power to decipher between athletes (Vaeyens et al., 2006; Gil et al., 2007).

The lack of differences found between the two selection groups of the current study could also indicate that at a certain level of athleticism coaches use a different set of criteria in order to identify those with the most potential. It could be that the presence of superior aerobic power and size allows an athlete to get to a certain level of elitism, where after this point is reached, non-physiological factors are more influential on team selection (Williams & Reilly, 2000; Vaeyens, et al., 2006; Baxter-Jones & Rowley, 1995). It has been suggested that when selecting high caliber athletes, coaches may focus on characteristics outside the realm of physical size and physiological performance, such as, psychological, sociological and cognitive skills, as well as game intelligence and previous sport experience (Williams & Reilly, 2000; Vaeyens, et al., 2006; Baxter-Jones & Rowley, 1995). Numerous studies have shown that the motivation of an athlete, as well as a strong support system from coaches and parents can lead to increased sport performance, and future selection onto elite level teams (Williams & Reilly, 2000; Baxter-Jones & Rowley, 1995). Furthermore, cognitive factors and game intelligence, including anticipation, decision-making and skilled perception can have a large impact on the performance of an athlete above physical and physiological factors (Williams & Reilly, 2000; Williams, 2000; Baxter-Jones & Rowley, 1995). A study by Williams and Reilly (2000) found that more elite players demonstrated superior anticipation skills when compared to less elite athletes; this skill was seen as crucial in soccer as the environment is complex and rapidly changing. Therefore it is possible that while these elite level athletes have superior aerobic power, it is their non-physical characteristics that set them aside from other athletes once a certain level of athleticism has been accomplished (Williams & Reilly, 2000).

Results of the current study, combined with earlier literature (Williams & Reilly, 2000; Vaeyens, et al., 2006; Baxter-Jones & Rowley, 1995), suggest that in order to properly identify

potential in an athlete one must consider the athlete as a whole, including their support systems. The use of physical characteristics, such as anthropometric measurements, to identify talent is extremely difficult as there are no identified cut-off values that athletes must meet in order to be deemed successful (Baxter-Jones & Rowley, 1995). In this regard, it is important for sporting organizations to be open to, and understand the multiple characteristics, including physical, behavioural and environmental traits, that produce a successful athlete.

5.4 Limitations

The current study was a cross-section design; therefore, data was collected on only one occasion and does not allow the tracking of aerobic power, or future involvement in elite sport. Furthermore, the small sample size was a large limitation in the study as it did not allow for a large comparison between players. Also in relation to sample is the uneven number of males and females, and selected and unselected players. In regards to study design, the measurement of aerobic power of individuals came almost one year after the original try-out, however, it should be noted that the players were preparing for the 2015 try-out.

5.5 Future Direction

As the identification of sporting talent has proven to be multifaceted, future studies should aim to measure psychological, physical, physiological and environmental factors of each athlete. It would be beneficial for such characteristics to be measured in a timely manner, relative to the try-out, as well as multiple times over the course of a few years. Following athletes for a longer period of time will provide the opportunity for the tracking of aerobic power with age as well as training. Longitudinal studies may help to determine if the athlete has a superior aerobic power prior to selection or if it is the benefits of selection, including increased training experience that leads to the higher aerobic power. Along this same route, testing athletes of

different ages and levels of competitive play may allow for larger variation in anthropometric size and aerobic power, as well as the impact of aerobic power is more important in certain age groups. Lastly future studies may want to include additional assessments to measure decision-making, anticipation and game-specific skills. The measurement of a wide variety of characteristics may help in narrowing down the combination of skills that coaches at an elite level are looking for when forming high caliber adolescent soccer teams. Lastly, when studying female soccer players, studies should incorporate the measurement of anaerobic power to determine if this measure is seen as advantageous in elite adolescent female soccer.

6.0 Conclusion

The current study found that there was no significant difference in aerobic power between selection groups for the Saskatchewan Provincial Selects camp. This lack of significant difference was seen when analyzing selected and not selected groups by gender, and with genders combined. These results suggest that other factors, such as cognitive, perceptual and behavioural characteristics may contribute to the selection of youth athletes onto an elite team. These findings are encouraging for all adolescent athletes who may be delayed in maturation, and therefore, smaller with less aerobic power. This study, as well as others in the area, supply evidence to support the idea that athletes that may lack in the areas of physical size and physiological performance are still beneficial additions to elite soccer teams. In regards to females specifically, it is possible that these non-physical characteristics, as well as anaerobic power are used as selection criteria onto elite level soccer teams.

