THE RELATIONSHIP BETWEEN MATURITY STATUS, CHRONOLOGICAL AGE AND TALENT IDENTIFICATION IN YOUTH HOCKEY

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

College of Kinesiology

University of Saskatchewan

Saskatoon, Saskatchewan

By

Lauren B. Sherar

PERMISSION TO USE

In presenting this thesis 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 in any manner, in whole or in part, for scholarly purposes may be granted by the professor or professors who supervised my thesis work or, in their absence, by the Head of the Department or the Dean of the College in which my thesis was done. It is understood that any copying or publication or use of this thesis or parts thereof for financial reasons 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.

Requests for permission to copy or to make use of material in this thesis in whole or part should be addressed to:

Dean of the College of Kinesiology
University of Saskatchewan
Saskatoon, Saskatchewan
S7N 5B2

ABSTRACT

During adolescence early maturing individuals are likely to have sporting performance advantages over late maturing individuals of the same chronological age because of maturity related increases in size, strength, speed and endurance. The present study explores the relationship between chronological age, maturity status and talent identification in youth hockey. 619 male (14 - 15 yrs) and 385 female (12 - 16 yrs) Saskatchewan hockey players attended provincial try-outs (Try-out #1) of which 281 and 137 participated in the study, respectively. Of the male hockey participants, 208 were not selected at Try-out #1, 51 were selected at Try-out #1 but not selected at Try-out #2 and 22 were selected at Try-out #2. Of the female hockey participants, 77 were not selected at Try-out #1, 40 were selected at Try-out #1 but not selected at Try-out #2 and 20 were selected at Try-out #2. 93 male and 119 female age matched subjects from the longitudinal Saskatchewan Pediatric Bone Mineral Accrual Study (1991-1997) acted as controls.

All of the participants had their height, sitting height and body mass measured. Age at peak height velocity (PHV), an indicator of physical maturity, was calculated in the controls and predicted in the hockey participants. Age at menarche was recalled in females only. Data were analyzed using one-way ANOVA, logistic regression and a Kolmogorov Smirnov test. Alpha level was set at $p<0.05$.

The male hockey players who were selected at Try-out #2 were significantly ($p<0.05$) taller and heavier than the controls and the players not selected. The female hockey players who were selected at Try-out #2 were not significantly ($p>0.05$) taller and heavier than the players not selected and the controls. The average age at PHV of the selected males was significantly ($p<0.05$) younger than the non-selected males and controls. The average age at menarche of the selected females was not significantly ($p>0.05$) different from non-selected females or controls. The birth dates of the males selected at Try-out #2 were skewed, with more players born in the first six months of the selection year. The birth dates of the females selected at Try-out #2 were evenly distributed ($p>0.05$) through the 12 months of the selection year.

Results from this investigation suggest that talent evaluators preferentially selected early maturing and chronologically older male hockey players. The same bias, however, was not demonstrated in female hockey.

ACKNOWLEDGEMENTS

Foremost I would like to give thanks to my supervisor Dr. Adam Baxter-Jones for his guidance, support, extensive knowledge and great sense of humor. Adam, I look forward to learning much more from you in the future. I would like to give thanks to my committee members Dr. Robert Faulkner and Dr. Keith Russell, and to my external examiner Dr. Tom Graham for their valuable feedback. This investigation would never have got off the ground without the amazing support from Bruce Craven and the directors, coaches and players from the Saskatchewan Hockey Association (SHA). I would like to give particular thanks to Todd Dixon, the hardworking director of SHA, who embraced this research wholly and patiently taught me all I needed to know about the great Canadian game of hockey.

DEDICATION

This thesis is dedicated to Terry, Jane, Emma and Sam. I have always had your love and support even from afar– thank you!

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF DEFINITIONS

Body mass index = Weight (kg) divided by height (cm), squared

CA = Chronological age in years

FFM = Fat free mass

GROUP 1 = Hockey players that were not selected at Try-out #1

GROUP 2 = Hockey players selected at Try-out #1 and not selected at Try-out #2

GROUP 3 = Hockey players selected at Try-out #2

PHV = Peak height velocity

Relative age = Period of the selection year born

RAE = Relative age effect

Relatively old = Born early in the selection year

Relatively young = Born late in the selection year

1. INTRODUCTION

Early prediction of an athlete's performance potential is of prime interest to many of those involved in the development of young athletes: coaches, teachers and parents, as well as theoreticians (Bar-Or 1975). The most popular method of identifying talent is through competition, in which athletes of similar age identify themselves through their performances. However, this strategy of using performance during adolescence can be misleading as it does not take into account the effects of maturity (years of progress towards the mature adult state) on performance. During adolescence there is considerable variation in the growth and maturity of individuals of the same chronological age (CA) both between and within the sexes. An early maturing individual (an individual who has above average physical maturity for his/her CA) when compared to a late maturing individual (an individual who has below average physical maturity for his/her CA) could be perceived as being more 'talented' in a try-out situation purely because of maturity related development in size, strength, speed and endurance. The risk of competitive mismatching is greatest during early adolescence when individuals of identical CA may differ by as much as five years in their age of maturity (Martens 1980). Based on this premise, the appropriateness of using CA to index youth sporting talent has been questioned (Baxter-Jones 1995). In addition to the effects of physical maturity, differences in CA (i.e. date of birth in the selection year) could potentially play a role in talent identification. Youth may be overlooked in a try-out situation due to a lack of physical maturity that is simply related to the period of selection year in which they were born (i.e. relative age effect) (Brewer, Balsom, &

Davis 1995). Evidence, however, suggests that once players reach maturity the physical advantages of the more mature, and/or chronologically older, youth diminish (Lindgren 1978). Nonetheless, late maturing and/or younger individuals may have been deprived of vital years of coaching, competition, playing time, and prestige that come with playing on high caliber teams. If so this could affect their confidence, skill development, and future opportunities within the sport.

Hockey is an example of a sport where size, strength and speed are valuable attributes (Twist 1997; Brown 2001). Literature (Barnsley, Thompson, & Barnsley 1985; Barnsley & Thompson 1988; Boucher & Murtimer 1994) suggests that successful hockey players are more likely to have birthdays early in the selection year. Researchers (Brewer et al. 1992; Verhulst 1992; Baxter-Jones & Helms 1994; Dudink 1994; Baxter-Jones et al. 1995) investigating this phenomenon in other sports have attributed the relative age effect solely to the physical advantages of chronologically older players. However, no research is available which relates sporting success to anthropometric characteristics, CA and maturity status of adolescent hockey athletes, thereby substantiating the suggestion of advantages associated with advanced physical maturity. Furthermore, the possibility of the combined effect of CA and maturity status on success in sports has not been studied. A relative age disadvantage, coupled with late maturation, could make it virtually impossible for young players to be selected at hockey try-outs. Lastly, the limited literature surrounding anthropometric characteristics and maturity status of hockey players applies exclusively to males. Female hockey has gained amazing popularity over the past 10 years, thus adolescent female hockey players are a population warranting investigation.

Historically, Saskatchewan has provided more National Hockey League (NHL) players per capita than any other Canadian province, American state or European country. Before the 2003-2004 season, 422 Saskatchewan born players (395 skaters, 27 goalies) had dressed for at least one NHL game (www.cbc.ca/sports/hockey) and at present there are 68 Saskatchewan born players in the NHL (www.foxsports.com). Saskatchewan female hockey also looks very promising with four women from the province playing on the Team Canada Olympic Gold Medal winning team in Salt Lake City, 2002 (www.cs.toronto.edu). Therefore, Saskatchewan hockey players are an important population to study.

This investigation aims to explore the relationship between physical maturity and individual opportunity in Saskatchewan youth hockey. The primary aim was to explore the relationship between maturity status and talent identification in male and female youth hockey. A secondary aim was to explore the relationship between relative age and talent identification in male and female youth hockey.

2 REVIEW OF LITERATURE

2.1 Growth during adolescence

The period of adolescence varies from 9 or 10 years through 21 or 22 years of age (Malina 1978), and is often referred to as the transitional years between childhood and adulthood. During adolescence, there is a sudden increase in velocity of growth (growth spurt), second only to the rate of growth during the prenatal period (Schroeder 1992). This acceleration of growth affects almost all parts of the body, including the long bones, vertebrae, skull and facial bones, heart, lung and viscera, and muscle mass (Bogin 1988). In addition to somatic growth, there are changes in reproductive tissues (including secondary sex characteristics), in body size and shape, in the relative proportions of muscle, fat and bone, and in a variety of physiological functions (Tanner 1989).

There is, between members of the same sex, considerable variation in the timing of adolescent maturity and growth. All individuals attain skeletal maturity, and reproductive maturity; however, the chronological age (CA) at which they attain these events varies greatly. Therefore, progress towards maturity implies variation in time or rate, whereas growth refers to changes in size of an individual, as a whole or in parts (Malina 1988). Maturity is thus not directly linked to time in a chronological sense; individuals of the same CA can dramatically differ in their degree of maturity. As well as individual variation, there is also a marked sex difference in the timing of somatic and sexual maturation. Girls enter and end puberty approximately 2 years before boys (Tanner 1962).

The maturity status of adolescents can be assessed through a variety of techniques. Although the methods vary considerably they all (with the exception of secondary sex staging technique) express maturity relative to CA. For example, youths are classified as early maturers if their maturity age is greater than their CA by one year or more. If youths' maturity age is within a year of their CA they are classified as average maturers. Finally, if youths' maturity age is less than their CA by one year or more, they are classified as late maturers (Malina 1994). Recognition that individuals of the same CA can dramatically differ in their degree of physical maturity has, in the past, led health educators and researchers to question the appropriateness of grouping individuals by CA for sports participation.

2.2 Historic endeavors at maturity based classifications for sports

The limitation of grouping youths on the basis of CA in sporting situations has long been recognized. For nearly 100 years, there have been advocates for various classification indexes to account for size and maturity in elementary, junior, and senior high school and college aged men and women (Crampton 1908; Rotch 1909; Espenschade 1963; Cumming, Garand, & Borysyk 1972; Whieldon 1978; Caine & Broekhoff 1987). The purpose of these classifications was to improve instruction and to place students into equitable groups according to their physiological capabilities and where they are most likely to succeed. As early as 1908, Crampton (1908) advocated the use of 'physiological age' based on the development of pubic hair (an indicator of maturity) rather than CA in an attempt to establish an age at which a child could work safely. In 1973 a renewed interest, accompanied by a concern about increased risk of injuries, led the New York Public High School Athletic Association (NYSPH-SAA) (Hafner et al. 1982) to evaluate more objectively a child's readiness for participation in sport at a specific level of competition. A selection/classification program was developed to determine if eligibility could successfully be established on new norms based on physical maturity (boys classified on axillary and facial hair growth; girls on age of menarche), fitness, skill, prior sports experience, and the demands of the given sport. It was shown that 80% of the students processed by the selection/classification program who qualified for team placement participated as either regulars or substitutes, and only 10% - 15% elected to drop out of their respective teams (although no study could be found at this time to compare adherence with non-screened participation).

In 1981 the American Academy of Pediatrics Committee on Pediatric Aspects of Physical Fitness, Recreation, and Sports stated that decisions about athletic programs for children of elementary school age should consider grouping according to body mass, size, physical condition, skill, physical maturation, and, when indicated, sex. In the same year, the American Academy of Pediatrics Committee on School Health (1981) stated that a complete physical examination for competitive sports should be done when the student is beginning junior high school and again when he/she is entering high school. They stated that the physical examination should include: *"Assessment of maturity by use of Tanner's classification to determine if the young athlete is capable of competing with peers in the desired sport"* (American Academy of Pediatrics Committee on School Health 1981).

The motivation behind the efforts of authorities, scientists and health educators to level out maturity differences in youth sports stems primarily from a desire to provide a safer (i.e. prevention of injuries), and more enjoyable, experience for the children participating in sport in schools or recreationally. Initiatives to prevent maturity biases during times of talent identification have been sparse. This may be because of the hurdles in the implementation, lack of solid proof that maturity biases exist and/or the perceived difficulties in changing beliefs of the individuals involved in the selection process.

2.3 Indicators of physical maturity

A maturity indicator is a definable and sequential change in any part of the body that is characteristic of the progression from immaturity to maturity (Cameron 2002). The most commonly used indicators involve assessment of skeletal age, secondary sex characteristics, menarcheal status, and somatic characteristics.

2.3.1 Skeletal age

Skeletal age assessment, through X-rays, is the only method that spans the entire growth period from birth to adulthood and is considered the gold standard (Malina & Bouchard 1991). The assessment of skeletal maturity is based on the observation that an individual more advanced in maturity will have more advanced bone development and a smaller amount of cartilage than a less mature child. The bones of the hand and wrist are most commonly assessed but other areas of the skeleton have been used (e.g., the knee, foot and ankle). The three most commonly used methods for the assessment of skeletal maturity of the hand and wrist are the Greulich-Pyle method (Greulich & Pyle 1959), the Tanner-Whitehouse Method (Tanner et al. 1975; 1983) and the Fels method (Roche et al. 1988). The methods involve matching a hand-wrist X-ray of a specific child as closely as possible with a set of pictorial or verbal criteria. The criteria correspond to different levels of skeletal maturity at specific ages. For example, if the hand-wrist X-ray of a 12 year old matches the criteria for 13 year old children, the youth's skeletal age is 13 years.

Skeletal assessment, unfortunately, does not lend itself to use outside of the clinical setting. The equipment needed is expensive and the methodology requires experienced technicians and exposure to radiation. Further, discrepancies of one or more years between skeletal ages of the knee and of the hand/wrist have been documented in individual youth (Roche, Wainer, & Thissen 1975). This reflects segmental growth differences and thereby questions whether the skeletal maturity of the hand and wrist represents the maturity of the whole skeleton.

2.3.2 Secondary sex characteristics

Sexual maturation is highly related to the overall process of physiological maturation. Therefore, assessment of sexual maturity is useful in estimating maturity. The most widely accepted assessment scale for secondary sex characteristics is commonly referred to as the "Tanner scale", or the "Tanner staging technique" (Tanner 1962). This technique was first documented by Reynolds and Wines (1948, 1951) and was described in more detail by Tanner (1962). Secondary sex staging technique is most often based on the development of pubic hair, breasts and genitalia, and ranges from immature to fully-developed. Facial hair, axillary hair, body odor, and body shape are other aspects of pubertal change which have been indexed. (Tanner 1962)

Secondary sex staging techniques are popular as they are inexpensive and do not require longitudinal assessment; however, this assessment tool is not without limitations. Secondary sex staging techniques lack precision. For example, an individual in the early phase of stage 3 of pubic hair development is rated the same as an individual in the late phase of this stage. Some boys have been shown to pass from genital stages 2 through 5 in 2 years whereas others have been shown to take up to 5 years to pass through the same stages (Marshall & Tanner 1970). In addition, there is no relationship between the CA at which a secondary sex characteristic begins and the length of time that it takes to pass through the stage (Marshall & Tanner 1969,1970).

A further concern with the use of secondary sex staging relates to possible misuse in alignment of individuals when making comparisons between sexes. Many pediatric studies align boys and girls on a) the same secondary sex characteristics b) on different secondary sex characteristics or c) more than one secondary sex characteristic to develop a composite score of sexual development. The assumption behind these strategies is that the order and timing of the appearance of the same secondary sex characteristic and/or different sex characteristics are identical in both sexes. It further presumes that the sequence of the appearance of secondary sex characteristics between sexes with other maturity indicators is also identical. It has been shown that there is considerable difference in the timing and tempo of somatic and sexual development between sexes during adolescence (Marshall & Tanner 1969, 1970; Sherar et al. 2004). This means that all three of these alignment strategies are inappropriate when making comparisons between boys and girls.

Traditionally, determination of sexual maturity has been obtained through direct visual observation. This approach is appropriate for clinical settings, but poses problems for the assessment of children in a research and/or sporting environment. Many adolescents (and their parents) may feel uncomfortable with the method of assessment and may not give consent. In an attempt to reduce ethical concerns, techniques have been developed based on self-assessment. It has been demonstrated that children and adolescents can rate their own sexual development accurately and reliably, with moderate to high correlations (r=0.59 to r=0.92) between self rating and physician rating of secondary sex characteristics development (Duke, Litt, & Gross 1980; Petersen et al. 1988; Matsudo & Matsudo 1994; Wacharasindhu, Pri-ngam, & Kongchonrak 2002; Williams et al. 2003).

2.3.3 Menarcheal status

Age at menarche (the first menstrual period) is the most commonly reported developmental milestone of female adolescence in both cross sectional and longitudinal studies (Malina 1978). Three methods are commonly used to establish age at menarche. The best and most reliable is to follow individuals and note the date menarche occurs; however, this method is limited to longitudinal studies. Alternatively, normative values can be established by the status quo method. This method involves asking a large number of girls (usually aged between 8 and 18 years) when they were born and whether they have started their menstrual flow. From their CAs and their answers (yes or no) it is possible to calculate mean and standard deviation values for age of menarche. The third method is the recall method. A simple questionnaire is used to establish if an individual has experienced menarche, if the answer is yes, they are asked to indicate the date. The recall method is useful for individuals after 17 years of age, when almost all girls have attained menarche (Beunen & Malina 1988).

Although age at menarche is a widely used maturity indicator in females its use is limited to later adolescence as menarche is a late event in the maturational process (Marshall & Tanner 1969). Most studies, especially in athletes, use the recall method which has the limitation of error in the recall (Malina 1988). Estimated mean ages are biased, since all subjects have not yet reached menarche (Malina 1994). Furthermore, age of menarche has no use in studies that compare males and females as no corresponding maturity indicator exists in males.

2.3.4 Somatic characteristics

2.3.4.1 Age at peak height velocity

The identification of landmarks on the human growth curve can be used for comparisons between individuals or among groups. The most commonly used somatic milestone in longitudinal studies of childhood growth is the age at peak height velocity (PHV). To obtain age at PHV whole year height velocity (cm/year) increments are plotted and mathematical curve fitting procedures are used to identify the age when the maximum velocity in statural growth occurs (Figure 2.1). Individuals can be characterized as early, average or late maturers depending on the age at which PHV is attained. Early maturers are those whose age at PHV occurs one year (or more) before mean age, whilst late matures are those whose age at PHV occurs one year (or more) after the mean age. The remainder are classified as average maturers.

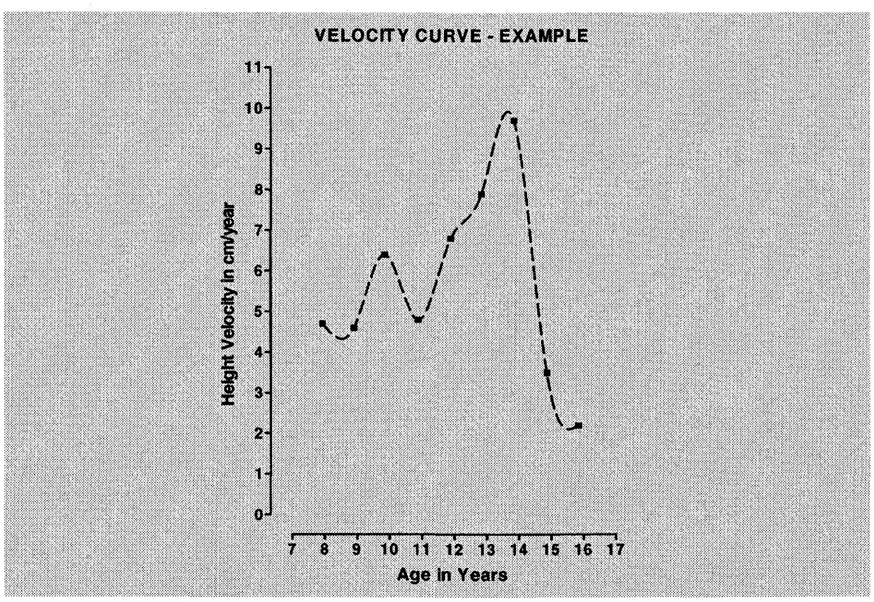

Figure 2.1 Whole year height velocities plotted against chronological age. Peak height velocity determined with a cubic spline fitting procedure. Data taken from the Saskatchewan Pediatric Bone Mineral Accrual Study (Bailey 1997)

2.3.4.2 Predictions based on differential timing of segmental growth

Methods of predicting age at PHV have been developed which do not require complete longitudinal data and are based on segmental growth of the body. During adolescence, leg length generally increases at a greater rate than trunk length in both boys and girls (Malina & Bouchard 1991). The lower extremity growth spurt occurs before the trunk; thus, the ratio of leg length to trunk length increases steadily before PHV, and decreases at and after PHV. If two measurements of sitting height (a measure of trunk length) and leg length are one year apart, a broad categorization of maturity is provided. If the ratio is increasing, the individual is pre PHV, if the ratio is decreasing then the individual is post PHV. A limitation to this method is that it requires at least two measurements, one year apart (Mirwald et al. 2002).

Based on this knowledge of segmental growth, equations have been developed which predict maturity from one time anthropometric measurements (Mirwald et al. 2002). The gender-specific multiple regression equation is composed of CA and three somatic dimensions (height, sitting height and leg length) and is used to predict years from PHV. The equations were calculated on Canadian children aged 8-16 years (79 boys and 73 girls measured from 1991 through 1997) and cross validated on a combined sample of Canadian (71 boys and 40 girls measured from 1964 through 1973) and Flemish children (50 boys and 48 girls measured from 1985 through 1999). The results indicated that maturity status can be estimated within an error of $\pm$ 1.18 years 95% of the time in boys and $\pm$ 1.14 years 95% of the time in girls. It was concluded that the equations were reliable as a non-invasive measure of physical maturity and sufficient for adolescent classification. The authors stated that maturity off-set could be used as a categorical (pre, or post PHV) as well as a continuous assessment.

2.3.4.3 Prediction of maturity from percentage of target height attained

Maturity status can also be predicted if a youth's target, or adult, height is predicted.

2.3.4.3.1 Prediction of target height

Height is a characteristic which is subject to both genetic and environmental influences (Susanne 1975; Mueller 1976). It is known that tall parents, in general, produce tall children and short parents short children (Tanner et al. 1970). In the clinical setting the most popular methods to predict target height are; 1) Bayley and Pinneau method (Bayley & Pinneau 1952), 2) Roche-Wainer-Thissen (RWT) method (Roche et al. 1975) and 3) Tanner-Whitehouse methods (Tanner et al. 1983, 2001) which all include assessment of skeletal age to account for variation in maturity. However, as previously mentioned, assessment of skeletal age is costly and requires exposure to radiation which hinders widespread use of these methods.

A child's target height can be estimated from parental heights with a fair degree of accuracy if the biological parents have had adequate nutrition and no untreated condition that compromises their final height (Tanner 1962). To estimate the child's target height, the mean parental height must first be known. Mean parental height is used because height is a polygenic trait; prediction improves when a combined estimate of parental height is used (Welch 1970; Susanne 1975; Bielicki & Welon 1976; Mueller 1976). Standard deviations of errors of prediction were reduced in males from 6.06 cm using father's heights, to 5.29 cm using mother's heights and 5.08 cm using mid parent height. In girls, the reduction was 5.83 cm to 5.21 cm and 5.17 cm respectively (Welch 1970).

The next step in predicting target height is to adjust the mean heights of the parents to allow for men being, on average, 13 cm taller than women. When estimating the adult height of a boy, the mean parental height is adjusted by adding 13 cm to the mother's height. For a girl, the mean parental height is adjusted by subtracting 13 cm from the father's height. The 95% confidence limits are 8 to 10 cm both above and below the parental height (Tanner 1962).

2.3.4.3.2 Prediction of maturity using target height

Once a predicted target height (based on parental heights) and a present height measurement are available, one can calculate the percentage of target height a child has attained. Children who are closer to their target height compared to children of the same CA are advanced in maturity status (Malina & Beunen 1996). Furthermore, percentage of target height attained can be used to provide a categorical classification of maturity. It has been shown that at PHV boys and girls are at approximately 92% of their adult height (Tanner 1962; Beunen et al. 2000). If an individual is measured at less than 92% of their predicted adult stature then he/she is pre PHV. If an individual is measured at greater than 92% of their predicted adult stature he/she is post PHV.

There are a few limitations to this technique. As for most polygenic characteristics, very short or very tall parents tend to produce less extreme offspring; this phenomenon is known as regression to the mean (Galton 1886). Thus mid-parental height is most useful for assessing children with heights within the normal range. In addition, the relationship between attained height and midparent height is greater in girls than in boys (Welon & Bielicki 1971; Bielicki & Welon 1976; Byard, Siervogel, & Roche 1988). Predictions of target height also have an associated error which is usually within the range of 3 to 5 cm (Malina, Bouchard, & Bar-Or 2004). Despite the aforementioned limitations, this method of predicting maturity is non-invasive, cheap, sex specific, easy to administer and does not require longitudinal data.

2.3.5 Interrelationships among maturity indicators

Both sexes demonstrate much variation in the development of sexual and somatic characteristics during adolescence. They are, nevertheless, related. The correlations between the indicators are generally moderate to high, but tend to be lower for boys than for girls. A correlation coefficient between skeletal age and age at

PHV has been shown to be 0.83 (Mirwald et al. 2002). The direction and strength of this relationship indicates a commonality between these two methods. Skeletal maturity is also related to the development of secondary sex characteristics. This association is clearly evident in the reduced variation in skeletal age at menarche (Malina 1988). Although a general maturity factor underlies the tempo of growth and maturation during adolescence in both sexes, there is sufficient variation to suggest that no single system (i.e. sexual, skeletal, or somatic) provides a complete description of the tempo of maturation during adolescence (Malina 1988). The apparent discord among the aforementioned indicators probably reflects individual variation in the timing and tempo of sexual and somatic maturity, and the methodological concerns that have been previously outlined; however, late and early maturing individuals tend to be categorized as late and early maturing no matter which maturity indicator is used.

2.4 Maturity status and somatic growth

2.4.1 Stature

Standing stature is a linear measurement of the distance from the floor, or standing surface, to the top of the skull (Malina & Beunen 1996). Growth in standing stature will on average cease at about 17.5 years in girls and 20 years in boys (Roche & Davila 1972). Peak height velocity refers to the maximum rate of growth during the adolescent period and occurs, on average, at 12 and 14 years of age in girls and boys, respectively (Beunen & Malina 1988; Malina & Bouchard 1991). Significant differences have been observed between the mean stature of boys of the same CA, but different skeletal ages during adolescence (Buyukgebiz et al. 1994); this implies that there is a closer association between skeletal age and stature than CA and stature. Adolescents with an early PHV are temporarily taller than adolescents with a late PHV (Frisch & Revelle 1969, 1971; Lindgren 1978; Yoneyama, Nagata & Sakamoto 1988).

There is an interest in whether early maturing youths, with their concomitant height advantage, will remain taller than their average and late maturing peers when adults. The research exploring the relationship between maturity status and final height show discrepant findings. Some studies have shown that early PHV (Tanner, Whitehouse, & Takaishi 1966a, 1966b; Quin, Shohoji, & Sumiya 1996) and onset of menses (Kaur & Singh 1994; Wellens et al. 2003) are associated with a larger magnitude of peak height gain, and thus an increased final stature. Conversely, some investigations indicate no relationship between adult height and the timing of PHV (Frisch & Revelle 1969; Onat & Ertem 1974; Lindgren 1978; Tanner 1989; Bielicki & Hauspie 1994; Gasser et al. 2001; Koziel 2001), time of menarche (Tanner 1962; Tanner, Whitehouse, & Takaishi 1966a; Frisch & Revelle 1969; Lindgren 1978) and appearance of secondary sex characteristics (Onat 1975).

Within the literature supporting the argument that maturity status has no influence on final height, there appears to be disagreement surrounding the CA at which the height differences between maturity groups disappear. Investigations have shown that late maturing girls catch up by 14 years of age (Lindgren 1978; Yoneyama, Nagata, & Sakamoto 1988), 18 years of age (Frisch & Revelle 1969) and 22 years of age (Roche 1989; Hagg & Taranger 1991). Late maturing boys have been shown to catch up at 17 years of age (Lindgren 1978), 18 years of age (Frisch & Revelle 1969) and 24 years of age (Roche, 1989; Hagg & Taranger 1991).

In contrast to the body of literature in this area, Hagg and Taranger (Hagg & Taranger 1991) found that, from 18 years onwards, late maturing boys were taller than average and early maturing boys, and that average maturing boys were taller than the early maturing boys (assessed through years from PHV). They suggested that other research failed to find a difference in adult height because they did not measure over the whole growth period of the late maturing individual (22 years of age in females and

24 years of age in males). Although discrepancies in the literature remain, the consensus supports the notion that the genetic control of the tempo of maturation is independent of the genetic control of final stature (Koziel 2001). Thus, the height advantage of the early maturer disappears by adulthood.

2.4.2 Total body mass

Maximum growth in body mass during adolescence (i.e. peak mass velocity) generally occurs after PHV. It has been demonstrated that early maturers are heavier than late maturers during adolescence (Lindgren 1978; Hauspie 2002). This evidence is further enhanced by a closer association between bone age and body mass than CA and body mass (Buyukgebiz et al. 1994). However, it has been shown that, upon reaching adulthood, the differences in body mass between early, average and late maturing boys and girls disappears (Frisch & Revelle 1970; Lindgren 1978; Zacharias & Rand 1986).

2.4.3 Body Composition

Changes in body composition occur in conjunction with growth in body size and shape. Female's percent body fat increases from age 8-20 years, with the velocity reaching a minimum about 15 years of age. Percentage body fat of males increases from age 8-12 years, and then decreases until about 18 years of age (Guo et al. 1997). On average, females have significantly more body fat than males during adolescence. This is primarily due to a greater production of estrogen in females (Forbes 1987). Fat free mass (FFM) increases with CA in both sexes throughout adolescence. However, the increase for females tends to slow down during adolescence, whereas in males there is a continual rapid increase into young adulthood (Guo et al. 1997).

In both sexes the average age at which the velocity in growth of lean mass and fat mass peak occurs is earliest in early maturers, later in average maturers youths and latest in late maturers (Iulliano-Burns, Mirwald, & Bailey 2001). This means that, on average during adolescence, the more mature child in a given CA group has larger measurements of muscle and fat than the less mature child (Tanner 1962; Johnston & Malina 1966; Roche, Wainer, & Thissen 1975; Forbes 1987). Data from the Fels Longitudinal study (1948-1987) (Wellens et al. 2003) demonstrated that late maturity in females, defined by age of menarche, was significantly related to thinner triceps skinfolds (i.e. subcutaneous fatness). In support, a cross sectional study (Johnston & Malina 1966) of radiographs of the upper arm of 182 males and 181 females demonstrated that early maturers (determined by skeletal age assessment) had greater fat breadths than average or late maturers. They also had greater absolute muscle breadths. Late maturers were shown to have greater relative muscle mass.

The larger FFM of boys advanced in maturity status is in part a function of their larger body size. When FFM is expressed per unit stature, the differences between maturity groups are reduced but not eliminated (Haschke 1983). Thus boys advanced in maturity within a CA group tend to have more FFM per unit body size than those who mature later. Maturity associated differences in body composition tend to be more marked as sexual maturation progresses (Haschke 1983).

In contrast to FFM in males, percent body fat has been shown to decline gradually with sexual maturity (shown through genital development). This decline is a function of the increase in FFM that accompanies sexual maturity in boys. Unfortunately, corresponding data is not available for females. It has, however, been suggested that the trends are similar to those of boys, with the exception that within each CA group, girls more advanced in maturity are absolutely and relatively fatter than less mature girls (Malina, Bouchard, & Bar-Or 2004).

Whether maturity associated variation in body composition during childhood and adolescence persists into adulthood is a controversial issue. Among male and female participants in the study of growth and health of teenagers in Amsterdam (van Lenthe, Kemper & Van Mechelen 1996), those classified as early maturing during adolescence (assessed through skeletal age, age at menarche, age at PHV) had more subcutaneous fatness (assessed through sum of four skinfolds) and an elevated body mass index compared with those classified as late maturing. This was the case not only during adolescence but also at 21 and 27 years. However, a different study (Beunen et al. 1994) which followed males from 13 to 18 years of age, and observed them again at 30 years of age, demonstrated that the majority of somatic (stature, mass, skeletal lengths and breadths, muscularity) differences among boys of contrasting maturity groups during adolescence, were not evident at 30 years of age.

In summary, at any given CA during adolescence, early maturing boys and girls are on average taller, heavier, have greater FFM (especially in boys), total body fat, and percent body fat (especially in girls) than their less mature peers. Some of these attributes may be considered favorable by talent evaluators in youth hockey. Although, not definitively evidence supports the notion that the physical differences between maturity groups disappear by adulthood. Therefore, the potential physique advantages of the early maturing adolescent hockey player will not be present when the individual reaches adulthood.

2.5 Maturity status and physical capabilities

To be able to hypothesize why early maturity may be an asset to hockey performance, it is necessary to investigate the adolescent changes that occur in strength, endurance (aerobic capacity) and speed (anaerobic power) alongside maturity.

2.5.1 Strength

Strength increases during adolescence are associated with the natural development in lean mass, and generally reaches a peak at the same time as PHV in girls and a year after PHV in boys (Sharp 1991). Muscular strength increases from early childhood through approximately 13 or 14 years of age in boys. This is followed by a marked acceleration late in adolescence. Girls' strength improves linearly with CA through about 15 years of age, with no clear evidence of an adolescent spurt. (Beunen & Malina 1988) So it is usually between 13 and 16 years of age that boys begin to demonstrate a superiority of strength over girls (Goldberg & Boiardo 1984).

As early as 1946, Jones reported a significant difference in static strength between early and late maturing adolescent males. In keeping with these early findings, Kreipe and Gewanter (1985) noted that immature and mature males (assessed through testicular volume and pubic hair) could be accurately differentiated by grip strength alone. In agreement, Backous and colleagues (Backous, Farrow, & Friedl 1990) demonstrated that a combination of height and average grip strength accurately predicts physician-assessed stage of pubic hair growth and genital development in males. Sexual maturity stage has also been demonstrated to be better correlated with lower extremity strength than CA in males (Pratt 1989). Early maturing girls tend to be slightly stronger than late maturing girls early in adolescence (11 through 13 years of age), but as adolescence continues the difference between maturity groups disappears (Jones 1949).

During adolescence, the majority of the strength advantages of early maturing boys, and all of the strength advantages of early maturing girls, are due to their larger body size. A study into the longitudinal development of strength in adolescent boys and girls showed that at PHV boys became stronger in the quadriceps and biceps in relation to body size (Nevill et al. 1998). However, at PHV girls' strength in their quadriceps developed in relation to their body size, and in the biceps became weaker in relation to their body size.

2.5.2 Aerobic power

Aerobic power reflects the ability to produce aerobic energy at a high rate and is usually indexed by measuring maximal oxygen intake (VO_{2max}). Absolute maximal oxygen uptake increases with CA (Godfrey 1974). As with other aspects of physical fitness, differences between sexes are minimal until the onset of adolescence, at which point boys begin a disproportional increase in absolute aerobic power and girls level off. The cause of the difference between sexes is probably a combination of physiological and cultural factors (Goldberg & Boiardo 1984).

It has been shown that early maturing individuals, when compared to late maturing individuals of the same CA, have a higher absolute VO_{2max}. However, the differences are reduced in males and disappear in females when VO_{2max} is expressed per unit body mass (ml/min/kg) (Bouchard et al. 1976; Kemper & Verschuur 1981; Kemper, Verschuur, & Ritmeester 1985; Armstrong et al. 1999; Reilly, Bangsbo, & Franks 2000). Although the size advantage of the early maturing individual is reflected in a greater VO_{2max}, functional or metabolic differences may exist between individuals of contrasting maturity status. Recent studies (Baxter-Jones, Goldstein, & Helms 1993; Armstrong & Welsman 1994; Armstrong, Welsman, & Kirby 1998), which statistically controlled for the effects of body size, demonstrate a maturity affect on VO_{2max} independent of body size. This difference in VO_{2max} between contrasting maturity groups is, however, more pronounced in males than in females which may be due to males developing greater muscle mass, red blood cells, hemoglobin, lung capacity, pulmonary ventilation, and oxygen uptake than females during adolescence (Malina et al. 1997). When both early and late maturers are fully grown, and have achieved the same stature, the differences in VO_{2max} disappears (Kemper, Verschuur, & Ritmeester 1985).

2.5.3 Anaerobic Power

Anaerobic power refers to the delivery of energy for physical activity at a high rate, without oxygen, for a limited period of time. Peak power is highly correlated with body size. Mass-related peak power continues to increase throughout a boy's childhood and adolescence, with a more linear pattern of progression than observed for absolute measures (Mercier et al. 1992). A boy's mass related peak power increases until the mid teen years. Girl's mass related mean power suggests a similar pattern of increase but data is too sparse to draw firm conclusions. Mass related peak power is consistently higher in boys than girls at all ages (Saavedra et al. 1991).

The influence of maturity on development of anaerobic fitness has been discussed since 1971 when Eriksson and colleagues (Eriksson, Karlsson, & Saltin 1971) reported a moderate correlation between maximal muscle lactate and testicular volume in 13-year old boys. This suggested an effect of testosterone on maximal lactate production. Investigations since this date have used skeletal age (Falk & Bar-Or 1993), and secondary sex characteristics (Nindl et al. 1995) to define subject groups but few investigations have examined anaerobic performance in relation to a broad range of maturity ages. Maturation (assessed through pubic hair development) and anaerobic performance (assessed through a Wingate test) was assessed in 100 boys and 100 girls (aged 12.2 ± 0.4 years) (Armstrong, Welsman, & Kirby 1997). The stage of pubic hair development was shown to have a significant relationship with peak power and mean power, independent of body mass. These findings concur with the observation of a marked increase in peak power at PHV (Mercier et al. 1992). Significant correlations have also been found between mass-related peak power and testosterone levels (r=0.45) and mean power and testosterone levels (r=0.47) (Falgairette et al. 1993). Furthermore, the peak anaerobic power of 36 boys measured over an 18 month period indicated an acceleration of peak mass related anerobic power between pubic hair stages 3 and 5 (Falk & Bar-Or 1993). The limited data available on maturity associated variations in anaerobic performance suggests that early maturing adolescents have greater anaerobic power than those who are late maturing. It should, however, be noted that this area requires further investigation.

2.6 Hockey

Hockey is a one-on-one sport which requires agility, stick handling, passing, shooting at speeds over 90 miles per hour, and interaction with team players. Other on-ice activities include body checking, absorbing hits by opponents, and crashing into the boards, posts and ice. Today's game centers on speed, size, strength and high skill levels (Horrigan & Kreis 2002). The belief that early identification of talent leads to improved performance has resulted in formal talent identification beginning in childhood and early adolescence. Talent identification in youth hockey is based solely on performance in CA-groupings. Although adolescent hockey players are selected for skill, size and physical characteristics are important attributes that talent evaluators look for.

2.6.1 Talent evaluation in youth hockey

Physical capabilities are a major determinant of team placement in junior hockey (Daniel & Janssen 1987). As well as good stick handling and puck control, talent evaluators look for physical attributes, such as overall size, strength, anaerobic and aerobic power (Twist 1997). Physical attributes are especially valuable during the adolescent years because players haven't fully developed an understanding for the game and thus rely heavily on physical prowess. The physical size of hockey players also becomes more important at higher levels of competition (Brown 2001). Dan Brennan, the coordinator of coach and player skill development for the United States of America, confirms the importance of physical size in times of talent identification;

> *The 6 feet 2 inches, 210 lbs player will get a much better look than the one who is 5 feet 10 inches and 185 lbs. The smaller player may be faster and carry the puck better, but the pro's are looking down the road. They will evaluate a player as being okay at a developmental level of the game, but they would rather have the bigger guy because he will be able to handle the rough going.* (Brown 2001)

Karen Kay, women's hockey coach at The University of New Hampshire, suggests that body size is an important attribute in female as well as male hockey;

> *Some coaches do not think that size matters in female hockey because there is no full checking. I think because of the way that sport is developing, size is a factor. The higher you go the more important it is. If you play in a small rink size is really important. If you play on a large rink speed is as important as size…given the choice between two players of equal ability, I would take the one who is bigger.* (Brown 2001)

Strength and anaerobic power is an absolutely essential requirement in hockey players. Hockey requires absolute strength (total muscular strength) as players must have mass and power to move others and withstand contact. Upper body strength contributes to shooting and puck control, as well as fending off opponents, whilst strength through the chest, shoulders and arms, and back is important for body checking, clearing the shot, or containing an opponent against the boards. Successful body checking also relies on strong legs as weight shifts upward during a body check (75% of the power coming from the legs) (Twist 1997). Leg strength assists such skills as acceleration, cornering, stopping, and starting, pivoting, shooting and dynamic balance. Relative strength (strength in relation to body weight) fosters quickness, agility and skating speed (Twist 1997). Tom Rennie, the former head coach of Canada Men's Hockey team, confirms the importance of skating speed at try-outs: *"Speed seems to be what catches your eye initially. You catch yourself thinking that if you can get your* *hands on an athlete with speed, you can fix the rest".* (Brown 2001) Good anaerobic power allows athletes to react to situations and explode into action by exercising maximum effort over short distances. Good anaerobic power is advantageous as it aids endurance for repetitive strides and helps players to recover quickly between shifts. (Twist 1997)

In summary, during adolescence boys and girls progressively become stronger, have greater absolute aerobic and anaerobic capacity and the maturity variation in these parameters is more apparent in boys than girls. Upon reaching adulthood, the differences in physical capabilities between maturity groups disappear (i.e. the late maturers catch up). Good strength, anaerobic capacity and aerobic capacity are a prerequisite for success in hockey, and are some of the important qualities for which talent evaluators are searching (Brown 1991). Therefore, one may speculate from these findings that, at any given CA during adolescence, an early maturing hockey player may possess performance enhancing physical traits that provide an advantage during times of talent identification.

In support of this speculation, many elite youth athletes participating in sports requiring size, strength, and power have demonstrated advanced maturity for their CA (Shaffer 1973; Caine & Broekhoff 1987). As early as 1955, it was shown that boys who participated in the little league world series for baseball were more mature (determined through assessment of sexual maturity) than indicated by their CA (Hale 1956). This suggests that early maturity was a significant factor in the selection of these players. Since this study, many young male athletes in baseball, basketball, cycling, football, rowing, swimming, and track have also demonstrated, on average, advanced skeletal maturation, development of secondary sex characteristics, or both (Malina, Meleski, & Shoup 1982). The literature available on the maturity status of female athletes concentrates on individual sports such as gymnastics, tennis and swimming. Youths successful in these sports are, on average, late maturers (Baxter-Jones et al. 1994). The majority of the literature reporting the anthropometric characteristics and maturity status of hockey players has focused exclusively on males.

2.6.2 Anthropometric characteristics of hockey players

There is sparse literature documenting the anthropometric characteristics of adolescent hockey players. The literature which exists does not suggest that successful hockey players are taller and heavier than average. Body mass differences of 53 kg and stature difference of 55 cm were reported amongst male Bantam age (13 and 14 year olds) players (Brust et al. 1992). Young male hockey player's (10 years of age) stature and body mass were shown to be within the normal limits (Cunningham, Telford, & Swart 1976). This observation appears to exist into adulthood. Likewise, no differences were found between stature and body mass of Major Junior A hockey players (aged 16-20 years) and University hockey players (aged 18-23 years) (Houston & Green 1976). Differences were found, however, in both teams between defensemen and forwards; with defensemen being taller and heavier. This has also been observed within National Hockey League (NHL) teams (Agre et al. 2003).