The current study was focused on Saskatchewan youth athletes who play at an elite provincial level. Results from this study can be added to the current knowledge in the area, and

can aid in expanding understanding of sport performance and talent identification in a younger cohort. This study helps enforce the idea that other factors, in addition to superior aerobic power and size may be beneficial to soccer performance. This knowledge may create sporting opportunities for a diverse set of athletes, thereby providing an environment that will foster further athletic potential and development for all athletes. The development and inclusion of all athletes, despite maturational stage or anthropometric size is crucial to sport participation and development. It is hoped that these results emphasize the importance of considering the multifaceted nature of sport including maturation, anthropometric size, and sport specific skills when analyzing current, and attempting to predict future sport performance. In addition such research should encourage athletes of all sizes and capacities to attend competitive try-outs and enlighten coaches to choose athletes based on more than just body size and physiological factors. Inclusion of more athletes or at the least allowing more athletes to feel eligible for try-outs will hopefully increase participation rates in sporting and recreation, thereby increasing physical activity levels, and concomitant health benefits.

7.0 References

- Abbott, A., Button, C., Pepping, G. J., & Collins, D. (2005). Unnatural selection: Talent identification and development in sport. *Psychology, and Life Sciences*, 9(1). Retrieved from <http://www.societyforchaostheory.org/ndpls/>
- Active healthy kids Canada. (2014). *Is Canada in the running? How Canada stacks up against 14 other countries on physical activity for children and youth*. Retrieved from http://dvqdas9jty7g6.cloudfront.net/reportcard2014/AHKC_2014_ReportCard_ENG.pdf
- Adie, J. W., Duda, J. L., & Ntoumanis, N. (2010). Achievement goal, competition appraisals and the well- and ill-being of elite youth soccer players over two competitive seasons. *Journal of Sport & Exercise Psychology*, 32(4). Retrieved from <http://journals.human.kinetics.com/jsep>
- Armstrong, N. (2006). Aerobic fitness of children and adolescents. *Jornal de Pediatria*, 82 (6). Retrieved from <http://jped.elsevier.es>
- Armstrong, N. (2013). Training and testing elite youth athletes. In M. Cohelo-E- Silva, A. Cupido-dos-Santos, A. J. Figueriredo, N. Armstrong, & J. P. Ferreira (Eds.), *Children and Exercise XXVIII: Proceedings of the 28th Pediatric Work Physiology Meeting* (pp. 77-83). New York: Routledge.
- Armstrong, N., Barrett, L. A., & Welsman, J. R. (2007). Cardiorespiratory training during childhood and adolescence. *Journal of Exercise Science and Physiotherapy*, 3(1). Retrieved from <http://medind.nic.in/jau/t07/i1/jaut07i1c.shtml>
- Armstrong, N., McManus, A. M., & Welsman, J. R. (2008). Aerobic Fitness. In N. Armstrong & W. Van Mechelen (Eds.), *Paediatric Exercise Science and Medicine*. (pp.269-281). New York, NY: Oxford Press.
- Armstrong, N., Tomkinson, G. R., & Ekelund, U. (2011). Aerobic fitness and its relationship to sport, exercise training and habitual physical activity during youth. *British Journal of Sports Medicine*, 45(11). Retrieved from <http://bjsm.bmj.com>
- Armstrong, N., & Welsman, J. R. (1997). *Young people & Physical Activity*. New York, NY: Oxford Press.
- Armstrong, N., & Welsman J. R. (2000). Development of aerobic fitness during childhood and adolescence. *Pediatric Exercise Science*, 12(2). Retrieved from <http://journals.human.kinetics.com/pes>