2.6.3 Maturity status of hockey players

The literature to date does not show hockey players to be predominantly of an early maturity status. However, within a group of 12-year old boys participating in a hockey tournament the boys advanced in skeletal age were taller and heavier than those boys of average skeletal maturity (Malina, Meleski, & Shoup 1982). In two samples of hockey players under 13 years of age, skeletal age was on average slightly younger relative to CA (Cunningham, Telford, & Swart 1976; Kotulan, Reznickova, & Placheta 1980) and the slight difference in one of the samples persisted from 12 through 15 years of age (Kotulan, Reznickova, & Placheta 1980). Cross sectional data on hockey players (9 years of age) from Finland indicated no differences between skeletal ages and CA's (Rahkila et al. 1988).Cconversely, longitudinal data for 16 select hockey players from Czechoslovakia, indicated that skeletal ages were behind corresponding CA's by about 0.5 years between 12-15 years of age (Kotulan, Reznickova, & Placheta 1980). Within a cross sectional sample of Canadian youths (10-16 years of age), individuals 10, 11 and 12 years of age, had skeletal ages that were behind corresponding CA's by an average of 1.7 and 1.3 years (Lariviere & LaFond 1986). Among 12-year-old international tournament participants (Malina, Meleski, & Shoup 1982), boys classified as average (43%) and delayed (37%) were represented almost equally, while those classified as advanced represented a small percentage (14%). However, the majority of 13-14, and 15-16, year old elite players were advanced in skeletal maturity, 82% and 62% respectively (Lariviere & LaFond 1986).

A variation in skeletal maturity (and corresponding body size) by position among 12 year old hockey players has been shown. Tournament participants (n=205), (mostly defensemen), were at least average or advanced in skeletal age, whilst most forwards and goal keepers were classified as average or late in skeletal age. Only 11 % of the forwards and 8% of the goalkeepers were classified as advanced. In comparison only 15% of the defensemen were late in skeletal age relative to CA (Malina & Bouchard 1991).

In summary, the anthropometric characteristics and maturity status of male hockey players is not consistent among studies. There is insufficient literature concerning female hockey players from which to draw any conclusions. In addition to maturity, there is a further confounding effect of date of birth within the selection year on eligibility for competitions and teams that are based on CA groupings.

2.7 Relative age effect

It has been suggested that CA-grouped youth competition not only gives an advantage to the early maturer but also to individuals with birthdays earliest in the selection year. The difference of CA between individuals in the same CA group is referred to as the relative age. For example, in a group of 14 year olds, the youngest player could be 14.0 years and the oldest 14.99 years. The consequence of the relative age is known as the relative age effect (RAE) (Musch & Grondin 2001).

In the 1980's, Barnsley and colleagues (Barnsley, Thompson, & Barnsley 1985) discussed a possible relationship between relative age and participation in sport that mirrors the relationship between relative age and scholastic achievement. Since their work, a number of studies have demonstrated that many CA structured sports are likely to have more participants whose birthdays are early in the selection year than late in the selection year. Such sports include tennis (Dudink 1994), swimming , cricket (Edwards 1994), soccer (Verhulst 1992; Baxter-Jones & Helms 1994; Brewer, Balsom, & Davis 1995; Musch & Hay 1999), baseball (Thompson, Barnsley, & Stebelsky 1991; Grondin & Koren 2000), football (Glamser 1992) and hockey (Barnsley, Thompson, & Barnsley 1985).

2.7.1 Proposed causes of relative age effect in sports

Climate influences have been offered as a cause of RAE (Sharp, Hutchinson, & Whetton 1994). For example, if warm weather during important phases of motor learning and out-door activities promotes critical sport-related skills, children born in certain months of the year could profit from the fact that their critical sensitive phases occur during summer months rather than winter months (Musch and Grondin 2001). Seasonal influences, however, have frequently been refuted as a cause of RAE in sports. International comparisons reveal that the birth months which appear to give advantage vary to reflect different selection years (Musch & Hay 1999). Furthermore, for some sports such as hockey, the selection year starts in January and ends in December. January and December are similar climatically but are at opposing ends of the selection year. This suggests that the cut off date rather than some seasonal influence is related to the RAE. A unique study (Helsen, Starkes, & Winckel 2000) provides strong evidence to further disprove climatic influences as a satisfactory explanation for RAE in sports. Since 1997, following the guidelines of the International Football (soccer) Association (FIFA), the Belgian Soccer Federation adopted January 1 as the start of the selection year rather than August 1. When the players of the national youth leagues birth dates for 1996 -1997 were compared with fresh birth date distributions for the 1997-1998 season a dramatic shift was seen; players born from January to March (the early part of the new selection year) were more likely to be identified as talented. These findings, again, suggest the cut-off date, rather than climatic or seasonal influences, as the cause of uneven birth date distribution.

A 1-2 year CA difference can cause a big variation in the stature and body mass of young children in youth sports programs. Due to this, several authors attribute RAE to the physical advantages of the relatively older players (Barnsley, Thompson, & Legault 1992; Baxter-Jones & Helms 1994; Brewer, Balsom, & Davis 1995). These developmental advantages could have a direct impact on perceived athletic potential and predicted sport success (Barnsley, Thompson, & Legault 1992). Research by Brewer (1995) showed that Swedish national soccer players were more likely to have birthdays early in the selection year. These players were further shown to be taller and heavier than average, which suggests above average physical maturity for their CA. The authors thus attributed RAE to the selection opportunities which favored the older and physically bigger children. Furthermore, fast bowlers birthdays are likely to be early in the selection year whereas spin bowlers birthdays are evenly distributed across the whole selection year (Edwards 1994). "Fast bowlers", in cricket, rely heavily on their strength and size whereas spin bowlers rely more on technique and less on physical attributes. The author stated that cognitive development is the same across all of the players; therefore the results must be due to an advanced physical maturity. However, all of the groups were found to be taller than average, implying that the RAE observed in the fast bowlers cannot be due to height alone. Although at present the most plausible explanation for RAE in sports is the greater physical maturity of relatively older players, no research has assessed maturity, anthropometric characteristics and CA in elite sports players to substantiate the suggestion of physical maturity.

2.7.2 Relative age effect and hockey

In the Canadian Amateur Hockey leagues, children born in January play in the same age category as their peers born in December of the same year. Some hockey associations use 24-month CA groupings, which mean that a difference of up to two chronological years is possible among hockey players of the same CA group and on the same teams (Boucher & Mutimer 1994). Barnsley and colleagues (Barnsley, Thompson, & Barnsley 1985) demonstrated a strong linear relationship between month of birth (January to December) and the proportion of players in two of Canada's junior 'A' development leagues. Across both leagues, approximately four times more players had birthdays in the first quarter of the 'hockey year' than in the last quarter. High correlations between birth date and success have been observed both in minor hockey players and a sample of NHL players ($r=0.96$, $p<0.01$ and $r=0.98$, $p<0.01$; respectively) (Boucher and Halliwell 1991). This confirms that the effect of CA on hockey success does not decrease as children get older.

In order to better understand how relative age and success in hockey is related, Barnsley and Thompson (Barnsley & Thompson 1988) analyzed the birth dates of 7, 313 players in the Edmonton Minor Hockey League. Children defined as having a relative age advantage (born between January and June) were more likely to participate in minor hockey and to play for top teams, while players born July through December were observed to drop out at a greater rate than those who possessed a relative age advantage. This might well explain why there is such a RAE at older ages. A second finding of the study was that teams chosen for more intensive training and competition largely reflected players who had greater physical development (e.g. stature, body mass, strength, coordination, etc.).

All of the information presented so far assumes that growth and maturation during adolescence affects sporting performance and success in sport. It has, however, been suggested that training for a sport affects the growth and maturation of the youth athlete (De Ridder 1957; Warren 1980; Frisch et al. 1981; Chen 1991).

2.8 Does participation in sports affect growth and maturation of the adolescent?

Regular physical activity has been suggested to have a stimulatory or an accelerating influence on growth and sexual maturation (Cacciari et al. 1989; Chen 1991). Others are concerned that training for sport has a negative influence on the growth and sexual maturation of the child athlete (De Ridder 1957; Warren 1980; Frisch et al. 1981). To date, the research surrounding this issue has been preoccupied with female athletes participating in individual sports (e.g. gymnastics, tennis, ballet, swimming), while research on male and female athletes participating in team sports (e.g. hockey) is limited. However, regardless of the sport the question remains the same: Does rigorous physical training affect the growth and maturation of the adolescent athlete?

Age at PHV and magnitude of PHV have repeatedly been shown not to be affected by regular physical activity or training (Kobayashi et al. 1978; Mirwald et al. 1981; Beunen et al. 1992). These observations are based primarily on male athletes as longitudinal investigations of female athletes are limited. Serial observations of the skeletal maturation of the hand and wrist demonstrated that skeletal development is not affected by regular physical training (Kotulan, Reznickova, & Placheta 1980; Beunen et al. 1992). Data on sexual maturation of either girls or boys undergoing regular physical training are sparse. They consist of mainly retrospective observation comparing the mean ages of menarche in trained individuals with the general population. The inference based on these observations is that physical training delays menarche with athletes from a variety of sports attaining menarche, on average, later than non-athletes (Malina 1983; Malina & Bouchard 1991); however, mothers of ballet dancers have been shown to attain menarche later than non-dancer controls (Brooks-Gunn & Warren 1988) and sisters of university swimmers have been shown to achieve menarche at an older CA than average (Stager & Hatler 1988). Therefore, it may be a familial tendency for later maturation in athletes rather than physical training that affects menarche.

The majority of the literature suggesting that physical training alters maturity is cross-sectional. Thus, the results cannot be considered causal. Only when a child is repeatedly measured from childhood through adolescence can the independent effects of training and normal growth be identified (Baxter-Jones & Maffulli 2002). Longitudinal studies in this area suggest that young athletes, on average, grow and mature in a similar manner to non-athletes. There is (as previously mentioned) variation in size, physique, body composition and maturity status associated with different sports. Part of the variation in size, physique and body composition is due to variation in maturity status. It may be that late maturation is a contributing factor in the youth's decision to take up a sport rather than the training causing the lateness. Likewise, the size advantage of the early maturing youngster may be a factor directing him or her towards sports such as basketball and football.

Growth at adolescence depends on genetic potential, nutritional status and hormone action. Energy expenditure may modify the effects of any of these three factors on linear growth rate and relative proportions of fat-free and fat mass. The growth and maturation of athletes in weight controlled sports have the additional burden of energy output being greater than intake; however, in only a minority is the energy deficit great enough to slow growth and maturation. (Roemmich, Richmond, & Rogol 2001) So if elite or successful hockey players demonstrate advanced maturity, one can conclude with reasonable confidence that they have been preferentially selected (whether by self, parents or talent evaluators) into the sport because of their advanced maturity status, and not because hockey training has altered their maturity.

2.9 Statement of problem

During adolescence there are big differences in the maturity of individuals of the same CA. This could mean that an adolescent hockey player could be perceived as more talented simply because of an advanced physical maturity. It has been repeatedly shown that successful youth and adult athletes are more often born early in the selection year. Researchers (Brewer et al. 1992; Verhulst 1992; Baxter-Jones & Helms 1994) have attributed this relative age effect solely to the physical advantages of the relatively older players. However, little research has investigated the relationship of sporting success, anthropometric properties and maturity status of an adolescent athlete to substantiate the suggestion of physical maturity. There is also a possibility of a combined effect of CA and maturational status on success in sports. That is, a relative age disadvantage, coupled with late maturation, could make it virtually impossible for young players to be selected.

Considering the popularity of the sport, the young CA at which boys and girls start participating, the physical demands, and the strict CA structure, surprisingly little research has specifically investigated the anthropometric and maturity status of elite adolescent hockey players. Limited research is available on the anthropometric characteristics of female hockey players and no research is available on maturity of female hockey players.

This investigation is unique because:

1. No previous research has investigated talent identification as a possible cause of an over-representation of chronologically older or more physically mature youths playing elite sports.
2. No previous literature has observed the relationship between success, anthropometric characteristics and maturity status on female hockey players and the literature on male players is sparse.
3. No previous literature has looked at the interaction between maturational status, CA, and success in hockey.

The purpose of this investigation is to describe the relationship between maturity status, chronological age and talent identification in hockey.

2.10 Hypotheses

This investigation tested the following hypotheses, in both males and females:

H1: Hockey players who are taller and heavier will be more likely selected than the shorter and lighter hockey players.

H2: Hockey players who mature earlier will be more likely selected than hockey players who mature later.

H3: There will be an uneven birth distribution among the hockey players who are selected, with more participants being born early in the selection year.

3 METHODS AND PROCEDURES

3.1 Subjects

Subjects were boys and girls who participated in the Saskatchewan Hockey Association Provincial try-outs, which is comprised of eight identification camps (zones) located around Saskatchewan. Try-out #1 for boys (February 27th-29th, 2004) and Try-out #1 for girls (January 16th-18th, 2004) was open to any youth of the appropriate age in the province. The selection year ran from January 1 to December 31. The boys were all born in 1989 (second year bantam players), and thus were 14 or 15 years of age at the time of testing. The girls were either born in 1987, 1988, 1989 or 1990 and thus were either 12, 13 14, 15 or 16 years of age (bantam, and first year midget players) at the time of testing. There were a total of 619 boys and 385 girls that took part in Try-out #1.

Ethical approval (see Appendix A) was received from the University of Saskatchewan Behavioural Research Ethics Board (BSC# 03-1128) to complete testing on the hockey players. Consent forms (see appendix B and C) were mailed to all the youths and their parents prior to the selection weekends. The children and/or parents returned the consent form at Try-out #1 prior to being tested.

From Try-out #1, 20 girls and 20 boys were selected from each zone, to make a total of 160 to participate in Try-out #2. From Try–out #2, 40 boys and 34 girls were finally selected. The talent identification model adopted is depicted in Figure 3.1 for boys and in Figure 3.2 for girls.

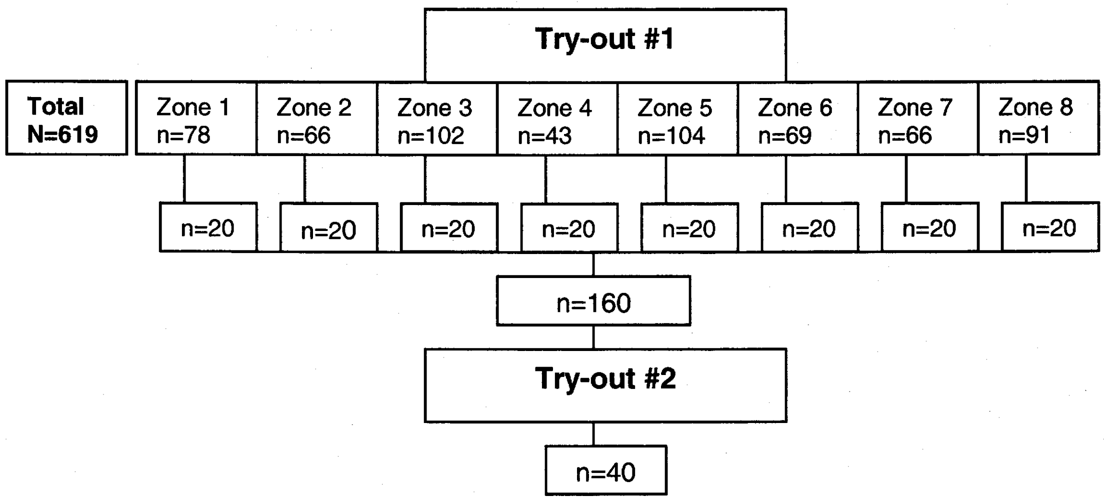

Figure 3.1 Talent identification model adopted for male hockey players

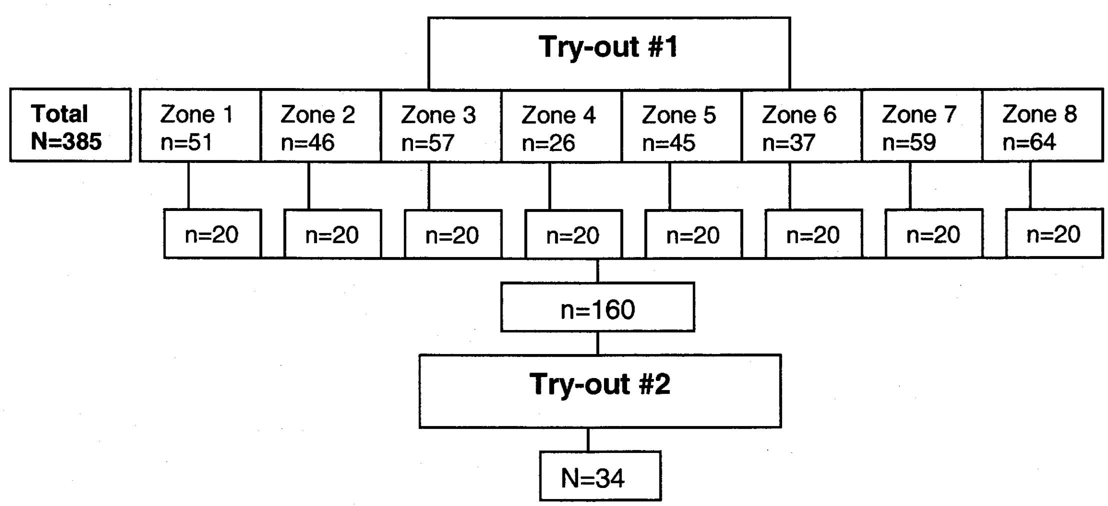

Figure 3.2 Talent identification model adopted for female hockey players

3.2 Participants

3.2.1 Hockey players

Measurements were taken on 139 of the girls and on 281 of the boys who attended Try-out #1. Birth dates were available on all participants.

The participants were grouped (1-3) according to their success (i.e. if they were selected or not) at the try-outs.

Group 1= Not selected at Try-out #1

Group 2 = Selected at Try-out #1 and not selected at Try-out #2

Group 3 = Selected at Try-out #2

3.2.2 Controls

The controls were part of the Saskatchewan Pediatric Bone Mineral Accrual Study (1991-1997) (SPBMAS) (Bailey 1997). The study utilized a mixed longitudinal design and incorporated eight age cohorts. The cohorts were aged between eight and 15 years at study entry (1991). During the six years of data collection the composition of these clusters remained the same. Of the 375 eligible students attending two elementary schools in middle-class neighbourhoods in Saskatoon, Saskatchewan, Canada the parents of 228 students (113 boys and 123 girls) provided written consent for their child to be involved in this longitudinal study. For the current investigation, data from 93 boys and 119 girls was used and ages were matched as closely as possible with the hockey players. The Saskatchewan Bone Mineral Accrual study received approval from the University and Hospital Advisory Committee on Ethics in Human Experimentation.

3.3 Chronological age (CA)

Participants' CA (years) was determined precisely to the decimal age value. Decimal age was calculated from date of birth and from the testing date (years + (days/365.25).

3.4 Anthropometric assessment

Two measurements were taken for standing stature, sitting stature and body mass. A third measure was required if the first two measurements differed by more than 4mm for standing stature and sitting stature and 0.4kg for body mass (Mirwald 1978; Bailey 1997). The average of the two closest readings was taken as the criterion measure (Ross & Marfell-Jones 1991). For individual measurements, standing stature was measured first, followed by sitting stature and then body mass. The cycle was then repeated. All researchers were trained by a Professional Fitness Lifestyle Consultant at the University of Saskatchewan, College of Kinesiology to ensure accuracy of data collection. The hockey players were assessed on one occasion at Try-out #1 (see Appendix D for form). The control group was assessed every six months, once in the spring and once in the fall, for six years.

3.4.1 Stretch stature

The participants' (both hockey players and control participants) standing stature was established without footwear using a stadiometer (Tanita). Stature was taken as the maximum distance from the floor to the vertex of the head. Technically the vertex is taken at the highest point on the skull when the head is held in the Frankfort plane. The measurer had the barefoot subject stand erect with the heels together and arms hanging naturally by the sides. The heels, buttocks, upper part of the back and back of the head were in contact with the back of the stadiometer. The subject was instructed to look straight ahead and to take a deep breath. The measurer ensured that the subject's heels were not elevated and then applied stretch force by cupping the subject's head and gently applying traction alongside the mastoid processes as the subject exhaled. The intervertebral disks become compressed throughout the ambulatory day as result of weight bearing, so traction was performed in an attempt to decompress the vertebral disks to attain a true stature measurement. The measurer brought the headpiece down and in contact with the vertex. The subject moved away from the wall and the measurement was recorded in centimeters (cm) to the nearest millimeter (mm). (Ross & Marfell-Jones 1991)

3.4.2 Stretch sitting stature

Stretch sitting stature was established using a sitting stadiometer (Karrimeter, Raven Equipment Ltd.). The subject sat on an elevated surface and the measurement was taken as the distance from the vertex to the base of the sitting surface. The seated subject was instructed to sit tall and gentle traction was applied to the mandible. The participant was instructed to stretch up as much possible, aided by traction under the chin; but instructed not to contract the muscles of the buttocks or thighs. (Ross & Marfell-Jones 1991) The participant's head pushed up the arm of the stadiometer and the counter of the instrument registered the result in cm to the nearest mm.

3.4.3 Leg length

Leg length was calculated from subtracting sitting stature from standing stature.

3.4.4 Total body mass

Body mass was measured by a digital scale (Toledo). The participant, bare foot and void of heavy clothing, was asked to step on to weighing scales and remain as motionless as possible. Readings were recorded in kilograms (kg) to the nearest 0.01kg.

3.5 Maturity assessment

3.5.1 Actual age at peak height velocity (controls)

Age at peak height velocity (PHV) was calculated for each individual by fitting a growth curve to annual height velocity using a cubic spline procedure (GraphPad Prism version 3.00 for Windows, GraphPad Software, San Diego California USA) (Bailey et al. 1999).

3.5.2 Prediction of age at peak height velocity (hockey players)

Chronological age, leg length and trunk length was entered into gender specific equations to predict age at PHV (Mirwald et al. 2002).

Male predictive equation:

Maturity offset = -9.236 + (0.0002708 * Leg Length and Sitting Height interaction) + (0.001663 * CA and leg length interaction) + (0.007216 * CA and Sitting Height interaction) + (0.02292 * Weight by Height ratio)

Female predictive equation:

Maturity offset = -9.376 + (0.0001882 * Leg Length and Sitting Height interaction) + (0.0022 * CA and leg length interaction) + (0.005841 * CA and Sitting Height interaction) + (0.002658 * Weight by Height ratio)

Table 3.1 demonstrates how the equation is used to predict PHV. Subtracting years from PHV from CA gave each participant a predicted age at PHV. If a participant's age at PHV was older than their CA then he/she was categorized as pre PHV. If a participant's age at PHV was younger than their CA he/she was categorized as post PHV.

Table 3.1 A worked example of predicting years from peak height velocity for a male

Maturity Offset = -9.236 + (0.0002708 * Leg Length & Sitting Height interaction) + (-0.001663 * CA & Leg Length interaction) + (0.007216 * CA & Sitting Height interaction) + (0.02292 * Weight by Height Ratio)

CA	11.253 years
Height	149.4 cm
Weight	40.0 kg
Leg Length	70.4 cm
Sitting Height	79.0 cm

Leg Length & Sitting Height interaction	70.44 * 79.0 = 5561.60
CA & Leg Length interaction	11.253 * 70.4 = 792.21
CA & Sitting Height interaction	11.253 * 79.0 = 888.99
Weight by Height Ratio	(40.0.0/149.4) * 100 = 26.77

Maturity Offset = -9.236 + (0.0002708 * 5561.60) + (-0.001663 * 792.21) + (0.007216 * 888.99) + (0.02292 * 26.77)
= - 2.0 years from PHV

3.5.3 Menarcheal age

The female hockey players were asked at Try-out #1 if they had started their menstrual flow. If they had started their menstrual flow they were asked to recollect the month and year that it had first occurred. The female hockey players were informed in advance of the question; this was designed to meet ethical requirements but also to give time to recall when the event occurred. If the girls could not recall when they started their menstrual flow they were provided with historic prompts such as: "Can you remember what grade you were in when it happened?" The females of the control group were asked semi-annually if they had started their menstrual flow and if they could remember when in the last six months it had occurred.

3.5.4 Parental heights

On the reverse side of the parental consent form, the parents were requested to record mother's height and father's height. Parents that did not fill out the questions were followed up by a telephone call after the try-outs.

3.5.4.1 Predictive equation based on parental heights and percentage of target height attained

The mothers and fathers heights were entered into an equation to predict the youth's target height.

Mean predicted target height for boys in cm:

$$\frac{\text{father's height} + (\text{mother's height} + 12.7\text{cm})}{2}$$

Mean predicted target height for girls in cm:

$$\frac{(\text{father's height} - 12.7\text{cm}) + \text{mother's height}}{2}$$

(Tanner 1962)

Percentage of target height was used to create a maturity classification. If a boy or girl was measured at less than 92% of expected target height then he/she was categorized as pre 92% of target height. If an individual was measured at greater than

92% of expected target height then he/she was categorized as post 92% of target height.

3.6 Birth date distribution

All subjects were given a number according to the month, in the selection year, in which they were born (i.e. 1=January and 12=December). Expected birth date distribution was calculated on the basis of an even distribution throughout any 12-month period.

3.7 Statistical procedure

All measurements were compared against reference norms (CDC 2000). One-way analysis of variance (ANOVA) and a Tukey's post hoc test was used to investigate if there was a significant difference in the means. A Kolmogorov Smirnov one sample test was used to assess differences between the observed and expected birth date distribution. Logistic regression was used to establish the relationship between success at try-outs and predictor variables. The alpha level of significance was set at $P<0.05$. SPSS (version 11.5) statistical package was used to analyze the data.

4 RESULTS

4.1 Subject characteristics - boys

Table 4.1 shows the average chronological age (CA), height and weight of the controls, participants of group 1, group 2 and group 3.

4.1.1 Chronological age – boys

There was no significant difference among the four groups in CA ($F(3, 370)=1.75$, $p>0.05$).

4.1.2 Height - boys

There was a significant difference among the four groups in height ($F(3,370)=8.66$, $p<0.05$). Post hoc analysis revealed that the players in group 3 were significantly ($p<0.05$) taller than the controls, players in group 1 and players in group 2.

The heights of the players of the four groups were compared against reference percentiles (10^{th}, 50^{th}, 90^{th}) (CDC 2000) in figure 4.1. Of the 93 controls, 64 (68.8%) were above the 50^{th} percentile for height and 24 (25.8%) were above the 90^{th} percentile for height. Of the 208 boys in group 1, 177 (85.1 %) were above the 50^{th} percentile and 44 (21.2%) were above the 90^{th} percentile for height. Of the 51 boys in group 2, 48 (94.1%) were above the 50^{th} percentile and 9 (17.6%) were above the 90^{th} percentile for height. Of the 22 boys in group 3, 22 (100%) were above the 50th percentile and 14 (63.6%) were above the 90th percentile for height.

4.1.3 Weight - boys

There was a significant difference among the four groups in weight ($F(3,370)=15.40$, $p<0.05$). Post hoc analysis revealed that the controls were significantly ($p<0.05$) lighter than group 1, group 2 and group 3. Players in group 1 and group 2 were significantly ($p<0.05$) lighter than players in group 3.

The weights of the players of the four groups were compared against reference percentiles (10th, 50th,90th) (CDC 2000) in Figure 4.1. Of the 93 controls, 66 (71.0%) were above the 50th percentile for weight and 14 (15.1%) were above the 90th percentile for weight. Of the 208 boys in group 1, 185 (88.9 %) were above the 50th percentile and 103 (49.5%) were above the 90th percentile for weight. Of the 51 boys in group 2, 48 (94.1%) were above the 50th percentile and 26 (51.0%) were above the 90th percentile for weight. Of the 22 boys in group 3, 21 (95.5%) were above the 50th percentile and 20 (90.9%) were above the 90th percentile for weight.

Table 4.1 Subjects' physical characteristics - boys

	Control (C)		Group 1 (1)		Group 2 (2)		Group 3 (3)		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	Post hoc
Age (years)	93	14.60 (0.27)	208	14.60 (0.27)	51	14.66 (0.27)	22	14.73 (0.27)	C=1= 2=3
Height (cm)	93	171.96 (7.35)	208	172.70 (7.35)	51	174.34 (5.80)	22	180.11 (4.66)	C,1, 2<3
Weight (kg)	93	60.62 (10.00)	208	67.15 (11.59)	51	67.79 (8.43)	22	75.79 (8.10)	C<1, 2<3

The number in the parentheses in column heads refer to the numbers used for illustrating significant ($p<0.05$) differences in the last column titled "Post hoc"

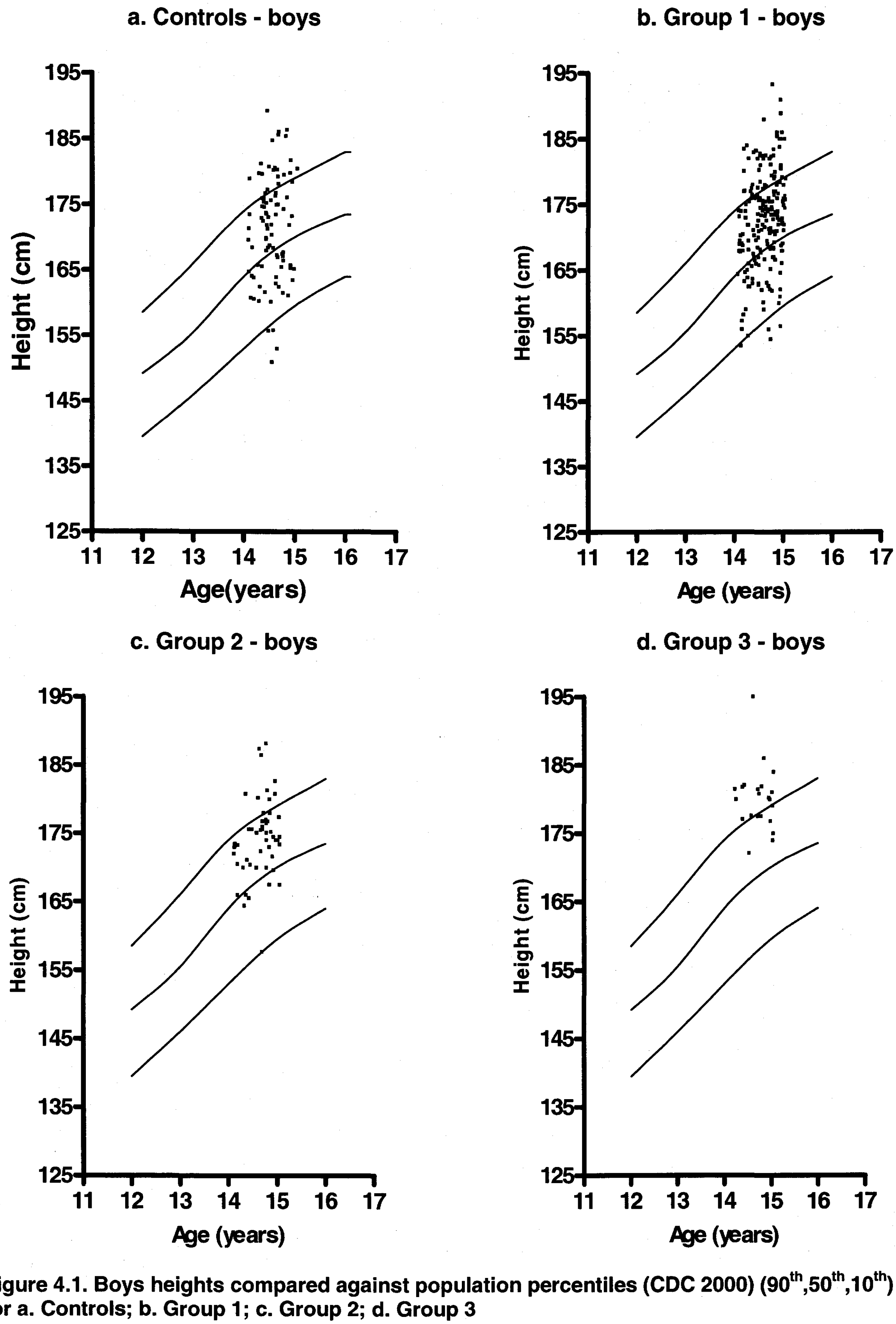

Figure 4.1. Boys heights compared against population percentiles (CDC 2000) (90th,50th,10th) for a. Controls; b. Group 1; c. Group 2; d. Group 3

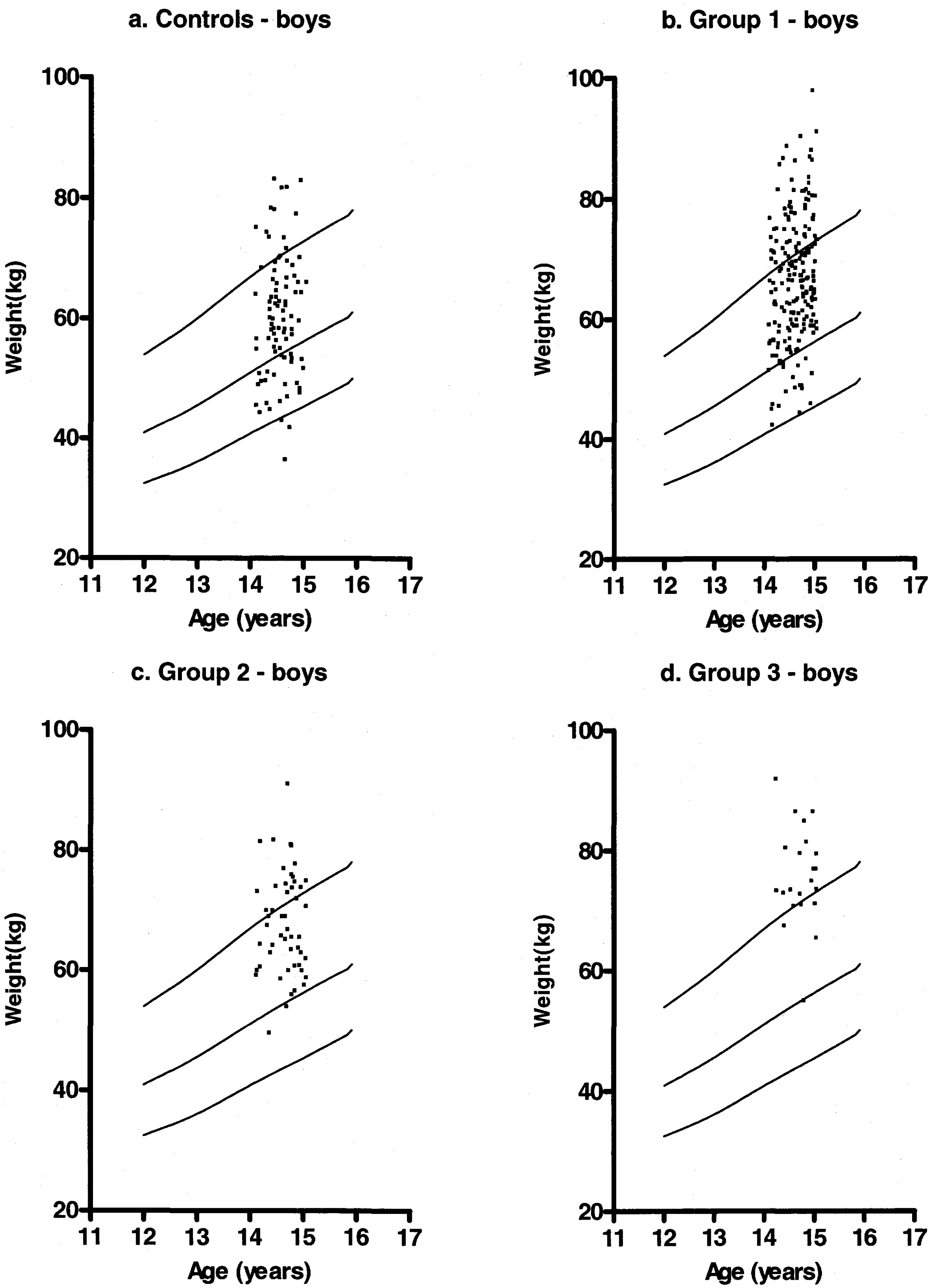

Figure 4.2. Boys weights compared against population percentiles (90th, 50th, 10th) for a. Controls; b. Group 1; c. Group 2; d. Group 3.

4.2 Parental characteristics and predictions - boys

The average mothers' height, fathers' height, target height, percentage of target height attained and age at PHV is shown in Table 4.2.

4.2.1 Fathers height - boys

There was no significant difference among the four groups in fathers' height ($F(3,11)=2.02$, $p>0.05$).

4.2.2 Mothers height - boys

There was no significant difference among the four groups in mothers' height ($F(3,12)=1.83$, $p>0.05$).

4.2.3 Target height - boys

There was a significant difference among the four groups in target height ($F(3,310)=3.63$, $p<0.05$). Post hoc analysis revealed that the predicted target height of group 3 was significantly ($p<0.05$) greater than the controls.

4.2.4 Percentage of target height attained – boys

There was a significant difference among the four groups in percentage of target height attained ($F(3,310)=4.16$, $p<0.05$). Post hoc analysis revealed that the percentage of target height attained by group 3 was significantly ($p<0.05$) greater than group 1.

4.2.5 Age at PHV - boys

There was a significant difference among the four groups in age at PHV ($F(3,370)=6.08$, $p<0.05$). Post hoc analysis revealed that the age at PHV of group 3 was significantly ($p<0.05$) younger than the controls, group 1 and group 2.

Table 4.2 Parental characteristics - boys

	Control (C)		Group 1 (1)		Group 2 (2)		Group 3 (3)		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	Post hoc
Mothers height (cm)	53	163.35 (7.51)	194	165.26 (5.91)	48	164.97 (6.16)	21	166.62 (5.43)	C=1= 2=3
Fathers height (cm)	52	176.64 (8.65)	194	178.09 (6.30)	48	178.73 (6.32)	21	180.77 (6.83)	C=1= 2=3
Target Height	51	176.20 (6.10)	194	178.03 (4.39)	48	178.20 (4.77)	21	180.04 (5.00)	C<3
Percentage of adult height	51	97.89 (4.61)	194	96.98 (3.98)	48	97.85 (3.03)	21	99.93 (2.83)	1<3
Age at PHV	93	13.48 (1.02)	208	13.48 (0.64)	51	13.31 (0.54)	22	12.81 (0.37)	C,1,2 <3

The number in the parentheses in column heads refer to the numbers used for illustrating significant (p<0.05) differences in the last column titled "Post hoc"

4.3 Maturity classifications - boys

The number and percentage of boys in each of the groups that are pre and post PHV and 92% of target stature is shown in Table 4.3.

4.3.1 Pre or post PHV - boys

Of the 93 controls 12.9% were pre PHV and 81 (87.9%) were post PHV. Out of group 1, 6.2 % were pre PHV and 93.8% were post PHV. Out of group 2, 2% were pre PHV and 98.0% were post PHV. All (100%) of group 3 were post PHV.

4.3.2 Pre or post 92% of target height - boys

Of the 51 controls 6 (11.8%) were pre 92% of target height and 45 (88.2%) were post 92% of target stature. Of the 194 boys in group 1 24 (12.4 %) were pre 92% of target stature and 170 (87.6%) were post 92% of target stature. Of the 48 boys in group 2, 2 (4.2%) were pre 92% of target stature and 46 (95.8%) were post 92% of adult stature. Of the 21 boys in group 3 0 (0%) were pre 92% of target stature and 21 (100%) were post 92% of target stature.

Table 4.3 Maturity classifications - boys

	Control		Group 1		Group 2		Group 3	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
				N (%)				
PHV	2 (12.9)	81 (87.1)	13 (6.2)	195 (93.8)	1 (2)	50 (98)	0 (0)	22 (100)
92% of adult stature	6 (11.8)	45 (88.2)	24 (12.4)	170 (87.6)	2 (4.17)	46 (95.8)	0 (0)	21 (100)

4.4 Logistic regression - boys

The combined influence of age at PHV, CA, height, weight, birth weight, mothers' height, and fathers' height, on success at the try-outs (1 and 2) was investigated using logistic regression. Success at the try-outs was interpreted as a categorical variable (selected or not selected). Each variable was entered in to the model individually to determine if it was a significant predictor ($p<0.05$). All significant predictors were presented in the final model (Table 4.4). Chronological age and age at PHV is presented initially in years as continuous variables. However, the small range in CA and age at PHV in this sample of males means that years, as a unit, are not that meaningful so the results are also presented in months. Weight is first presented in kilograms as a continuous variable and then to make the results more meaningful weight is presented in intervals of 10kg.

4.4.1 Model 1: Boys success at Try-out #1

Model 1 (Table 4.4) indicated that age at PHV, CA and weight significantly predicted success at Try-out #1 (selected or not selected). Thus boys who achieved PHV at a younger age, who were older and lighter were more likely to be selected at

Try-out #1. The overall model for predicting males success at Try-out #1 was significant ($p<0.05$) according to the model chi-square statistic ($\chi^2 = 22.84$ (df=3)). The model predicted 74.7% of the responses correctly.

Age at PHV variable had a Wald statistic of 13.09 ($p<0.05$). The associated odds ratio was 0.2, thus with a one year increase in age at PHV males were 0.2 times (80%) less likely to be selected at Try-out #1. The odds ratio for age at PHV by month was 0.88 (exp(0.08*-1.632)=0.88). Thus with every one month increase in age at PHV males were 0.88 times (12%) less likely to be selected at Try-out #1.

Chronological age variable had a Wald statistic of 5.47 ($p<0.05$). The associated odds ratio was 3.60, thus with every one year increase in age the males were 3.6 times (260%) more likely to be selected at Try-out #1. The odds ratio for age by month was 1.11 (exp(0.08*1.281)=1.11). Thus with every one month increase in age males were 1.11 times (11%) more likely to be selected at Try-out #1.

Weight variable had a Wald statistic of 3.87 ($p<0.05$). The associated odds ratio was 1. The odds ratio for 10kg change in weight was 0.64 (exp(10*-0.045)=0.64). Thus with every 10kg increase in weight males were 0.64 times (36%) less likely to be selected at Try-out #1.

4.4.2 Model 2: Boys success at Try-out #2

Model 2 (Table 4.4) indicated that age at PHV predicted success at Try-out #2 (selected or not selected). Thus boys who achieved PHV at a younger age were more likely to be selected at Try-out #2. The overall model for predicting males success at try-out 2 was significant ($p<0.05$) according to the model chi-square statistic ($\chi^2 = 26.20$ (df=1)). The model predicted 91.5% of the responses correctly.

Age at PHV variable had a Wald statistic of 19.07 ($p<0.05$). The associated odds ratio was 0.09, thus with a one year increase in age at PHV males were 0.09

times (91%) less likely to be selected at Try-out #2. The odds ratio for age at PHV by month was 0.83 (exp(0.08*-2.366)=0.83). Thus with a one month increase in age at PHV males were 0.83 times (17%) less likely to be selected at Try-out #1.

Table 4.4. Logistic regression predicting boys' success at Try-out #1 and #2 from CA, age at PHV, height and weight.

Predictor	B	SE	Wald	Odds Ratio
	Model 1: Predictors of being selected at Try-out #1			
*CA	1.28	0.54	5.46	3.43
*Age at PHV	-1.63	0.45	13.09	0.20
*Weight	-0.04	0.02	3.87	0.96
	Model 2: Predictors of being selected at Try-out #2			
*Age at PHV	-2.36	0.54	19.70	0.09

*= significant (p<0.05) predictors

4.5 Month born distribution - boys

Figure 4.3 depicts the birth date distributions of the controls and the three groups of hockey players. The controls birth dates were evenly distributed throughout the 12 months of the year ($p<0.05$); of the 93 boys 50 (53.8%) were born in the first half of the selection year. Players in group 1 had a non-significant ($p>0.05$) birth date distribution, which meant their birth dates were skewed. Of the 459 boys 252 (54.9%) were born in the first 6 months of the selection year. Players in group 2 had a non-significant ($p>0.05$) birth date distribution, which meant their birth dates were skewed. Of the 120 boys 85 (70.8%) were born in the first six months of the selection year. Players in group 3 had a non-significant ($p>0.05$) birth date distribution, which meant their birth dates were skewed. Of the 40 boys 31 (77.5%) were born in the first six months of the selection year.