- Baquet, G., Van Praagh, E., & Berthoin, S. (2003). Endurance training and aerobic fitness in young people. *Sports Medicine*, 33(15). Retrieved from <http://link.springer.com/journal/40279>
- Barker, A.R., Jones, A. M., Williams, C. A., & Armstrong N. (2011). Establishing maximal oxygen uptake in young people during a ramp cycle test to exhaustion. *British Journal of Sports Medicine*, 45(6). Retrieved from <http://bjsm.bmj.com>
- Barreiros A., Cote J., & Fonseca A. M. (2014). From early to adult sport success: Analyzing athletes' progression in national squads. *European Journal of Sport Science*, 14(1). Retrieved from <http://www.tandfonline.com/toc/tejs20/current#.VTbGalzqLww>
- Baty International. (2015). Harpenden Skinfold Caliper. Retrieved from <http://www.harpenden-skinfold.com>
- Baxter-Jones, A.D.G., & Rowley, S. (1995). TOYA Training of Young Athletes Study: TOYA and Identification of talent 2. Ipswich, England: Ancient House Press
- Baxter-Jones, A., Goldstein, H., & Helms, P. (1993). The development of aerobic power in young athletes. *Journal of Applied Physiology*, 75(3). Retrieved from <http://jap.physiology.org/front>
- Baxter-Jones, A. D. G., & Maffulli, N. (2003). Endurance in young athletes: It can be trained. *British Journal of Sports Medicine*, 37(2). Retrieved from <http://bjsm.bmj.com>
- Baxter-Jones, A. D. G., Eisenmann, J. C., & Sherar, L. B. (2005). Controlling for maturation in pediatric exercise science. *Pediatric Exercise Science*, 17(1). Retrieved from <http://journals.humankinetics.com/pes>
- Boltin . (2001). Healthy Growth and Development. In C. Green-Hernandez, J. K. Singleton & D. Z Aronzon (Eds.), *Primary Care Pediatrics* (pp. 151-160). Philadelphia, PA: Lippincott Williams & Wilkins
- Boone, J., Vaeyens, R., Steyaert A., Vanden Bossche, L., & Bourgois, J. (2012). Physical fitness of elite Belgian soccer players by player position. *The Journal of Strength Conditioning and Research*, 26(8). Retrieved from <http://journals.lww.com/nsca-jscr/Pages/default.aspx>
- Canadian Heritage. (2013). *Sport participation 2010: Research paper*. Retrieved from http://publications.gc.ca/collections/collection_2013/pc-ch/CH24-1-2012-eng.pdf
- Carling, C., Bloomfield, J., Nelsen, L., Reilly, T. (2008). The role of motion analysis in elite soccer. *Sports Medicine*, 38(10). Retrieved from <http://link.springer.com/journal/40279>

- Carling, C., Le Gall, F., & Malina, R. M. (2012). Body size, skeletal maturity, and functional characteristics of elite academy soccer players on entry between 1992 and 2003. *Journal of Sports Sciences*, 30(15). Retrieved from <http://www.tandfonline.com/toc/rjsp20/current#.VTbI0VzqLww>
- Centers for Disease Control and Prevention (CDC). (2009). *Clinical Growth Charts*. Retrieved from http://www.cdc.gov/growthcharts/clinical_charts.htm#Set2
- Centers for Disease Control and Prevention (CDC). (2014). *Physical activity facts*. Retrieved from <http://www.cdc.gov/healthyyouth/physicalactivity/facts.htm>
- Centers for Disease Control and Prevention (CDC). (2015). *Measuring Physical Activity Intensity: Target Heart Rate and Estimated Maximal Heart Rate*. Retrieved from <http://www.cdc.gov/physicalactivity/basics/measuring/hearttrate.htm>
- Coelho e Silva, M. J., Figueiredo, A. J., Simoes, F., Seabra, A., Natal, A., Vaeyens, R., ... Malina, RM. (2010). Discrimination of U-14 soccer players by level and position. *International Journal of Sports Medicine*, 31(11). Retrieved from <https://www.thieme-connect.com/products/ejournals/journal/10.1055/s-00000028>
- Cunha, G., Lorenzi, T., Sapata, K., Lopes, L., Gaya, AC., & Oliveira, A. (2011). Effect of biological maturation on maximal oxygen uptake and ventilator thresholds in soccer players: An allometric approach. *Journal of Sports Science*, 29(10). Retrieved from <http://www.tandfonline.com/toc/rjsp20/current#.VTbKFlzqLww>
- Dwyer, G. B., & Davis, S. E. (Eds.). (2008). ACSM. (2008). Maximal exercise testing. In *ACSM's health-related physical fitness assessment manual* (2nd ed.). (pp. 125-139). Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins.
- Dickau, L. (2006). Examination of aerobic and anaerobic contributions to yo-yo intermittent recovery level 1 test performance in female adolescent soccer players. (Master's Thesis). Available from <http://dspace.library.uvic.ca/handle/1828/97>
- Dillern, T., Ingebrigtsen, J., & Shalfawi, S. A. I. (2011). Aerobic capacity and anthropometric characteristics of elite-recruit female soccer players. *Journal of Strength Conditioning and Research*, 25(12). Retrieved from <http://journals.lww.com/nsca-jscr/Pages/default.aspx>
- DuRant R.H., Pendergrast, R. A., Donner, J., Seymore, C., & Gaillard G. (1991). Adolescents' attrition from school-sponsored sports. *American Journal of Diseases of Children*, 145(10). Retrieved from http://archpedi.jamanetwork.com/issues.aspx?journalID=75&year=1991#issues_tabContentWrapper