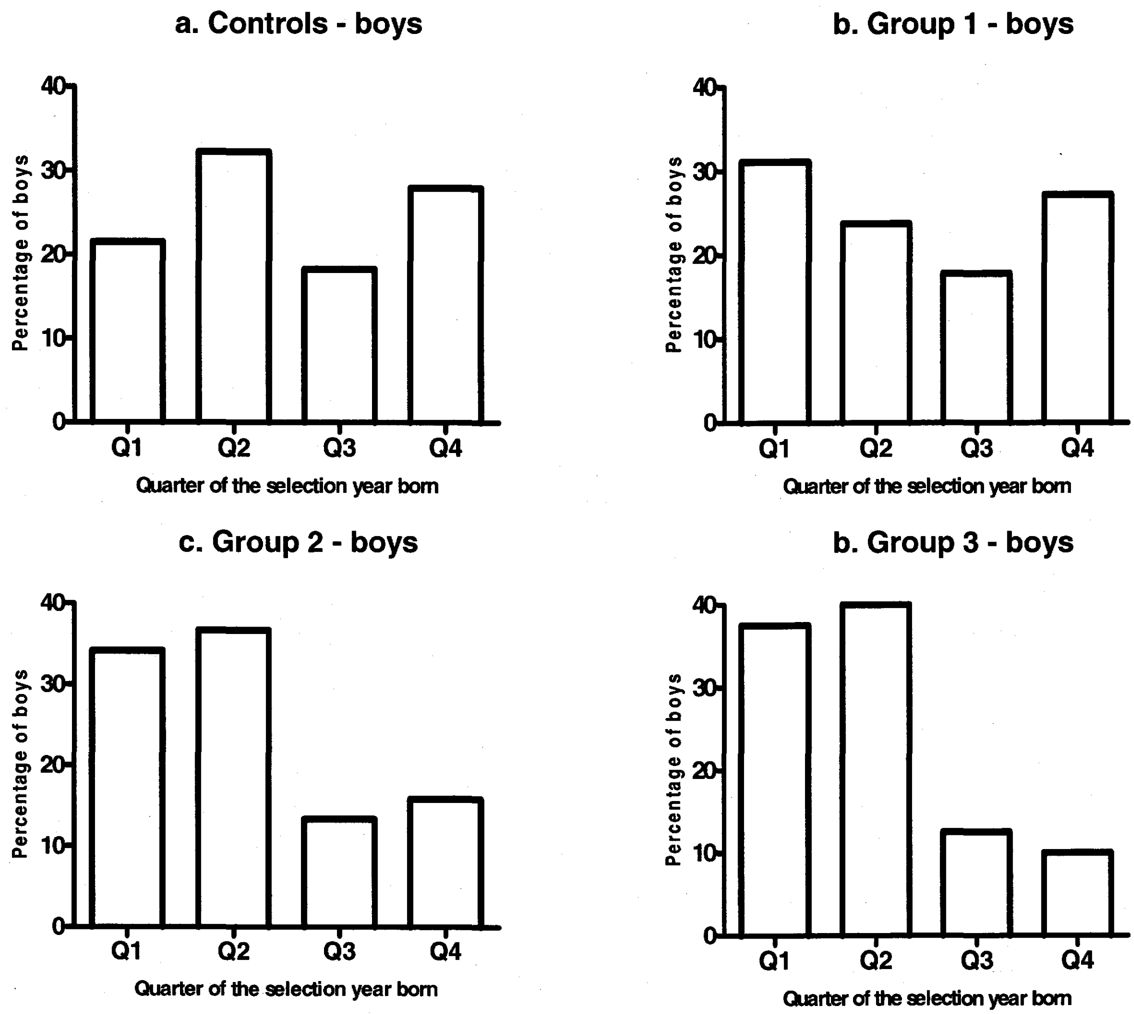

Figure 4.3. The percentage of boys born in each of the four quarters of the selection year for a. Controls; b. Group 1; c. Group 2; d. Group 3

4.6 Chronological age and physical maturity - boys

To investigate whether a combined influence of maturity (age at PHV) and CA (month born) on success at hockey try-outs existed the hockey participants (n=281) were divided into quartiles for age at PHV (the oldest 25% = 11.63-13.01 years; the second oldest 25% = 13.02-13.10 years; the third oldest 25% = 13.11-13.75 years; the youngest 25% 13.76-16.23 years). The numbers and percents of players in group 1 are depicted in table 4.5. Of the players in group 1, 52 (25%) were born in the first six months of the selection year and were in the top 50% for maturity (youngest age at PHV). The numbers and percents of players in group 2 are depicted in table 4.6. Of the boys in group 2, 22 (43.1%) were born in the first six months of the selection year and were in the top 50% for maturity. The numbers and percents of players in group 3 are depicted in table 4.7. Of the boys in group 3, 11 (50%) were born in the first six months of the selection year and were in the top 50% for maturity.

Table 4.5 Number and percent of boys in group 1 displayed by quarter of the year born and quartiles of age at PHV.

Quarter year born	Age at PHV n (%)				
	25% most mature	25%-50%	50%-75%	25% least mature	Total n(%)
Q1(oldest)	15 (7.2)	17 (8.2)	16 (7.7)	14 (6.7)	62 (29.8)
Q2	10 (4.8)	10(4.8)	18 (8.7)	18 (5.3)	56 (26.9)
Q3	10 (4.8)	14 (6.7)	8(8.7)	17 (8.2)	49 (23.6)
Q4(youngest)	7 (3.4)	11 (5.3)	10(4.8)	13 (6.3)	41 (19.7)
Total	42 (20.2)	52 (25.0)	52 (25.0)	62 (29.8)	208 (100)

Table 4.6 Number and percent of boys in group 2 displayed by quarter of the year born and quartiles of age at PHV.

Quarter year born	Age at PHV n (%)				
	25% most mature	25%-50%	50%-75%	25% least mature	Total
Q1(oldest)	3 (5.9)	2 (3.9)	10 (19.6)	2 (3.9)	17 (33.3)
Q2	8 (15.7)	9 (17.6)	0 (0)	4 (7.8)	21 (41.2)
Q3	0 (0)	4 (7.8)	3 (5.9)	2 (3.9)	9 (17.6)
Q4(youngest)	2 (3.9)	1 (2.0)	1 (2.0)	0 (0)	4 (7.8)
Total	13 (25.5)	16 (31.4)	14 (27.5)	8 (15.7)	51 (100)

Table 4.7 Number and percent of boys in group 3 displayed by quarter of the year born and quartiles of age at PHV.

Quarter year born	Age at PHV n (%)				
	25% most mature	25%-50%	50%-75%	25% least mature	Total
Q1(oldest)	5 (22.7)	1 (4.5)	3 (13.6)	0 (0)	9 (40.9)
Q2	4 (18.2)	2 (9.1)	1 (4.5)	0 (0)	7 (31.8)
Q3	5 (22.7)	0 (0)	0 (0)	0 (0)	5 (22.7)
Q4(youngest)	1 (9.1)	0 (0)	0 (0)	0 (0)	1 (4.5)
Total	15 (68.2)	3 (13.6)	4 (18.2)	0 (0)	22 (100)

4.7 Subject characteristics - girls

Table 4.8 shows the average CA, height and weight of the controls, participants of group 1, group 2 and group 3. Each group is separated into age categories (i.e. CA rounded up or down)

4.7.1 Chronological age – girls

There was no significant difference among the four groups in CA at age 13 ($F(2, 36)=3.09$, $p>0.05$), age 14 ($F(3, 99)=1.65$, $p>0.05$), age 15 ($F(3, 99)=2.43$, $p>0.05$), age 16 ($F(3, 95)=1.08$, $p>0.05$) and age 17 ($F(3, 55)=0.79$, $p>0.05$).

4.7.2 Height - girls

There were no significant differences in the heights of the four groups at age 13 ($F(2,36)=2.24$, $p>0.05$), age 14 ($F(3,99)=0.61$, $p>0.05$), age 15 ($F(2, 99)=0.15$, $p>0.05$) and age 17 ($F(3,55)=0.28$, $p>0.05$). There was a significant difference among the four groups in height at age 16 ($F(3,95)=2.65$, $p<0.05$). Post hoc analysis revealed that the players in group 3 were significantly ($p<0.05$) taller than players in group 1.

The heights of the players of the four groups were compared against reference percentiles (10^{th}, 50^{th},90^{th}) (CDC 2000) in figure 4.1. Of the 267 controls 86 (32.2%) were above the 50^{th} percentile for height and 21 (7.9%) were above the 90^{th} percentile for height. Of the 77 girls in group 1 37 (48.1 %) were above the 50^{th} percentile and 9 (11.7%) were above the 90^{th} percentile for height. Of the 40 girls in group 2, 23 (57.5%) were above the 50^{th} percentile and 5 (12.5%) were above the 90^{th} percentile for height. Of the 20 girls in group 3 12 (60%) were above the 50^{th} percentile and 4 (20.0%) were above the 90^{th} percentile for height.

4.7.3 Weight - girls

There were no significant differences in the weights of the four groups at age 13 (F(2,36)=0.04, p>0.05), age 14 (F(3,99)=0.52, p>0.05), age 15 (F(3, 99)=0.28,p>0.05), age16 (F(3,95)=1.59, p>0.05) and age 17 (F(3,55)=0.24, p>0.05).

The weights of the players of the four groups were compared against reference percentiles (10th, 50th,90th) (CDC 2000) in figure 4.1. Of the 267 controls 90, (33.7%) were above the 50th percentile for weight and 26 (9.7%) were above the 90th percentile for weight. Of the 77 girls in group 1, 65 (84.4%) were above the 50th percentile and 15 (19.5%) were above the 90th percentile for weight. Of the 40 girls in group 2, 35 (87.5%) were above the 50th percentile and 4 (10%) were above the 90th percentile for weight. Of the 20 girls in group 3, 19 (95.0%) were above the 50th percentile and 1 (5%) was above the 90th percentile for weight.

Table 4.8. Subjects' physical characteristics – girls

	Control (C)		Group 1 (1)		Group 2 (2)		Group 3 (3)		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	Post hoc
Age (years)									
Age 13	22	13.20 (0.17)	12	13.14 (0.14)	5	13.34 (0.10)	0	- (-)	C=1=2=3
Age 14	69	13.89 (0.18)	26	14.00 (0.32)	7	13.97 (0.25)	1	14.13 (-)	C=1=2=3
Age 15	60	14.90 (0.17)	27	14.85 (0.32)	10	15.08 (0.30)	6	14.95 (0.29)	C=1=2=3
Age 16	66	15.85 (0.22)	9	15.93 (0.27)	13	15.87 (0.27)	11	15.98 (0.30)	C=1=2=3
Age 17	49	16.80 (0.23)	3	16.69 (0.12)	5	16.73 (0.10)	2	16.60 (0.94)	C=1=2=3
Height (cm)									
Age 13	22	159.90 (7.16)	12	159.79 (7.25)	5	166.96 (5.28)	0	- (-)	C=1=2=3
Age 14	69	161.79 (1.17)	26	159.11 (6.23)	7	161.20 (5.19)	1	159.0 (-)	C=1=2=3
Age 15	60	154.05 (5.32)	27	163.27 (6.68)	10	163.46 (5.51)	6	163.18 (2.61)	C=1=2=3
Age 16	66	165.34 (5.40)	9	161.60 (5.92)	13	164.08 (5.32)	11	168.08 (7.08)	1<3
Age 17	49	165.60 (6.11)	3	165.60 (6.11)	5	163.72 (8.29)	2	165.65 (0.64)	C=1=2=3
Weight (kg)									
Age 13	22	55.03 (13.02)	12	55.78 (8.0)	5	56.36 (6.95)	0	- (-)	C=1=2=3
Age 14	69	54.23 (12.10)	26	56.80 (10.11)	7	52.92 (5.93)	1	61.80 (-)	C=1=2=3
Age 15	60	58.23 (11.11)	27	59.80 (7.02)	10	60.56 (4.42)	6	59.93 (7.62)	C=1=2=3
Age 16	66	60.66 (10.69)	9	64.98 (5.32)	13	62.22 (6.57)	11	67.10 (5.49)	C=1=2=3
Age 17	49	62.50 (11.81)	3	64.67 (6.83)	5	66.56 (9.66)	2	60.90 (5.52)	C=1=2=3

The number in the parentheses in column heads refer to the numbers used for illustrating significant ($p<0.05$) differences in the last column titled "Post hoc"

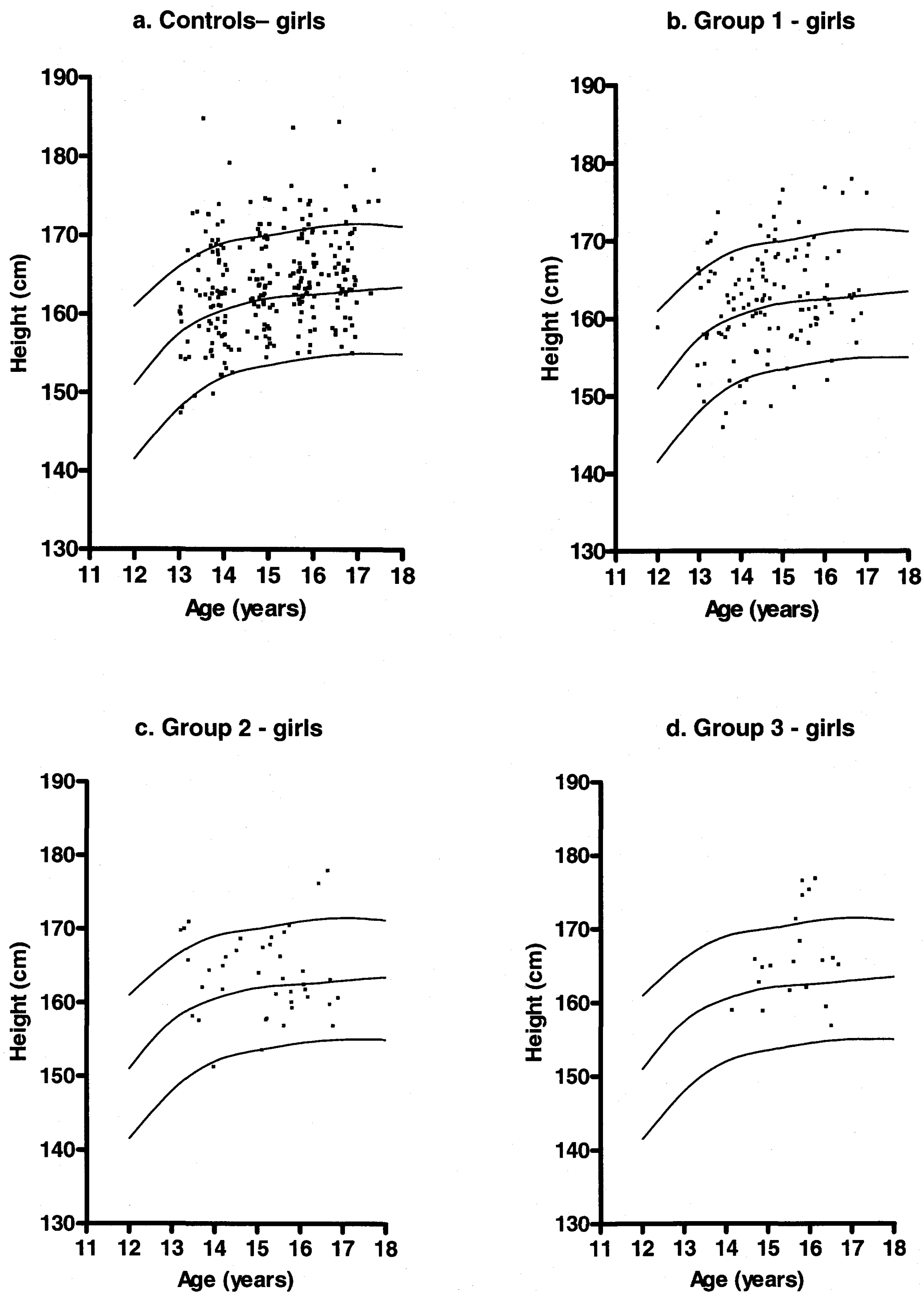

Figure 4.4. Girls heights compared against population percentiles (CDC 2000) (90^{th},50^{th},10^{th}) for a. Controls; b. Group 1; c. Group 2; d. Group 3.

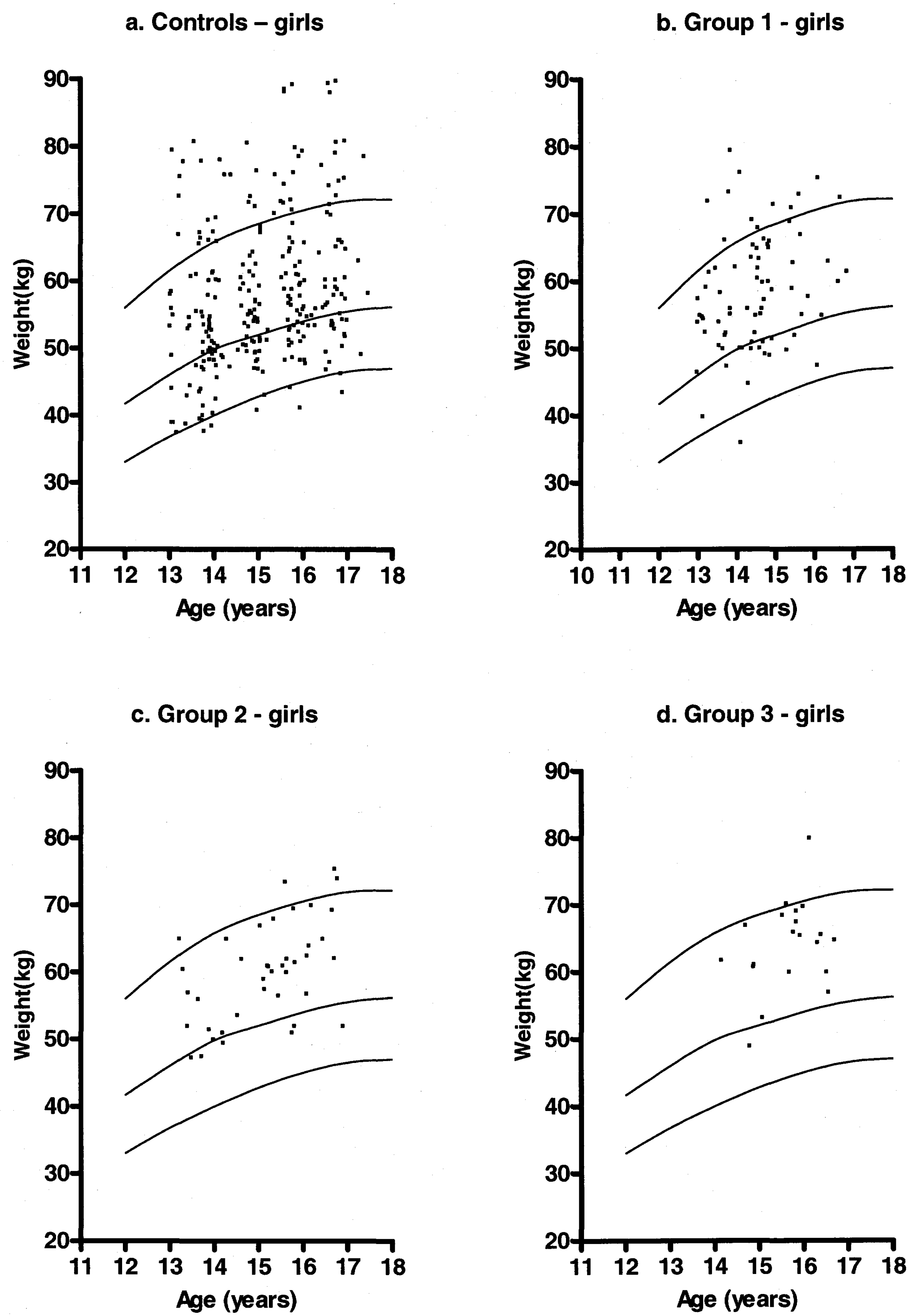

Figure 4.5. Girls weights compared against population percentiles (90th, 50th, 10th) for a. Controls; b. Group 1; c. Group 2; d. Group 3.

4.8 Parental characteristics and predictions - girls

The average mothers' height, fathers' height, target height, percentage of target height attained, age at menarche and age at PHV is shown in Table 4.8.

4.8.1 Fathers height - girls

There was no significant difference among the four groups in fathers' height ($F(3,196)=0.74$, $p>0.05$).

4.8.2 Mothers height - girls

There was no significant difference among the four groups in mothers' height ($F(3,198)=0.46$, $p>0.05$).

4.8.3 Target height - girls

There was no significant difference among the four groups in target height attained ($F(3,196)=0.95$, $p>0.05$).

4.8.4 Percentage of target height - girls

There were no significant differences in the percentage of target height attained between each of the four groups at age 13 ($F(2,21)=0.50$, $p>0.05$), age 15 ($F(3,72)=2.41$, $p>0.05$), age 16 ($F(3,73)=1.92$, $p>0.05$) and age 17 ($F(3,41)=1.41$, $p>0.05$). There was a significant difference among the four groups in percentage of target height attained age 14 ($F(3,74)=3.45$, $p<0.05$). Post hoc analysis revealed that the controls were at a significantly ($p<0.05$) greater percentage of their target height than players in group 1.

4.8.5 Age at PHV - girls

There was a significant difference among the four groups in age at PHV ($F(3,252)=16.21$, $p<0.05$). The age at PHV of group 1, group 2 and group 3 were significantly ($p<0.05$) younger than the controls.

4.8.6 Age at menarche - girls

There was no significant difference among the four groups in age at menarche ($F(3,201)=1.35$, $p>0.05$).

Table 4.9 Parental characteristics - girls

	Control (C)		Group 1 (1)		Group 2 (2)		Group 3 (3)		
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	Post hoc
Age at PHV	119	11.90 (0.90)	77	12.45 (0.53)	40	12.60 (0.60)	20	12.64 (0.44)	C<1, 2,3
Age at menarche	83	12.75 (1.03)	67	12.56 (0.92)	36	12.97 (0.98)	19	12.64 (0.28)	C=1 =2=3
Mothers height (cm)	80	164.28 (6.36)	70	164.30 (6.92)	32	165.48 (6.22)	20	165.61 (6.24)	C=1 =2=3
Fathers height (cm)	78	177.68 (7.30)	70	178.25 (6.71)	32	179.71 (6.16)	20	179.07 (6.53)	C=1 =2=3
Target Height	78	164.64 (5.5)	70	164.93 (5.02)	32	166.24 (0.80)	20	165.99 (4.94)	C=1 =2=3
Percentage of target height									
Age 13	12	97.72 (3.12)	9	96.96 (3.58)	3	99.07 (1.89)	0	- (-)	C=1 =2=3
Age 14	44	99.48 (2.81)	26	96.94 (4.34)	7	97.14 (2.13)	1	98.58 (-)	C=1 =2=3
Age 15	40	100.78 (2.52)	24	99.03 (3.26)	6	99.78 (1.90)	6	98.84 (2.71)	C=1 =2=3
Age 16	45	100.71 (2.33)	9	98.81 (2.50)	12	99.62 (2.31)	11	100.68 (3.18)	C=1 =2=3
Age 17	37	101.20 (2.33)	2	98.83 (0.40)	4	98.63 (6.08)	2	101.51 (0.95)	C=1 =2=3

The number in the parentheses in column heads refer to the numbers used for illustrating significant ($p<0.05$) differences in the last column titled "Post hoc"

4.9 Maturity classifications - girls

The number and percentage of girls in each of the groups that are pre and post PHV and 92% of target stature is shown in Table 4.10.

4.9.1 Pre or post PHV - girls

Out of the controls aged 13, 9.1% were pre PHV and 90.9 % were post PHV. Out of the controls age 14, 1.4% were pre PHV and 98.6% were post PHV. All (100%) of the controls aged 15, 16 and 17 were post PHV. All (100%) of the 13, 14, 15, 16 and 17 year old hockey players in each of the 3 groups were post PHV.

4.9.2 Pre or post 92% of target stature - girls

Out of the controls aged 13, 8.3% were pre 92% of target stature and 91.7 % were post 92% of target stature. All (100%) of the controls aged 14, 15, 16 and 17 were post 92% of target stature. Of the 13 year old hockey players in group 1, 11.1% were pre 92% of target stature and 88.9% were post 92% of target stature. Of the 14 year old hockey players in group 1, 3.8% were pre 92% of target stature and 96.2% were post 92% of target stature. All (100%) the rest of the players in the three groups were post 92% of target stature.

Table 4.10 Maturity classifications – girls

	Control		Group 1		Group 2		Group 3	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
				N (%)				
PHV								
Age 13	2(9.1)	20 (90.9)	0 (0)	12 (100)	0 (0)	5 (100)	- (-)	- (-)
Age 14	1(1.4)	69 (98.6)	0 (0)	26 (100)	0 (0)	7 (100)	0 (0)	1 (100)
Age 15	0 (0)	60 (100)	0 (0)	27 (100)	0 (0)	10 (100)	0 (0)	6 (100)
Age 16	0 (0)	66 (100)	0 (0)	9 (100)	0 (0)	13 (100)	0 (0)	11 (100)
Age 17	0 (0)	49 (100)	0 (0)	3 (100)	0 (0)	5 (100)	0 (0)	2 (100)
92% target stature								
Age 13	1(8.3)	11 (91.7)	1(11.1)	8 (88.9)	0 (0)	3 (100)	- (-)	- (-)
Age 14	0 (0)	44 (100)	1 (3.8)	25 (96.2)	0 (0)	7 (100)	0 (0)	1 (100)
Age 15	0 (0)	40 (100)	0 (0)	24 (100)	0 (0)	6 (100)	0 (0)	6 (100)
Age 16	0 (0)	45 (100)	0 (0)	9 (100)	0 (0)	12 (100)	0 (0)	11 (100)
Age 17	0 (0)	37 (100)	0 (0)	2 (100)	0 (0)	4 (100)	0 (0)	2 (100)

4.10 Logistic regression - girls

The combined influence of age at PHV, CA, height, weight, birth weight, mothers height, fathers height and menarcheal age on success at the try-outs (1 and 2) was investigated using logistic regression. Success at the try-outs was investigated as a categorical variable (selected or not selected). Each variable was entered into the model individually to determine if it was a significant predictor ($p<0.05$). All significant predictors were presented in the final model (Table 4.11). Chronological age was presented initially in years as a continuous variable. However, the small range in CA demonstrated in this sample of females' means that year as a unit was not that meaningful so the results are also presented in months. Height was first presented in centimeters as a continuous variable and then to make the results more meaningful height was presented in intervals of 10cm.

4.10.1 Model 1: Girls success at Try-out #1

The results from Model 1 (Table 4.11) indicated that CA and height predicted success at Try-out #1 (selected or not selected). Thus girls who were older and taller were more likely to be selected at Try-out #1. The overall model for predicting females' success at Try-out #1 was significant ($p<0.05$) according to the model chi-square statistic ($\chi^2 = 25.91$ (df=2)). The model predicted 66.4% of the responses correctly.

Chronological age variable had a Wald statistic of 14.23 ($p<0.05$). The associated odds ratio of age was 2.08, thus with every one year increase in CA the females were 2.08 times (108%) more likely to be selected at Try-out #1. The odds ratio for age by month was 1.06 (exp(0.08*0.73)=1.06). Thus with a one month increase in age females were 1.06 times (6%) more likely to be selected at Try-out #1.

Height variable had a Wald statistic of 5.47 ($p<0.05$). The associated odds ratio of height was 1.07, thus with every one centimeter increase in height the females were 1.07 times (7%) more likely to be selected at Try-out #1. The odds ratio for height by interval of 10cm was 2.03 (exp(10*0.07)=2.03). Thus with every 10cm increase in height the players were 2.03 times (103%) more likely to be selected at Try-out #1.

4.10.2 Model 2: Girls success at Try-out #2

The results from Model 3 (Table 4.9) indicated that CA predicted success at Try-out #2 (selected or not selected). Thus girls who were older were more likely to be selected at Try-out #2. The overall model for predicting females success at Try-out #2 was significant ($p<0.05$) according to the model chi-square statistic ($\chi^2 = 13.98$ (df=1)). The model predicts 85.4% of the responses correctly.

Chronological age variable has a Wald statistic of 11.39 ($p<0.05$). The associated odds ratio of CA by years was 2.57, thus with every one year increase in CA the females were 2.57 times (157%) more likely to be selected at Try-out #2. The odds ratio for CA by month was 1.07 (exp(0.08*0.944)=1.07). Thus with every one month increase in CA females were 1.07 times (7%) more likely to be selected at Try-out #2.

Table 4.11 Logistic regression predicting girls' success at Try-out #1 and #2 from CA, height and weight.

Predictor	B	SE	Wald	Odds Ratio
		Model 1: Predictors of being selected at Try-out #1		
*CA	0.73	0.19	14.23	2.08
*Height	0.07	0.03	4.77	1.07
		Model 2: Predictors of being selected at Try-out #2		
*CA	0.94	0.28	11.39	2.57

*= significant ($p<0.05$) predictors

4.11 Month born distribution - girls

Figure 4.6 depicts the birth date distributions of the controls and the three groups of hockey players. The controls birth dates were evenly distributed throughout the 12 months of the year ($p<0.05$); of the 119 girls, 59 (49.6%) were born in the first half of the selection year. Players in group 1 birth dates were evenly distributed throughout the 12 months of the year ($p<0.05$); of the 225 girls, 124 (55.1%) were born in the first 6 months of the selection year. Players in group 2 birth dates were evenly distributed throughout the 12 months of the year ($p<0.05$); out of the 126 girls, 73 (57.9%) were born in the first six months of the selection year. Players in group 3 birth dates were evenly distributed throughout the 12 months of the year ($p<0.05$); out of the 34 girls, 23 (49.6%) were born in the first six months of the selection year.

4.12 Year born distribution - girls

Figure 4.7 depicts the distribution of players born in 1987, 1988, 1989 and 1990. The players in group 1 birth dates were evenly distributed through the four years ($p<0.05$); of the 225 girls, 68 (30.2%) were born in 1987 or 1988. The players in group 2 had a non-significant ($p>0.05$) birth date distribution, which meant their birth dates were skewed. Of the 126 girls, 80 (63.5%) were born in 1987 and 1988. The players in group 3 had a non-significant (p>0.05) birth date distribution, which meant their birth dates were skewed. Of the 34 girls, 30 (88.2%) were born in 1987 or 1988.

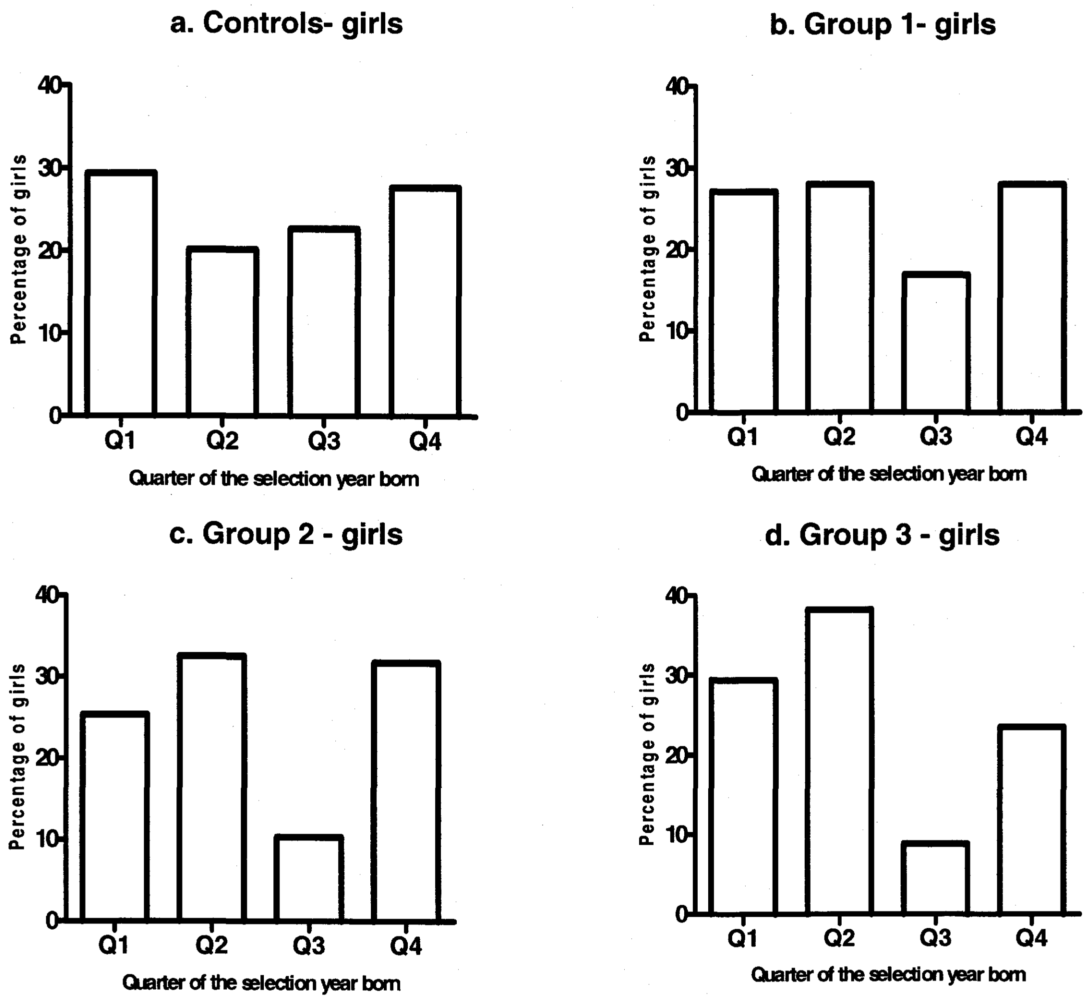

Figure 4.6. The percentage of girls born in each of the four quarters of the selection year for a. Controls; b. Group 1; c. Group 2; d. Group 3

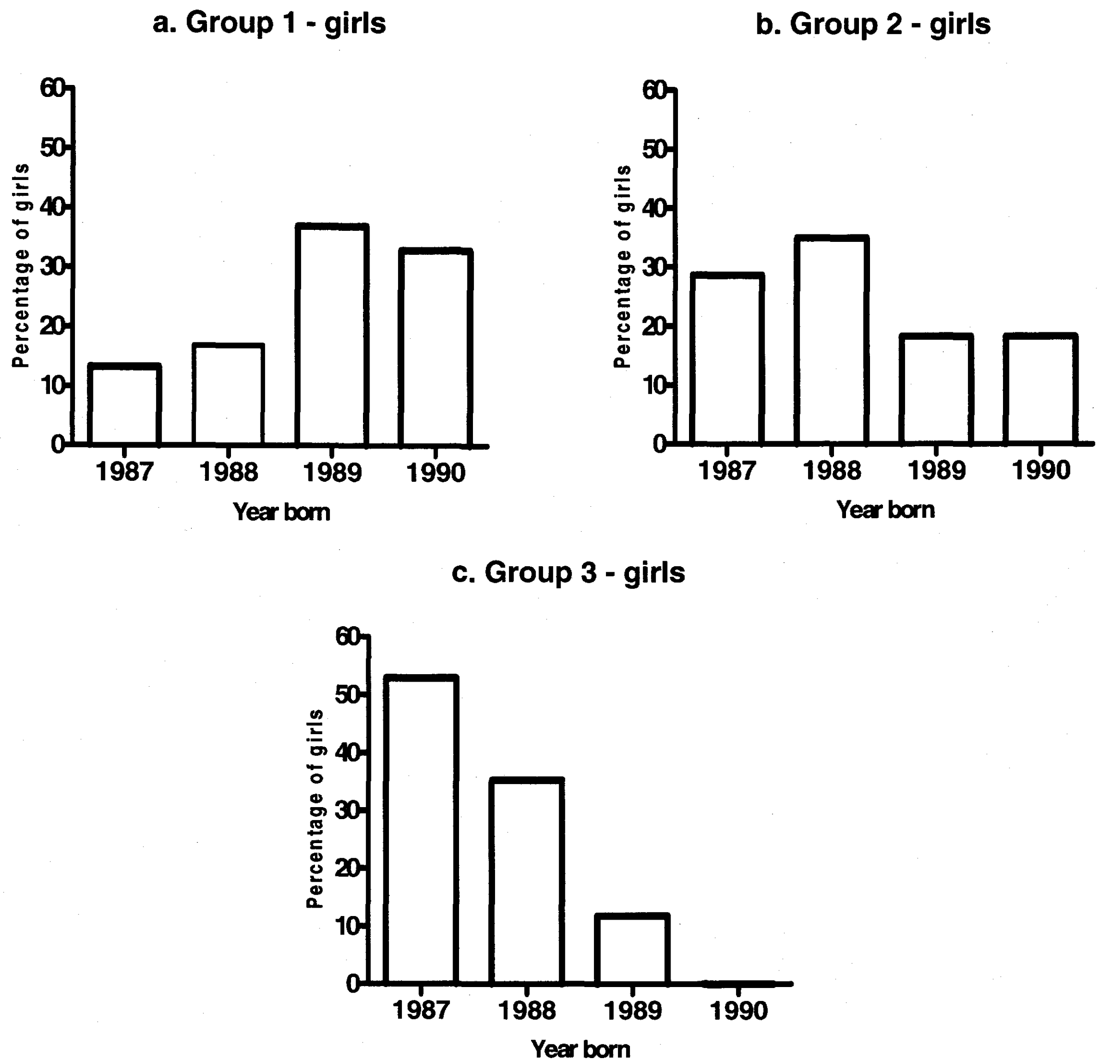

Figure 4.7. The percentage of girls born in each year for a. Group 1; b. Group 2; c. Group 3

5. DISCUSSION

This investigation explored the relationship between maturity status, chronological age (date of birth) and success at hockey try-outs. The first hypothesis was concerned with anthropometric characteristics (i.e. height and weight), the second with maturity status and the third with chronological age (CA). Each hypothesis is discussed separately for males and females in the context of previous literature. Finally there is a general discussion which includes some controversies and hurdles in the implementation of maturity classifications in youth sports.

5.1.1 Boys: Hypothesis 1: Hockey players who are taller and heavier will be more likely selected than shorter and lighter hockey players

This investigation provided strong support for this hypothesis. The boys selected at Try-out #2 were, on average, taller and heavier than boys not selected, and taller and heavier than the controls. Comparisons of the boys' height with reference data showed that 100% of the boys selected at Try-out #2 were taller, and 95.5% were heavier than 50% of boys of the same CA (i.e. greater than 50^{th} percentile). Furthermore, 63.6% of the boys selected at Try-out #2 were taller and 90.9% were heavier than 90% of the boys of the same CA. This demonstrated that the majority of the hockey players selected at Try-out #2 were taller and heavier than average. Furthermore, the percentage of hockey players over the 50^{th} and 90^{th} percentile for height and weight was greater among the individuals selected at Try-out #2 than the individuals not selected and the controls. This suggests that the taller and heavier boys in the CA group were preferentially selected at the hockey try-outs.

Logistic regression showed that an increase in weight, when adjusted for CA and maturity, decreased the chances of being selected at Try-out #1. Thus boys' weight, over and beyond the weight associated with maturity, was negatively associated with being selected; the selectors weren't preferentially selecting heavier boys, just boys that were more mature.

5.1.2 Boys: Hypothesis 2: Hockey players who mature earlier will be more likely selected than hockey players who mature later

This investigation provided strong support for this hypothesis. The boys who were selected at Try-out #2 were more mature than boys not selected and the controls. The boys had a significantly younger age at PHV and were at a greater percentage of their target height (although the differences were not significant). Furthermore, all of the boys selected at Try-out #2 were post-PHV and post 92% of target height, whereas the controls and the players not selected included boys that were pre-PHV and pre 92% of target height. Logistic regression further proved age at PHV to be a significant predictor of being selected at Try-out #1 and Try-out #2. All of these indicators show that the early maturing boys were preferentially selected at the hockey try-outs.

5.1.3 Boys: Hypothesis 3: There will be an uneven birth date distribution among the hockey players who are selected, with more participants being born early in the selection year

The investigation provides support for this hypothesis. The controls' birth dates were evenly distributed through the 12 months of the selection year. However, all boys, whether selected or not, demonstrated a skewed birth date distribution with more players being born in the first six months of the selection year. This suggests that that the older boys in the CA group may have been self selected into attending the try-outs because Try-out #1 was open to any boy of the right age in the province. Although the relative age effect (RAE) was apparent at the beginning of the selection process the RAE became stronger with each try-out, with 77.5% of the boys selected at Try-out #2 being born in the first six months of the selection year. This provides strong evidence to suggest that talent evaluators were preferentially selecting older players in the CA group.

5.2.1 Girls: Hypothesis 1: Hockey players who are taller and heavier will be more likely selected than shorter and lighter hockey players

Support was not provided for this hypothesis. The female try-outs were open to any bantam and first year midget girl in the province (unlike the male camp which was only open to second year bantam players), so the girls eligible to compete were of a wide CA range (12.96 years to 16.88 years). It was therefore appropriate when comparing the heights and weights of the controls, hockey players selected and hockey players not selected, to compare individuals of the same CA. There was no difference in the heights and weights of the girls selected and those not selected. The only exception was that the 16 year old players who were selected at Try-out #2 were significantly taller than the players who were not selected at Try-out #1. However, the girls selected at Try-out #2 were not significantly taller than the controls.

Comparisons of the girls' heights and weights with reference data revealed that 60% of the girls selected at Try-out #2 were taller, and 95% were heavier, than 50% of girls of the same CA (i.e. greater than 50th percentile). Furthermore, 20% of the girls selected at Try-out #2 were taller and 5% were heavier than 90% of the girls of the same CA. This demonstrated that the hockey players, as a group, were taller and heavier than average. The percentages of girls over the 50th and 90th percentile for height were slightly greater among the girls selected at Try-out #2 than the controls and the girls not selected. The only exception was that the players not selected at Try-out #2 had a greater percentage over the 90th percentile for weight than the players selected for Try-out #2. However, logistic regression only showed height to be a significant predictor of being selected at Try-out #1 and #2. There is thus some evidence to suggest that the taller girls are preferentially selected at hockey try-outs.

5.2.2 Girls: Hypothesis 2: Hockey players who mature earlier will more likely selected than hockey players who mature later

Support was not provided for this hypothesis. The girls selected at Try-out #2 average age at PHV and average age at menarche was not significantly younger than the controls and the players not selected. In confirmation there was also no significant difference between the percentage of target height attained by the girls selected at Try-out #2, and the girls not selected or the controls. The maturity classifications (i.e. pre- or post-PHV or 92% of target height) revealed that the majority of the girls from all four groups were past these two maturational milestones.

5.2.3. Girls: Hypothesis 3: There will be an uneven birth date distribution among hockey players that are selected, with more participants being born early in the selection year.

Support was not provided for this hypothesis. The birth dates of the controls, the girls selected and the girls not selected, were evenly distributed throughout the 12 months of the selection year, so no proof of a RAE in female hockey was provided in this investigation. However, one must take into account the wide CA range of females eligible to compete at the try-outs (12.96 years through to 16.88 years). Although there was no RAE there was a strong chronological year effect. The birth dates of the girls taking part in Try-out #1 were evenly distributed throughout the four years (1987, 1988, 1989 and 1990). At each of the try-outs the chronologically older players (players born in 1987, 1988) were more likely to be selected. In fact none of the players born in 1990, (the youngest age group), were selected at Try-out #2; whereas the majority (52.9%) of the girls selected were born in 1987 (the oldest CA group).

5.3 Relationship between anthropometric characteristics, physical maturity, chronological age and success at hockey try-outs

Physical capabilities are a major determinant of team placement in youth hockey; as well as strong skating, shooting, stick handling and puck control, talent evaluators look for physical attributes, such as overall size, strength, anaerobic power and aerobic power (Twist 1997; Brown 2001). In try-outs for hockey an early maturing individual, when compared to a late maturing individual, could be perceived as being more 'talented' purely because of maturity related development in size, strength, speed and endurance (caused by an early maturity status and/or greater CA). The relationship between date of birth and participation in female hockey has not been studied until now.