- Ehrman, J. K., Gordon, P. M., Visich, P. S., & Keteyian, S. J. (2009). Children. In M. S. Bahrke, M. Eckstein, & A. Ewing (Eds.), *Clinical Exercise Physiology* (2nd ed.) (pp.111-134). Champaign, IL: Human Kinetics.
- Eisenmann, J. C., Laurson, K. R., & Welk, G. J. (2011). Aerobic fitness percentiles for U.S. adolescents. *American Journal of Preventative Medicine*, 41(4). Retrieved from <http://www.ajpmonline.org>
- Fitzgerald, M. D., Tanaka, H., Tran, Z. T., & Seals, D. R. (1997). Age-related declines in maximal aerobic capacity in regularly exercising vs sedentary women: A meta-analysis. *Journal of Applied Physiology*, 83(1). Retrieved from <http://jap.physiology.org/front>
- Geithner, C. A., Thomis, M. A., Vanden Eynde, B., Maes, H. H. M., Loos, R. J. F. ... Beunen, G. P. (2004). Growth in Peak Aerobic Power during Adolescence. *Medicine and Science in Sports and Exercise*, 36(9). Retrieved from <https://www.acsm.org/access-public-information/acsm-journals/medicine-science-in-sports-exercise>
- Gil, S. M., Gil, J., Ruiz, F., Irazusta, A., & Irazusta, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: relevance for the selection process. *Journal of Strength and Conditioning Research*, 21(2). Retrieved from <http://journals.lww.com/nsca-jscr/Pages/default.aspx>
- GraphPad Software, Inc. (2015). Prism 6 [computer software]. California.
- Haugen, T. A., Tonnesson, E., Hem, E., Leirstein, S., & Seiler S. (2014). VO₂max characteristics of elite female soccer players, 1989-2007. *International Journal of Sport Physiology and Performance*, 9(3). Retrieved from <http://journals.humankinetics.com/ijsp>
- Hawkins, S. A., & Wiswell, R. A. (2003). Rate and mechanism of maximal oxygen consumption decline with aging: Implications for exercise training. *Sports Medicine*, 33(12). Retrieved from <http://link.springer.com/journal/40279>
- Helmantel, A. J., Elferink-Gernser, & Visscher, C. (2009). Trainability of VO₂max in Childhood and Adolescence. In M. Coelho e Silva, A. J. Figueiredo, M. T. Elferink-Gemser, & R. M. Malina (Eds.). *Youth Sports: Participation, Trainability and Readiness* (pp. 139-163). Coimbra, Portugal: Coimbra University Press.
- IBM. (2014). SPSS Statistical Package (Version 22) [computer software]. New York
- Janssen, I., & LeBlanc, AG. (2010). Systematic review of sedentary behavior and health indicators in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, 8(98). Retrieved <http://www.ijbnpa.org>

- Kohl, H. W. III, & Cook, H. D. (Eds.). (2013). Physical activity and physical education: Relationship to growth, development and health. In *Educating the Student Body: Taking Physical Activity and Physical Education to School* (pp. 97-141). Washington: The National Academies Press.
- Kowalski, K. C., Crocker, P. R. E., & Donen, R. M. (2004). The physical activity questionnaire for older children (PAQ-C) and Adolescents (PAQ-A) Manual. Retrieved from http://www.dapa-toolkit.mrc.ac.uk/documents/en/PAQ/PAQ_manual.pdf
- Loe H., Rognmo, O., Saltin, O., & Wisloff, U. (2013). Aerobic Capacity Reference Data in 3816 Healthy Men and Women 20–90 Years. *PLoS One*, *8*(5). Retrieved from <http://www.plosone.org>
- Malina, R. M., Bouchard, C., & Bar-Or, O. (2004a). *Growth, Maturation and Physical Activity* (2nd ed.). Windsor, ON: Human Kinetics.
- Malina, R. M., Eisenmann, J. C., Cumming, S. P., Ribeiro, B. R., & Aroso, J. (2004b). Maturity-associated variation in the growth and functional capacities of youth football (soccer) players 13-15 years. *European Journal of Applied Physiology*, *91*(5-6). Retrieved from <http://link.springer.com/journal/421>
- McArdle, W. D., Katch, F. I., & Katch V. L. (2010). Aerobic Systems of Energy Delivery and Utilization. In *Exercise Physiology: Nutrition, Energy and Human Performance* (7th edition). Philadelphia, PA: Lippincott Williams & Wilkins.
- Mirwald, R.L., Baxter-Jones, A. D., Bailey, D. A., & Beunen, G. P. (2002). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports & Exercise*, *34*(4). Retrieved from <https://www.acsm.org/access-public-information/acsm-journals/medicine-science-in-sports-exercise>
- Mujika, I., Santisteban, J., Impellizzeri, F. M., & Castagna, C. (2009). Fitness determinants of success in men's and women's football. *Journal of Sports Sciences*, *27*(2). Retrieved from <http://www.tandfonline.com/toc/tjsp20/current#.VTeQWVzqLww>
- Nevill, A., Rowland T., Goff, D., Martel, L., & Ferrone, L. (2004). Scaling or normalizing maximum oxygen uptake to predict 1-mile run time in boys. *European Journal of Applied Physiology*, *92*(3). Retrieved from <http://www.springer.com/biomed/human+physiology/journal/421>
- Pearson, D. T., Naughton, G. A., & Torode, M. (2006). Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *Journal of Science and Medicine in Sport*, *9*(4). Retrieved from <http://www.jsams.org>

- Perkins, D., Jacobs, J. E., Barber, B. L., & Eccles, J. S. (2004). Childhood and adolescent sport participation as predictors of participation in sports and physical fitness activities during young adulthood. *Youth & Society, 35*(4). Retrieved <http://yas.sagepub.com>
- Phillippaerts, R. M., Vaeyens, R., Janssens, M., Van Renterghem, B., Matthys, D., ... Malina, R. M. (2007). The relationship between peak height velocity and physical performance in youth soccer players. *Journal of Sports Sciences, 24*(3). Retrieved from <http://www.tandfonline.com/toc/rjsp20/current#.VTeTzFzqLww>
- Polar. (2015). T31 coded transmitter. Retrieved from http://www.polar.com/ca-en/products/accessories/T31_coded_Transmitter
- Reilly, T., Williams, A. M., Nevill, A., & Franks, A. (2010). A multidisciplinary approach to talent identification in soccer. *Journal of Sports Sciences, 18*(9). Retrieved from <http://www.tandfonline.com/toc/rjsp20/current#.VTeTzFzqLww>
- Rowland, T. W., & Cunningham, L. N. (1992). Oxygen uptake plateau during maximal treadmill exercise in children. *CHEST, 101*(2). Retrieved from <http://journal.publications.chestnet.org>
- Rowland, TW. (2005). Aerobic Fitness. In M.S. Bahrke & R.T. Pyrtel (Eds.), *Children's Exercise Physiology* (pp. 89-108). Champaign, IL: Human Kinetics.
- Russell, M. & Tooley, E. (2011). Anthropometric and performance characteristics of young male soccer players competing in the UK. *Serbian Journal of Sports Sciences, 5*(4). Retrieved from <http://www.sjss-sportsacademy.edu.rs>
- Sacheck, J. M., Nelson, T., Ficker, L., Kafka, T., Kuder, J., & Economos, C. D. (2011). Physical activity during soccer and its contribution to physical activity recommendations in normal weight and overweight children. *Pediatric Exercise Science, 23*(2). Retrieved from <http://journals.humankinetics.com/pes>
- Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J, Van Loan, M. D, & Bembien, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology, 60*(5). Retrieved from <http://digitalcommons.wayne.edu/humbiol>
- Statistics Canada. (2013). *Canadian health measures survey: Directly measured physical activity of Canadians from, 2007-2011*. Retrieved from www.statcan.gc.ca/dailyquotidien/130530/dq130530d-eng.htm