5.3.1 Boys

The findings from this investigation show that the boys who were more physically mature have an increased chance of being selected at hockey try-outs. These results differ from previously published findings which do not show adolescent elite hockey players to be taller, heavier (Cunningham, Telford, & Swart 1976; Houston & Green 1976) or more mature (Cunningham, Telford, & Swart 1976; Kotulan, Renickova, & Placheta 1980; Lariviere & La Fond 1986; Rahkila et al. 1988; Malina, Meleski, & Shoup 1982), However, it is problematic comparing the findings from this investigation with findings from previous investigations. Prior studies differ in their subject groups; some investigations compared elite hockey players to non-elite hockey players, some compared elite hockey players to reference standards however no study in the past, has directly looked at the relationship between success at try-outs, maturity status and anthropometric characteristics. Furthermore, the past research concerning hockey players occurred almost two decades ago. It is possible that the game of hockey has progressed into a more physical game over the past 20 years. Thus early maturity, with the concomitant increase in size, could be more of an advantage now than 20 years ago.

The predicted target height of the boys who were selected at the hockey try-outs was not significantly different from the controls and the players that were not selected. Although the target height is a prediction, this finding agrees with other literature (Frisch & Revelle 1969; Onat & Ertem 1974; Lindgren 1978; Tanner 1989; Bielicki & Hauspie 1994; Gasser et al. 2001; Koziel 2001) which demonstrates that the height advantages of the early maturing male disappear by adulthood. This is an important finding because the boys selected at the hockey try-outs were significantly taller, probably because of their above average maturity, at the time of selection, but are likely not be taller than the boys not selected when they all reach adulthood.

The limited number of past studies investigating the relationship between date of birth and participation in hockey has unanimously found adolescent male hockey players to be born in the early months of the selection year (Barsley, Thompson, & Barnsley 1985; Barnsley & Thompson 1988). The results from this investigation support these previous findings with all the hockey players being more likely to be born in the first six months of the selection year. This bias becomes more pronounced with each try-out.

No research to date has examined the combined influence of date of birth and physical maturity on hockey participation. The results from this investigation show that the CA and physical maturity status of a boy had a combined influence on selection at hockey try-outs. Out of the boys who attended Try-out #1, 19% were born in the last quarter of the selection year and were in the bottom 25% for physical maturity. Not one of these players was selected at Try-out #2. One boy was selected at Try-out #2 who was born in the last quarter of the selection year; he was, however, in the top 25% for physical maturity. Likewise the five individuals who were born in the third quarter of the selection year and were selected for Try-out #2 were all in the top 25% for physical maturity. Thus, the relatively younger children who were selected were probably not at a disadvantage in terms of physical maturity because they were of an early maturity status. The relatively young, average and late maturers probably lacked physical maturity and were therefore not selected. It appears, based on the findings from this investigation, unlikely that late maturing boys born late in the selection year will be selected at hockey try-outs.

5.3.2 Girls

Unfortunately, findings from this investigation cannot be directly compared to findings from other studies because of the absence of data documenting anthropometric and maturity characteristics of female hockey players, and female team athletes in general.

The female hockey players selected were not found to be early maturers when compared to the girls not selected and the controls. However, there was a discrepancy in the results obtained from two different maturity indicators. Estimated age at PHV showed the hockey players to be less mature than the controls, while recalled age at menarche showed no significant difference. The most plausible explanation for the discrepancy lies in the accuracy and sensitivity of the maturity predictive equation. Girls mature on average two years before boys; girls' average age at PHV is 12.0 years and the boys' average age at PHV is 14.0 years (Beunen & Malina 1988; Malina & Bouchard 1991). The maturity predictive equation was based on the timing of leg length velocity and upper body velocity to predict years from PHV. As with any form of prediction, the greater the time elapsed from the predicted event, the less accurate the prediction. The male hockey players' average CA was 14.35 years, the youngest player was 14.07 years old and the oldest player was 15.05 years old. Thus, the boys (if average maturers) would be very close to PHV when tested. One would therefore expect the maturity predictive equation to be a sensitive measure of the boys' maturity status in this investigation. The female hockey players' average CA was 14.84 years, with the youngest player being 12.96 years old and the oldest player being 16.88 years old. The girls in this investigation were therefore, on average, nearly three years past the expected age at PHV. One would therefore anticipate that the estimated age at PHV of the female hockey players would be relatively inaccurate; probably producing an over-estimation of age at PHV.

On average menarche occurs a year later than PHV (Tanner 1962), this timing and sequencing of events is demonstrated in the controls (average age at PHV = 11.89 years, average age at menarche = 12.68 years). It should be kept in mind that the controls had actual age PHV whereas the hockey players had predicted age at PHV. The hockey players' estimated age at PHV and recalled age at menarche were nearly the same. This further suggests that the predictive equation did not produce an accurate estimate of the girls' age at PHV, so age at menarche can be considered a more suitable maturity indicator in this sample. There were no significant differences between reported age at menarche of the hockey players and controls, thus the female hockey players' maturity status was not significantlv different from the controls.

Although there was no difference in maturity status of the girls selected and girls not selected, the average CA did significantly change with each try-out. At each of the try-outs the older girls (aged 16 years) were preferentially selected. As expected these players were more mature (and taller and heavier) because of their older CA; for example, the hockey players' age at menarche did not significantly differ, but their years from menarche did. However, one cannot confidently conclude that these older players were preferentially selected solely because of their greater physical maturity. It is likely that the older players, as well as being more physically developed, also had a greater exposure to hockey (more coaching and ice time) which could result in a more proficient motor control and a greater understanding of the technical aspects of the game. Within the scope of this investigation it is impossible to extract the reasons why the chronologically older female was more likely to be selected at the hockey try-outs. One could speculate that it was due to a combination of advantages that are synonymous with being chronologically older (i.e. taller, heavier, stronger, broader scope of experiences, greater confidence, and so on).

If a larger number of girls had been tested in each age group (especially at age 16) one may have seen the more physically mature individuals in the age group being preferentially selected. Because of the smaller number of girls participating at the try-outs, and the wide CA range, the chronologically older girls had an advantage that could have masked any maturity bias or RAE that was present.

Another explanation for why there was no maturity selection bias found among the female hockey players could be due to the differences in the timing of maturity between males and females. As previously mentioned females mature, on average, two years before males. The biggest disparity in physical maturity is known to be around

PHV (Marshall & Tanner 1969, 1970), which is approximately 12 years in girls and 14 years in boys. The more years past PHV, the less variation in physical maturity exists among children of the same CA. Selection for hockey teams during the mid years of adolescence may show less of a bias in females than in males, because the majority of females will be post PHV and therefore as a group will not vary much in physical maturity. On the other hand, males during mid-adolescence are around PHV, so as a group will demonstrate a large variation in physical maturity.

Lastly, maturity status may have less of an influence in girls because the female game is less physical than the male game. Full body checking is allowed in male hockey but not in female hockey. Having this aspect absent from the game may put more emphasis on skill rather than physical strength and size.

5.4 The cause of relative age effect

It has been suggested that the climate could be a cause of RAE in sporting situations (Sharp, Hutchinson, & Whetton 1994). A climatic difference does not provide a satisfactory explanation for the RAE found in the present sample of male hockey players. The selection year in Saskatchewan, and the rest of Canada, runs from January through to December. January and December are similar climatically but are at completely different ends of the selection year. Relative age effect in sports has also been attributed to the physical advantages of the relatively older players (Barnsley, Thompson, & Legault 1992; Baxter-Jones et al. 1994; Brewer, Balsom, & Davis 1995). The results from this investigation add support for this suggestion. The boys that were selected at each of the try-outs, as well as being more mature and more likely born early in the selection year, were also taller and heavier which suggests that these relatively older players had a physical advantage over the relatively younger players in the age group.

5.5 Possible implications for youth hockey

The findings from this investigation strongly suggest that the physically mature (taller and heavier) boys were preferentially selected at hockey try-outs. Past research shows that average and late maturing boys catch up with early maturing boys by adulthood (Lindgren 1978). Therefore, upon reaching adulthood early maturing individuals will have no performance advantage that is associated with physical development. The important question is whether preferentially selecting more mature individuals will have a long lasting detrimental effect on the average and late maturing individuals not selected. It is likely that the selected early maturing players will be exposed to top level coaching for more years, become known to selectors and experience the pressures of international competitions and tournaments which are likely to contribute to an increased chance of success in later years. The talented players who are overlooked due to lack of maturity are yet to be tracked, so the question of whether they participate at an older CA, and at what level, remains unanswered. Nevertheless, it is probable that many may be lost to hockey because they turn their attention to other sports in which they achieve selection, or they may be lost to sport altogether.

5.6 Potential methods for reducing biases associated with chronological age grouping

5.6.1 Maturity classifications

This investigation provides support for replacing CA categories with maturity categories when identifying male hockey talent. Maturity categories would help select the truly talented males regardless of maturity status. There have, in the past, been advocates for maturity classifications in sports. Despite this past interest, however, there is little evidence to show successful implementation of maturity classifications in the sporting environment. One possible reason could be associated with the assessment of physical maturity. Popular methods of assessing maturity can be costly (i.e. the assessment of skeletal age through wrist radiographs), intrusive (i.e. the assessment of sexual maturity) or require longitudinal observations (i.e. assessment of actual age at PHV). This makes them all inappropriate to use in the sporting world. The method of estimating age at PHV, adopted in this investigation, is a fairly new approach and has the potential to be utilized in the organized sport setting. The measurement of standing stature, sitting stature and weight are simple to take and the predictive equation simple to calculate. Furthermore, the method is non-intrusive and inexpensive which adds to its attractiveness. However, one must remember that the accuracy of the predictive equation is dependent on measurement technique. Correct protocols need to be followed when measuring sitting stature, standing stature and weight as prediction is only as good as the measurement technique itself. Self reported heights and weights should not be used.

The accuracy of the predictive equation is also largely dependent on the maturity status of the adolescent. The further a child is from PHV the less accurate the equation. Thus it would be inappropriate to use this tool to assess maturity of most 16 year olds as the calculated age at PHV would be spuriously old. Likewise, using the equation to predict the maturity of most eight year olds would provide a spuriously young age at PHV. This narrow age range (-2 years and +2 years from PHV, as a general rule) may limit the use of the equation in maturity screening. However, this equation is most sensitive around PHV which is also when the biggest variation in maturity occurs between children of the same CA. Recalled age at menarche may be a suitable maturity indicator in the screening of 14-17 year old females. This method is cheap and simple to administer. However, the recall method has the limitation of error in the recall and an equivalent indicator does not exist in males. Skeletal age assessment, in males and females, is the gold standard and can be utilized in both males and females. However, one would not expect widespread use of skeletal age assessment in the maturity screening of youths as it is expensive, incurs radiation safety issues and requires trained personnel to administer the scans. Another indicator that could be used among males and females that fall outside of the recommended age range for the predictive equation, is the assessment of secondary sex characteristics. Unfortunately, the major hurdle with this tool is the intrusive nature of the assessment.

Maturity structured competitive sports has potential problems outside of the assessment difficulties. For example, one cannot ignore the fact that chronologically older players have been alive for more years than chronologically younger players; thus the older players are likely to have been exposed to hockey and other sports for a longer period of time. By placing individuals into maturity groups one may argue that the chronologically older players will have an unfair advantage. One must also consider the potential psychological harm that may occur to a 15 year old boy who is requested to play and compete with predominantly 11 year old boys. Maturity classifications could, in this situation, reduce enjoyment and satisfaction and lead to children dropping out of the sport.

5.6.2 Current squads and potential squads

Regarding the methods by which athletes are selected, it may be that an awareness of the impact of the biases of CA groupings could change the way in which players, parents, coaches and sport federations perceive potential 'talent' and predict success. However, there will probably always be underlying dilemmas for hockey coaches (and other sport coaches) between the need to develop talent for the future and the need to produce a currently successful team. Brewer and colleagues (1995) suggested that one solution to this dilemma would be to establish 'current' and 'potential' teams; the current team could contain the best players (both technically and physically) at the time of the try-out, whilst the potential team could contain players who are technically at a high standard, but who are lacking in terms of physical maturity. This may help to foster talent regardless of maturity status.

5.6.3 Changing chronological age categories

Purely concerning the relative age biases Barnsley and Thompson (1988) suggested that a reduction in the range of the CA groups, an alteration of cut-off dates for the selection year, and a requirement of 'quotas' of children throughout the selection year might help to reduce birth-date bias in competitive sports.

5.6.4 Reduce physical contact

Another possible way to reduce the biases towards the more mature individual in a CA group is to put more restrictions on the amount of physical contact allowed in the adolescent game of hockey (i.e. eliminate body checking). Reducing physical contact could make the game more focused on skill rather than size; thus allowing the less physically developed (often shorter and lighter) players to play and compete against other players of more advanced maturity within the CA-group structure.

5.7 Limitations

The predictive equation and recalled age at menarche that were used to assess maturity in this investigation have the potential to be used in sporting situations because unlike skeletal assessment, they are cheap, easy to use and do not require exposure to radiation. However, the maturity equation used in this investigation is a prediction, and like any form of prediction the associated errors are likely to be larger than a direct assessment method. The prediction equation has been validated on one sample and was shown to be a reliable measure of age at PHV (Mirwald et al. 2002). Validation on more samples would add further support for the equation as a reliable measure of maturity. Age at menarche has the possibility of error associated with recalling the age at which the event occurred. The years from menarche of the hockey players ranged from 0.01 year to 5.46 years. The girls furthest away from menarche are likely to have greater error in recalling the age at which it occurred than girls that are closer to the event. Furthermore, the hockey players' average age at menarche is slightly biased since 15 of the girls tested had not yet reached menarche.

Not all the girls and boys participating in the try-outs were tested in this investigation. Dates of birth were available on all participants, however maturity and anthropometric data was available on 45.4% of the male hockey players and 35.6% of the female hockey players. Confidence in the results would increase if more of the hockey players had participated in the study.

6. SUMMARY AND CONCLUSIONS

In the past it has been suggested that the chronological age (CA) structure of team sports gives advantage to early maturers and individuals with birthdays early in the selection year. The literature in the area has been purely observational; no prior work has provided reasons to why there is an over-representation of early maturing and chronologically older males in team sports. For example, one reason could be that early maturers and individuals born early in the selection year self-select themselves into the sports where size is an advantage (i.e. basketball, hockey and football). Conversely late maturers and/or individuals born late in the selection could self select themselves into sports at which a late maturing physique gives a performance advantage (i.e. gymnastics).

Another reason for the over-representation of early maturers, and relatively older players, in team sports could be because talent evaluators preferentially select children with a greater physical development. The findings from this investigation suggest that early maturation with its concomitant size advantages increases a boy's chance of being selected for an elite hockey team. In fact the results show that it was impossible for a late maturing boy born late in the selection year to be selected at hockey try-outs. Thus many potentially talented and gifted players are not selected purely because of a lack of physical development. Although other factors (such as self selection and drop out) could contribute to the maturity bias observed in previous literature, the findings from this investigation strongly suggest that selection bias is one probable cause.

Most literature concerned with female athletes and sports have concentrated on individual sports such as gymnastics, ballet and swimming. These studies have predominantly shown elite females to be of a late maturity. There is no literature that has observed the maturity and anthropometric characteristics of female hockey players. The results from this investigation did not show any maturity selection bias in females. However, any maturity bias may have been masked because of the wide range of CAs eligible to compete and the small number of girls in each CA group. The individuals selected were more mature but this was a direct reflection of the preferential selection of chronologically older girls.

Future investigation needs to observe the maturity status, anthropometric characteristics and birth dates of different CA groups in different hockey leagues (across the Canadian provinces and across different countries). This will provide a more comprehensive picture of the biases that are linked with CA groupings. To what extent late maturation is associated with dropping out in adolescent hockey needs to be elucidated through longitudinal studies. If female hockey continues to gain in popularity one would expect the numbers at try-outs to increase and the CA competitive groups to reduce to one chronological year (as seen in male hockey). When, and if, this occurs one can more accurately determine the relationship between CA, physical maturity and talent identification in female hockey.

6.1 Hypotheses summary

H1: Hockey players who are taller and heavier will be more likely selected than the shorter and lighter hockey players

Boys: SUPPORTED

Girls: NOT SUPPORTED

H2: Hockey players who mature earlier will be more likely selected than hockey players who mature later

Boys: SUPPORTED

Girls: NOT SUPPORTED

H3: There will be an uneven birth distribution among the hockey players selected, with more participants being born early in the selection year

Boys: SUPPORTED

Girls: NOT SUPPORTED

7. REFERENCES

Agre, J. C., Casal, D. C., Leon, A. S., McNally, C., Baxter, L., & Serfass, R. C. 2003, "Professional ice hockey players: Physiologic, anthropometric, and musculoskeletal characteristics", *Archives Physical Medical Rehabilitation*, vol. 69, pp. 188-192.

American Academy of Pediatrics Committee on school health 1981, "School Health Examinations", *Pediatrics*, vol. 67, no. 4, pp. 576-577.

Armstrong, N. & Welsman, J. R. 1994, "Assessment and interpretation of aerobic fitness in children and adolescents", *Exercise and Sport Sciences Reviews*, vol. 22, pp. 435-476.

Armstrong, N., Welsman, J. R., & Kirby, B. J. 1997, "Performance on the Wingate anaerobic test and maturation", *Pediatric Exercise Science*, vol. 9, pp. 253-261.

Armstrong, N., Welsman, J. R., & Kirby, B. J. 1998, "Peak oxygen uptake and maturation in 12-yr olds", *Medicine and Science in Sports and Exercise*, vol. 30, no. 1, pp 165-169.

Armstrong, N., Welsman, J., Nevill, A. M., & Kirby, B. 1999, "Modeling growth and maturation changes in peak oxygen uptake in 11-13 yr olds", *Journal of Applied Physiology*, vol. 87, no. 6, pp. 2230-2236.

Backous, D. D., Farrow, J. A., & Friedl, K. E. 1990, "Assessment of pubertal maturity in boys, using height and grip strength", *Journal of Adolescent Health Care*, vol. 11, pp. 497-500.

Bailey, D. A. 1997, "The Saskatchewan Pediatric Bone Mineral Accrual Study: Bone mineral acquisition during the growing years", *International Journal of Sports Medicine*, vol. 18, no. 3, pp.191-194.

Bar-Or, O. 1975, "Predicting athletic performance", *The Physician and Sportsmedicine*, vol. 3, pp. 81-85.

Barnsley, R. H. & Thompson, A. H. 1988, "Birthdate and success in minor hockey: The key to the NHL", *Canadian Journal of Behavioural Science Review*, vol. 20, no. 2, pp. 167-176.

Barnsley, R. H., Thompson, A. H., & Barnsley, P. E. 1985, "Hockey success and birthdate: The relative age effect", *Canadian Association for Health, Physical Education and Recreation*, vol. 51, pp. 23-28.

Barnsley, R. H., Thompson, A. H., & Legault, P. 1992, "Family Planning: Football Style. The relative age effect in football", *International review for the sociology of sport*, vol. 27, pp. 77-87.

Baxter-Jones, A. D. G. 1995, "Growth and development of young athletes: Should competition levels be age related?", *Sports Medicine*, vol. 20, no.2, pp. 59-64.

Baxter-Jones, A. D. G., Goldstein, H., & Helms, P. 1993, "The development of aerobic power in young athletes", *Journal of Applied Physiology*, vol. 75, pp. 1160-1167.

Baxter-Jones, A. D. G. & Helms, P. 1994, "Born too late to win?", *Nature*, vol. 370, no. 186, pp. 186.

Baxter-Jones, A. D. G., Helms, P., Baines Preece, J., & Preece, M. 1994, "Menarche in intensively trained gymnasts, swimmers and tennis players", *Annals of Human Biology*, vol. 21, no. 5, pp. 407-415.

Baxter-Jones, A. D. G., Helms, P., Maffulli, N., & Preece, M. 1995, "Growth and development of male gymnasts, swimmers, soccer and tennis players: A longitudinal study", *Annals of Human Biology*, vol. 22, no. 5, pp. 381-394.

Baxter-Jones, A. D. G. & Maffulli, N. 2002, "Intensive training in elite young female athletes", *British Journal of Sports Medicine*, vol. 36, no. 1, pp. 13-15.

Bayley, N. & Pinneau, S. R. 1952, "Tables for predicting adult height from skeletal age: Revised for use with Greulich-Pyle hand standards", *Journal of Pediatrics*, vol. 40, pp. 423-441.

Beunen, G. & Malina, R. M. 1988, "Growth and physical performance relative to the timing of the adolescent spurt", *Exercise and Sport Sciences Reviews*, vol. 16, pp. 503-540.

Beunen, G., Malina, R. M., Lefevre, J., Claessens, A. L., Renson, R., Simons, J., Maes, H., Vanreusel, B., & Lysens, R. 1994, "Size, fatness and relative fat distribution of males of contrasting maturity status during adolescence and as adults", *International Journal of Obesity*, vol. 18, pp. 670-678.

Beunen, G. P., Malina, R. M., Renson, R., Simons, J., Ostyn, M., & Lefevre, J. 1992, "Physical activity and growth, maturation and performance: A longitudinal study", *Medicine and Science in Sports and Exercise*, vol. 24, pp. 576-585.

Beunen, G., Thomis, M., Maesm, H. H., Loos, R., Malina, R. M., Claessens, A. L., & Vlietinck, R. 2000, "Genetic variance in adolescent growth in stature", *Annals of Human Biology*, vol. 27, no. 2, pp. 173-186.

Bielicki, T. & Hauspie, R. C. 1994, "On the independence of adult stature from the timing of the adolescent growth spurt", *American Journal of Human Biology*, vol. 6, pp. 245-247.

Bielicki, T. & Welon, Z. 1976, "Parent-child height correlations at ages 8 to 12 years in children from Wroclaw, Poland", *Human Biology*, vol. 38, pp. 167-174.

Bogin, B. 1988, *Patterns of Human Growth* University Press, Cambridge.

Bouchard, C., Malina, R. M., Hollmann, W., & Leblanc, C. 1976, "Relationships between skeletal maturity and submaximal working capacity in boys aged 8 to 18 years", *Medicine and Science in Sports*, vol. 8, pp. 186-190.

Boucher, J. & Halliwell, W. 1991, "The novem system: a practical solution to age grouping", *Canadian Association for Health, Physical Education and Recreation*, vol. 57, no. 1, pp. 16-20.