- Stroyer, J., Hansen, L., & Klausen, K. (2004). Physiological profile and activity pattern of young soccer players during match play. *Medicine & Science in Sports & Exercise*, 36(1). Retrieved from <https://www.acsm.org/access-public-information/acsm-journals/medicine-science-in-sports-exercise>
- The Saskatchewan Soccer Association. (2014). *SSA Showcase Provincial Selects Program (PSP-SK)*. Retrieved from www.sasksoccer.com/page.php?page_id=58997
- Tremblay, M. S., LeBlanc, A. G., Kho, M. E., Saunders, T. J., Larouch, R., Colley, R. C., Goldfield, G., & Connor Gorber, S. (2011). Systematic review of sedentary behavior and health indicators in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, 8(98). Retrieved from <http://www.ijbnpa.org>
- Vaeyens, R., Malina, R. M., Janssens, M., Van Renterghem, B., Bourgois, J., ... Philippaerts, R. M. (2006). A multidisciplinary selection model for youth soccer: the Ghent Youth Soccer Project. *British Journal of Sports Medicine* 40(11). Retrieved from <http://bjsm.bmj.com>
- Viickberg U., Purge P., Jurimae T., Saar M., Latt E., ... Jurimae J. (2013). Interpretation of peak oxygen consumption in 10-12 year old soccer players: Effect of biological maturation and body size. *Acta Kinesiologiae Universitatis Tartuensis*, 19(NA). Retrieved from <https://ojs.utlib.ee/index.php/AKUT/index>
- World Health Organization (WHO). (2015). *Global Strategy on Diet, Physical Activity and Health: What is Moderate-intensity and Vigorous-intensity Physical Activity?* Retrieved from http://www.who.int/dietphysicalactivity/physical_activity_intensity/en/
- Williams A. M., & Reilly T. (2000). Talent identification and development in soccer. *Journal of Sports Sciences*, 18(9). Retrieved from <http://www.tandfonline.com/toc/rjsp20/current#.VTedD1zqLww>
- Wilson, T. M., & Tanaka, H. (2000). Meta-analysis of the age-associated decline in maximal aerobic capacity in men: Relation to training status. *American Journal of Physiology – Heart and Circulatory Physiology*, 278(3). Retrieved from <http://ajpheart.physiology.org>
- Woo S. J., Derleth, C., Stratton, J. R., & Levy W. C. (2006). The influence of age, gender, and training on exercise efficiency. *Journal of the American College of Cardiology*, 47(5). Retrieved from <http://content.onlinejacc.org/journal.aspx>
- Yeung D. C., & Hui S. S. (2010). Validity and reliability of skinfold measurement in assessing body fatness in Chinese children. *Asia Pacific Journal of Clinical Nutrition*, 19(3). Retrieved from <http://apjcn.nhri.org.tw>

Appendix A

The Role of Aerobic Power on Predicting Selection onto Elite Adolescent Sport Teams College of Kinesiology, University of Saskatchewan Research Participant Information and Consent Form

Researchers

Principal Investigator:

Dr. Adam Baxter-Jones
College of Kinesiology
University of Saskatchewan
306-966-5759
baxter.jones@usask.ca

Student investigator

Jessica Murphy
Student: College of Graduate Studies
University of Saskatchewan
306-716-4315
jessica.murphy@usask.ca

Introduction:

Please note that when “you” appears in the following consent form it will be referring to your child/the athlete.

You are being invited to take part in this research study because you have previously been involved with the University of Saskatchewan’s *Sport Participation Research Initiative* (REB:13-22). During that study you indicated that you would be willing to be contacted to be part of upcoming studies. Please know that your participation in this study is entirely voluntary. You may withdraw at any time without reason and/or penalty. If you choose not to participate it will not affect any relationship with the University, or your affiliated sports team. This consent form will give information about the study, the importance of the research, the role you will play in this study, along with the possible benefits, and risks or discomforts involved. If you decide to participate in this study you and your parent/legal guardian will be required to sign this consent form. Please read this form carefully and feel free to contact either the principal or student investigator with any further questions.

Who is conducting the Study?

This study is being conducted by researchers in the College of Kinesiology, both of whom were involved in the previous study. This new study is being done as the Master’s degree project of the student investigator. The investigators are not being paid to conduct this study. This study is funded by Sport Canada and Social Sciences and Humanities Research Council (SSHRC).

Why is this study being conducted?

The objective of this study is to determine the relationship between an adolescent athlete’s aerobic power and selection onto an elite junior sports team. By observing the selection of an athlete, and the athlete’s aerobic power, comparisons can be made to indicate influencing factors in team selection. The aim is to discover if the aerobic power of an athlete is an important factor in being successfully drafted onto an elite level junior sports team. This study will require the participation of about 80 adolescent athletes from the Saskatoon area.

Who can participate in the study?

You are eligible to participate in this study if you are between the ages of 11-17, from the Saskatoon area. In addition, to be eligible you must have tried out for one or more of the provincial level teams (basketball, hockey, soccer, football, or volleyball) involved in the *Sports Participation Research Initiative* (REB13-22) conducted by the University of Saskatchewan.

What does the study involve?

All athletes will come to the University of Saskatchewan and complete a series of physical tests. In addition athletes will be asked to fill out a questionnaire regarding sport and physical activity participation on an average week. Only one visit will be required and will be completed in one to two hours.

The following measurements will be taken either by the student investigator or by the research assistant in the company of the student investigator:

- 1) Bodily Measurements: this will include measuring the height, weight and sitting height of each athlete.
- 2) Skin-Fold Thickness: skin-fold thickness measurements will be performed at the calves, sub-scapula and triceps.
- 3) Dual Energy X-ray Absorptiometry: a low dosage of radiation (less than a chest x-ray) will be used in order to measure fat mass and fat free mass.
- 4) Aerobic Fitness (peak VO₂): You will be required to perform a run on a standard treadmill until voluntary exhaustion. Prior to this test it is suggested that you do not perform any heavy exercise for 24 hours prior, or eat a heavy meal 2 hours before.
- 5) You will also be required to supply the investigator with your date of birth in order to accurately calculate age.

The bodily measurements and birth date will be used in a calculation to determine the athlete's maturational status. The skin-fold measurements will be used to determine fat free mass; this will be used as a scaling method to fairly compare aerobic fitness between athletes. The physical activity questionnaire allows us to analyze the effect of sport and activity on the athlete's aerobic fitness.

What are the participant's responsibilities?

If you choose to participate in this study it will be expected that you:

- 1) Show up to the scheduled appointment on time
- 2) Be dressed in appropriate fitness attire
- 3) Do not participate in exercise within 24 hours, or eat a large meal within 2 hours, prior to the visit to the PAC
- 3) Follow the directions of the investigators/research assistant
- 4) Report any changes in your health (illness, medications, discomfort)
- 5) Give your best effort during the aerobic fitness treadmill test

Potential Benefits of Participation:

Upon completion of the study, you will receive your individual test results from the study visit. This will give you information regarding your fitness ability and maturational status. The group results will help to broaden the knowledge surrounding team selection. This information will hopefully help to equalize the playing field in sport try-outs, determine the factors considered during elite team try-outs, and clarify those individual factors that could be used to identify talent at a relatively young age.

Potential Risks and Discomfort:

Skin-fold measurement can occasionally cause pinching of the skin. There is very little radiation exposure from the dual energy X-ray scans (DEXA). The amount of radiation is less than 1% from what you would receive from a routine full-mouth dental X-ray. The treadmill run to voluntary exhaustion can cause the following: fatigue, shortness of breath, temporary abnormal blood pressure, chest pain, fainting, disorders of heartbeat (too fast/slow/unusual beats), muscle aches or joint pain and, in very rare cases, heart attacks. Risks will be minimized by having a Certified Exercise Physiologist present for the testing. You can stop the run at anytime that you feel necessary.

What if something goes wrong?

If an adverse event related to the study occurs, trained staff will be available throughout the conduct of the study who can respond immediately. Necessary medical treatment will be made available at no additional cost to you. Parents will be immediately contacted. By signing this document, you do not waive any of your legal rights.

What happens if withdrawal is requested?

As a participant in this study it is understood that you are free to withdraw from any part of the study at any time without penalty. Participation in this study will not affect any current relationships with your coaches, sports organization or the University of Saskatchewan. If you chose to withdraw during the study, any data that has been collected will be kept for analysis but no other information will be collected.

What happens after completion of the study?

Following completion of the study all participants will be supplied with their individual results as well as where they rank in comparison to average aerobic fitness values and other participants. These results can be delivered via e-mail or traditional mail, whichever way you chose.

What will the costs of the study be?

Participation in this study will not result in any costs to you. Travel costs and parking will be reimbursed by the study.

Will participation be kept confidential?

In Saskatchewan, the Health Information Protection Act (HIPA) defines how the privacy of personal information must be maintained so that participant privacy is respected. All data collected will be kept confidential. You will be given a participant number and code; therefore no documents will contain the actual name of any participant. Likewise, during any future publication, names of all participants, as well as any information which could be used to identify an individual will be kept out. All results will be kept in a secure location where only the researchers and investigators involved in the study will have access.

Further questions?

If there are any further questions or more information is needed about any part of this study before, during or after participation the principal and/or student investigator will be more than willing to address questions or concerns. The principal and student investigator can be contacted by phone or email at:

- 1) Principal Investigator: Dr. Adam Baxter-Jones, 306-966-5759, baxter.jones@usask.ca
- 2) Student investigator: Jessica Murphy, 306-716-4315, jessica.murphy@usask.ca

Furthermore, any concerns regarding participant rights or experiences can be directed to the Chair of the University of Saskatchewan Research Ethics Board at 306-966-2975, or toll-free (out of town calls) 1-888-966-2975 or by email at ethics.office@usask.ca.

Consent to Participate

- I have read the information in this consent form
- I understand the purpose and procedures and the possible risks and benefits of the study
- I was given sufficient time to think about whether or not I wanted to participate in the study
- I had the opportunity to ask questions and have received satisfactory answers
- I am free to withdraw from this study at any time for any reason and the decision to stop taking part will not affect my current or future relationships with any coaches, sports organizations or the University of Saskatchewan
- I agree to follow the instructions of the researchers conducting the study and will tell them if I start to feel sick or uncomfortable during the study. I will tell the study researcher at once if I feel I have had an unexpected or unusual symptom.
- I understand that by signing this document I do not waive any of my legal rights.
- I will be given a signed and dated copy of this consent form

I agree to participate in this study:

Printed name of participant:

Assent Signature:

Printed name of parent/legal guardian

Consent Signature

Printed name of person obtaining the assent of the adolescent and consent of the parent/legal guardian:

Signature:

Date

Appendix B

Stage	Time (min:s)	Speed (mph)	Grade (%)
1	0:00	1.7	10.0
2	3:00	2.5	12.0
3	6:00	3.4	14.0
4	9:00	4.2	16.0
5	12:00	5.0	18.0
6	15:00	5.5	20.0
7	18:00	6.0	22.0

Bruce Protocol

Appendix C

Physical Activity Questionnaire

Name: _____

Age: _____

Sex: M _____ F _____

We are trying to find out about your level of physical activity from *the last 7 days* (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
 2. Please answer all the questions as honestly and accurately as you can — this is very important.
-

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row.)

	No	1-2	3-4	5-6	7 times or more
Skipping	m	m	m	m	m
Rowing/canoeing	m	m	m	m	m
In-line skating	m	m	m	m	m
Tag	m	m	m	m	m
Walking for exercise	m	m	m	m	m
Bicycling	m	m	m	m	m
Jogging or running	m	m	m	m	m
Aerobics	m	m	m	m	m
Swimming	m	m	m	m	m
Baseball, softball	m	m	m	m	m
Dance	m	m	m	m	m

Football	m	m	m	m	m
Badminton	m	m	m	m	m
Skateboarding	m	m	m	m	m
Soccer	m	m	m	m	m
Street hockey	m	m	m	m	m
Volleyball	m	m	m	m	m
Floor hockey	m	m	m	m	m
Basketball	m	m	m	m	m
Ice skating	m	m	m	m	m
Cross-country skiing	m	m	m	m	m
Ice hockey/ringette	m	m	m	m	m
Other:					
_____....	m	m	m	m	m
_____....	m	m	m	m	m

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

- I don't do PE m
- Hardly ever m
- Sometimes m
- Quite often m
- Always m

3. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

- Sat down (talking, reading, doing schoolwork)... m
- Stood around or walked around m
- Ran or played a little bit m
- Ran around and played quite a bit m
- Ran and played hard most of the time m

4. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

- None m
- 1 time last week m
- 2 or 3 times last week m
- 4 times last week m
- 5 times last week m

5. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

- None m
- 1 time last week m
- 2 or 3 times last week m
- 4 or 5 last week m
- 6 or 7 times last week m

6. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

- None m
- 1 time m
- 2 — 3 times m
- 4 — 5 times m
- 6 or more times m

7. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

- A. All or most of my free time was spent doing things that involve little physical effort m
- B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) m
- C. I often (3 — 4 times last week) did physical things in my free time m
- D. I quite often (5 — 6 times last week) did physical things in my free time m
- E. I very often (7 or more times last week) did physical things in my free time ... m

8. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

		Little			Very
	None	bit	Medium	Often	often
Monday	m	m	m	m	m
Tuesday	m	m	m	m	m
Wednesday	m	m	m	m	m
Thursday	m	m	m	m	m
Friday	m	m	m	m	m
Saturday	m	m	m	m	m
Sunday	m	m	m	m	m

9. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes m

No m

If Yes, what prevented you? _____

Thank you for completing the questionnaire.