Boucher, J. L. & Mutimer, T. P. 1994, "The relative age phenomenon in sport: A replication and extension with ice-hockey players", *Research Quarterly for Exercise and Sport*, vol. 65, no. 4, pp. 377-381.

Brewer, J., Balsom, P., & Davis, J. 1995, "Seasonal birth distribution amongst European soccer players", *Sports Exercise and Injury*, vol. 1, no. 3, pp. 154-157.

Brewer, J., Balsom, P. D., Davis, J. A., & Ekblom, B. 1992, "The influence of birth date and physical development on the selection of male junior international soccer squad", *Journal of Sports Sciences,* vol 10, no. 6, pp. 561-562. Abstract

Brooks-Gunn, J. & Warren, M. P. 1988, "Mother-daughter differences in menarcheal age in adolescent girls attending national dance company schools and non-dancers.", *Annals of Human Biology*, vol. 15, no. 3, pp. 35-44.

Brown, J. 2001, *Sports Talent* Human Kinetics, Champaign, Illinois.

Brust, J. D., Leonard, B. J., Pheley, A., & Roberts, W. O. 1992, "Children's Ice Hockey Injuries", *American Journal of Diseases of Children*, vol. 146, pp. 741-747.

Buyukgebiz, A., Eroglu, Y., Karman, O., & Kink, E. 1994, "Height and weight measurements of male Turkish adolescents according to biological maturation", *Acta Paediatrica Japonica*, vol. 36, pp. 80-83.

Byard, P. J., Siervogel, R. M., & Roche, A. F. 1988, "Age trends in transmissible and non-transmissible components of family resemblance for stature", *Annals of Human Biology*, vol. 15, no. 2, pp. 111-118.

Cacciari, E., Mazzanti, L., Tassinari, D., Bergamaschi, R., Magnani, C., Ghini, T., Tani, G., Drago, E., Nanni, G., & Cobianchi, C. 1989, "Growth and sport", *Journal of Endocrinology Investigation*, vol. 12, pp. 53-57.

Caine, D. J. & Broekhoff, J. 1987, "Maturity assessment: a viable preventative measure against physical and psychological insult to the young athlete", *The Physician and Sportsmedicine*, vol. 15, no. 3, pp. 67-80.

Cameron, N. 2002, "Assessment of maturation," in *Human Growth and Development*, N. Cameron, ed., Academic Press, San Diego, pp. 363-382.

Centers for disease control and prevention (CDC). 2000, *National Center for Health Statistics CDC growth charts*: United States. Retrieved: March 15, 2004, from www.cdc.gov/growthcharts.htm.

Chen, J. D. 1991, "Growth, exercise, nutrition and fitness in china", *Medicine and Sports Science*, vol. 31, pp. 19-32.

Crampton, C. W. 1908, "Physiological age: A fundamental principle", *American Physical Education Review*, vol. 8, no. 3, pp. 141-154.

Cumming, G. R. 1973, "Correlation of athletic performance and aerobic power in 12 to 17 year old children with bone age, calf muscle, total body potassium, heart volume, and two indices of anaerobic power," in *Pediatric work physiology: Proceedings of the Fourth International Symposium*, O. Bar-Or, ed., The Wingate Institute for Physical Education and Sport, Netanya, pp. 109-134.

Cunningham, D. A., Telford, P., & Swart, G. T. 1976, "The cardiopulmonary capacities of young hockey players: age 10.", *Medicine and Science in Sports*, vol. 8, no. 1, pp. 23-25.

Daniel, T. E. & Janssen, C. T. L. 1987, "More on the relative age effect", *Canadian Association for Health, Physical Education and Recreation*, vol. 53, pp. 21-24.

De Ridder, C. M. 1957, *Sexual maturation of pubertal girls* Hermen v.d.Weiden, Arnhem.

Duck, S. C. 1996, "Identification and assessment of the slowly growing child", *American Family Physician*, vol. 53, no. 7, pp. 2305-260.

Dudink, A. 1994, "Birth date and sporting success", *Nature*, vol. 368, pp. 592.

Duke, P. M., Litt, I. F., & Gross, R. T. 1980, "Adolescents' self-assessment of sexual maturation", *Pediatrics*, vol. 66, pp. 918-920.

Edwards, S. 1994, "Born too late to win?", *Nature*, vol. 370, pp. 186.

Eriksson, B. O., Karlsson, J., & Saltin, B. 1971, "Muscle metabolites during exercise in pubertal boys", *Acta Paediatrica Scandinavica Supplement*, vol. 217, pp. 154-157.

Espenschade, A. S. 1963, "Restudy of the relationships between physical performances of school children and age, height and weight", *Research Quarterly*, vol. 34, pp. 144-153.

Falgairette, G., Duche, P., Bedu, M., Fellmann, N., & Coudert, J. 1993, "Bioenergetic characteristics in prepubertal swimmers - Comparison with active and non-active boys", *International Journal of Sports Medicine*, vol. 14, pp. 444-448.

Falk, B. & Bar-Or, O. 1993, "Longitudinal changes in peak aerobic and anaerobic mechanical power of circumpubertal boys.", *Pediatric Exercise Science*, vol. 5, no. 4, pp. 318-331.

Final Roster for 2002 Winter Olympics, 2002. Retrieved: March 12 2004, from http://www.cs.toronto.edu/~andria/country/canada/roster/2002.html

Forbes, G. B. 1987, *Human body composition and growth, aging, nutrition and activity* Springer-Verlag, New York.

Frisch, R. E., Gotz-Welbergen, A. V., McArthur, J. W., Albright, T., Witschi, J., Bullen, B., Birnholz, J., Reed, R. B., & Hermann, H. 1981, "Delayed menarche and amenorrhea of college athletes in relation to age of onset of training", *J Am Med Ass*, vol. 246, no. 14, pp. 1559-1563.

Frisch, R. E. & Revelle, R. 1969, "The height and weight of adolescent boys and girls at the time of peak velocity of growth in height and weight: Longitudinal data", *Human Biology*, vol. 41, pp. 536-559.

Frisch, R. E. & Revelle, R. 1971, "Height and weight at menarche and a hypothesis of menarche", *Archives of Disease in Childhood*, vol. 46, pp. 695-701.

Galton, F. 1886, "Regression towards mediocrity in hereditary stature", *Journal of the Anthropometric Institute*, vol. 15, pp. 277-280.

Gasser, T., Sheehy, A., Molinari, L., & Largo, R. H. 2001, "Growth of early and late maturers", *Annals of Human Biology*, vol. 28, no. 3, pp. 328-336.

Glamser, F. D. 1992, "The birth date effect and college athletic participation: Some comparisons", *Journal of Sport Behavior*, vol. 15, no. 3, pp. 227-237.

Godfrey, S. 1974, *Exercise Testing in Children.* W.B. Saunders Company Ltd, London.

Goldberg, B. & Boiardo, R. 1984, "Profiling children for sports participation", *Clinics in Sports Medicine*, vol. 3, no. 1, pp. 153-159.

Greulich, W.W. & Pyle, S.I. 1959, Radiographic atlas of skeletal development of the hand and wrist, 2nd edition. Stanford University Press, Stanford, CA.

Grondin, S. & Koren, S. 2000, "The relative are effect in professional baseball: A look at the history of major league baseball and at current status in Japan", *Avante*, vol. 6, no. 2, pp. 64-74.

Guo, S. S., Chumlea, W. C., Roche, A. F., & Siervogel, R. M. 1997, "Age-and maturity-related changes in body composition during adolescence into adulthood: The Fels Longitudinal Study", *International Journal of Obesity*, vol. 21, pp. 1167-1175.

Hafner, J. K., Scott, S. E., Veras, G., Goldberg, B., Nicholas, J. A., & Shaffer, T. E. 1982, "Interscholastic athletes", *New York State Journal of Medicine*, vol. 82, pp. 1165-1906.

Hagg, U. & Taranger, J. 1991, "Height and height velocity in early, average and late maturers followed to the age of 25: a prospective longitudinal study of Swedish urban children from birth to adulthood", *Annals of Human Biology*, vol. 18, no. 1, pp. 47-56.

Hale, J. C. 1956, "Physiological maturity of Little League baseball players", *Research Quarterly*, vol. 27, pp. 276-284.

Harrison, D. 2004, *Hockey's prairie home.* Retrieved: March 14, 2004, from http://www.cbc.ca/sports/hockey/hdic2004/stories/sasktalent.html

Haschke, F. 1983, "Body composition of adolescent males", *Acta Paediatrica Scandinavica*, vol. 307, pp. 1-23.

Hauspie, R. C. 2002, "Adolescence: Somatic growth and sex differences," in *Human Growth and Development*, N. Cameron, ed., Academic Press, San Diego, pp. 45-63.

Helsen, W. F., Starkes, J. L., & Winckel, J. V. 2000, "Effect of a change in selection year on success in male soccer players", *American Journal of Human Biology*, vol. 12, pp. 729-735.

Horrigan, J. M. & Kreis, E. J. 2002, *Strength, conditioning, and injury prevention for hockey* Contemporary Books, Chicago.

Houston, M. E. & Green, H. J. 1976, "Physiological and anthropometric characteristics of elite Canadian ice hockey players", *Journal of Sports Medicine*, vol. 16, pp. 123-128.

Iulliano-Burns, S., Mirwald, R. L., & Bailey, D. A. 2001, "Timing and magnitude of peak height velocity and peak tissue velocities for early, average, and late maturing boys and girls", *American Journal of Human Biology*, vol. 13, pp. 1-8.

Johnston, F. E. & Malina, R. M. 1966, "Age changes in the composition of the upper arm in Philadelphia children", *Human Biology*, vol. 38, pp. 1-21.

Jones, H. E. 1946, "Skeletal maturing as related to strength", *Child Development*, vol. 17, pp. 173-185.

Jones, H. E. 1949 in Malina, R. M., Bouchard, C., & Bar-Or, O. 2004, "Maturity-association variation in growth and performance," in *Growth, maturation, and physical activity*, 2 edn, Human Kinetics, Champaign, Il.

Kaur, B. & Singh, R. 1994, "One year follow-up study of stature, weight, emergence of dentition, and sexual maturation of well-nourished Indian girls from birth to 20 years", *American Journal of Human Biology*, vol. 6, pp. 425-436.

Kemper, H. C. G. & Verschuur, R. 1981, "Maximal aerobic power in 13- and 14-year-old teenagers in relation to biological age", *International Journal of Sports Medicine*, vol. 2, pp. 97-100.

Kemper, H. C. G., Verschuur, R., & Ritmeester, J. M. 1985, "Maximal aerobic power in early and late maturing teenagers," in *Children and Exercise*, 7 edn, J. Rutenfranz, R. Mocellin, & F. Klimt, eds., Human Kinetics Books, Champaign, Illinois, pp. 213-225.

Kobayashi, K., Kitokazu, K., Miura, M., Sodeyama, H., Murase, Y., Miyashita, M., & Matsui, H. 1978, "Aerobic power as related to body growth and training in Japanese boys: a longitudinal study", *Journal of Applied Physiology*, vol. 44, pp. 666-672.

Kotulan, J., Reznickova, M., & Placheta, Z. 1980, "Exercise and growth.," in *Youth and Physical Activity.*, Z. Placheta, ed., Brno: JE Purkyne University Medical Faculty, Purkyne, pp. 61-117.

Koziel, S. 2001, "Relationship among tempo of maturation, midparent height, and growth in height of adolescent boys and girls", *American Journal of Human Biology*, vol. 13, pp. 15-22.

Kreipe, R. E. & Gewanter, H. L. 1985, "Physical maturity screening for participation in sports", *Pediatrics*, vol. 75, no. 6, pp. 1076-1080.

Lariviere, G. & LaFond, A. 1986, "Physical maturity in young elite ice hockey players", *Canadian Journal of Applied Sport Sciences*, vol. 11, pp. 24.

Lindgren, G. 1978, "Growth of schoolchildren with early, average and late ages of peak height velocity", *Annals of Human Biology*, vol. 5, no. 3, pp. 253-267.

Malina, R. M. 1978, "Adolescent growth and maturation: Selected aspects of current research", *Yearbook of Physical Anthropology*, vol. 21, pp. 63-94.

Malina, R. M. 1983, "Menarche in athletes: a synthesis and hypothesis", *Annals of Human Biology*, vol. 10, no. 1, pp. 1-24.

Malina, R. M. 1988, "Competitive youth sports and biological maturation," in *Competitive Sports for Children and Youth*, E. W. Brown & C. F. Branta, eds., Human Kinetics Books, Champaign, Illinois, pp. 227-245.

Malina, R. M. 1994, "Physical growth and biological maturation of young athletes", *Exercise and Sport Sciences Reviews*, vol. 22, pp. 389-434.

Malina, R. M. & Beunen, G. 1996, "Monitoring growth and maturation," in *The Child and Adolescent Athlete*, O. Bar-Or, ed., Blackwell Science, Oxford, UK, pp. 647-672.

Malina, R. M., Beunen, G., Lefevre, J., & Woynarowska, B. 1997, "Maturity-associated variation in peak oxygen uptake in active adolescent boys and girls", *Annals of Human Biology*, vol. 24, pp. 19-31.

Malina, R. M. & Bouchard, C. 1991, *Growth, Maturation and Physical Activity* Human Kinetics, Champaign, Il.

Malina, R. M. Bouchard, C. & Bar-Or, O. 2004, *Growth, Maturation and Physical Activity, 2nd Ed.* Human Kinetics, Champaign, Il.

Malina, R. M., Meleski, B. W., & Shoup, R. F. 1982, "Anthropometric, body composition and maturity characteristics of selected school-age athletes", *Pediatric Clinics of North America*, vol. 29, pp. 1305-1323.

Marshall, W. A. & Tanner, J. M. 1969, "Variations in pattern of pubertal changes in girls", *Archives of Disease in Childhood*, vol. 44, no. 235, pp. 291-303.

Marshall, W. A. & Tanner, J. M. 1970, "Variations in the pattern of pubertal changes in boys", *Archives of Disease in Childhood*, vol. 45, pp. 13-23.

Martens, R. 1980, "The uniqueness of the young athlete: psychological considerations", *American Journal of Sports Medicine*, vol. 8, pp. 382-385.

Matsudo, S. M. M. & Matsudo, V. K. R. 1994, "Self-assessment and physician assessment of sexual maturation in Brazilian boys and girls: Concordance and reproducibility", *American Journal of Human Biology*, vol. 6, pp. 451-455.

Mercier, B., Mercier, J., Granier, P., Le Gallais, D., & Prefaut, C. 1992, "Maximal anaerobic power: Relationship to anthropometric characteristics during growth", *International Journal of Sports Medicine*, vol. 13, pp. 21-26.

Mirwald, R. L., Bailey, D. A., Cameron, N., & Rasmussen, R. L. 1981, "Longitudinal comparison of aerobic power in active and inactive boys aged 7.0 to 17.0 years", *Annals of Human Biology*, vol. 8, pp. 405-414.

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 and Exercise*, vol. 34, no. 4, pp. 689-694.

Mueller, W. H. 1976, “Parent-child correlations for stature and weight among school ages children: A review of 24 studies”. *Human Biology* vol. 48, no. 2, 379-397. Abstract

Musch, J. & Grondin, S. 2001, "Unequal competition as an impediment to personal development: A review of the relative age effect in sport", *Developmental Review*, vol. 21, pp. 147-167.

Musch, J. & Hay, R. 1999, "The relative age effect in soccer: Cross sectional evidence for a systematic discrimination against children born late in the competition year", *Sociology of Sport Journal*, vol. 16, pp. 54-64.

Nevill, A. M., Holder, R. L., Baxter-Jones, A., Round, J. M., & Jones, D. A. 1998, "Modeling developmental changes in strength and aerobic power in children", *Journal of Applied Physiology*, vol. 84, no. 3, pp. 963-970.

NHL Team Roster. 2004, Retrieved: March 12 2004, from http://www.foxsports.com/ named/ FS/NHL/teamRoster?statsId=23

Nindl, B. C., Mahar, M. T., Harman, E. A., & Patton, J. F. 1995, "Lower and upper body anaerobic performance in male and female adolescent athletes", *Medicine and Science in Sports and Exercise*, vol. 27, pp. 235-241.

Onat, T. 1975, "Prediction of adult height of girls based on the percentage of adult height at onset of secondary sexual characteristics, at chronological age, and skeletal age", *Human Biology*, vol. 47, no. 1, pp. 117-130.

Onat, T. & Ertem, B. 1974, "Adolescent female height velocity: Relationships to body measurements, sexual and skeletal maturity", *Human Biology*, vol. 46, no. 2, pp. 199-217.

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. 1988, "A self-report measure of pubertal status: Reliability, validity, and initial norms", *Journal of Youth and Adolescence*, vol. 17, pp. 117-133.

Pratt, M. 1989, "Strength, flexibility, and maturity in adolescent athletes", *American Journal of Diseases of Children*, vol. 143, pp. 560-563.

Quin, T., Shohoji, T., & Sumiya, T. 1996, "Relationship between adult stature and timing of the pubertal growth spurt", *American Journal of Human Biology*, vol. 8, pp. 417-426.

Rahkila, P., Lintunen, T., Silvennoinen, M., & Osterback, L. 1988, "Physical fitness of novice ice hockey players in relation to skeletal age.," in *Young athletes.*, R. M. Malina, ed., Human Kinetics, Champaign, Illinois, pp. 193-202.

Reynolds, E. L. & Wines, J. V. 1948, "Individual differences in physical changes associated with adolescence in girls", *American Journal of Diseases of Children*, vol. 75, pp. 329-350.

Reynolds, E. L. & Wines, J. V. 1951, "Physical changes associated with adolescence in boys", *American Journal of Diseases of Children*, vol. 82, pp. 529-547.

Roche, A. F. 1989, "The final phase of growth in stature", *Growth, Genetics and Hormones*, vol. 5, no. 4, pp. 4-6.

Roche, A.F., Chumlea, W.C. & Thissen, D. 1988, "Assessing the skeletal maturity of the hand-wrist: Fels Method". C.C. Thomas Springfield, IL.

Roche, A. F. & Davila, G. H. 1972, "Late adolescent growth in stature", *Pediatrics*, vol. 50, no. 6, pp. 874-880.

Roche, A. F., Wainer, H., & Thissen, D. 1975, "The RWT method for the prediction of adult stature", *Pediatrics*, vol. 56, pp. 1026-1033.

Roemmich, J. N., Richmond, E. J., & Rogol, A. D. 2001, "Consequences of sport during puberty", *Journal Endocrinology Investigation*, vol. 24, pp. 708-715.

Ross, W. D. & Marfell-Jones, M. J. 1991, "Kinanthropometry," in *Physiological Testing of the High-Performance Athlete*, 2nd edn, J. D. MacDougall, H. A. Wenger, & H. J. Green, eds., Human Kinetics Books, Champaign, Illinois, pp. 223-308.

Rotch, T. M. 1909, "A study of the development of the bones in children by roentgen method, with the view of establishing a developmental index for grading of and the protection of early life", *Transactions of the Association of American Physicians*, vol. 24, pp. 603-630.

Saavedra, C., Lagasse, P., Bouchard, C., & Simoneau, J. 1991, "Maximal anaerobic performance of the knee extensor muscle during growth", *Medicine and Science in Sports and Exercise*, vol. 23, no. 9, pp. 1083-1089.

Schroeder, B. A. 1992, *Human Growth and Development* West Publishing Company, St. Paul.

Shaffer, T. E. 1973, "The adolescent athlete", *Pediatric Clinics of North America*, vol. 20, pp. 837-849.

Sharp, C., Hutchinson, D., & Whetton, C. 1994, "How do season of birth and length of schooling affect children's attainment of key stage 1", *Educational Research*, vol. 36, no. 2, pp. 1107-121.

Sherar, L.B., Baxter-Jones, A.D.G., & Mirwald, R.L. 2004, "Limitations to the use of secondary sex characteristics in gender comparisons", Annals of Human Biology. In Press

Stager, J. M. & Hatler, L. K. 1988, "Menarche in athletes: The influence of genetics and prepubertal training", *Medicine and Science in Sports and Exercise*, vol. 20, pp. 369-373.

Susanne, C. 1975, "Genetic and environment influences on morphological characteristics", *Annals of Human Biology*, vol. 2, no. 3, pp. 279-287.

Tanner, J. M. 1962, *Growth at Adolescence*, 2 edn, Blackwell Scientific Publications, Oxford.

Tanner, J. M. 1989, *Foetus into man. Physical growth from conception to maturity*, 2 edn, Castlemead Publications, London.

Tanner, J. M., Goldstein, H., & Whitehouse, R. H. 1970, "Standards for children's height at ages 2-9 years allowing for height of parents", *Archives of Disease in Childhood*, vol. 45, pp. 755-762.

Tanner, J. M., Healy, M. J. R., Goldstein, H., & Cameron, N. 2001, *Assessment of skeletal maturity and prediction of adult height (TW2 Method)*, 3 edn, Saunders, London.

Tanner, J. M. & Whitehouse, R. H. 1976, "Clinical longitudinal standards for height, weight, height velocity, weight velocity and stages of puberty", *Archives of Disease in Childhood*, vol. 51, pp. 170-179.

Tanner, J. M., Whitehouse, R. H., Cameron, N., Marshall, W. A., Healy, M. J. R., & Goldstein, H. 1983, *Assessment of skeletal maturity and prediction of adult height*, 2 edn, Academic Press, New York.

Tanner, J.M., Whitehouse, R.H., Marshall, W.A., Healy, M.J.R, Goldstein, H. (1975) Assessment of skeletal maturity and prediction of adult height (TW2 method). Academic Press, New York.

Tanner, J. M., Whitehouse, R. H., & Takaishi, M. 1966a, "Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965 Part I", *Archives of Disease in Childhood*, vol. 41, pp. 454-471.

Tanner, J. M., Whitehouse, R. H., & Takaishi, M. 1966b, "Standards from birth to maturity for height, weight, height velocity, and weight velocity: British Children, 1965 Part II", *Archives of Disease in Childhood*, vol. 41, pp. 613-635.

Thompson, A. H., Barnsley, R. H., & Stebelsky, G. 1991, "Born to play ball: The relative age effect and major league baseball", *Sociology of Sport Journal*, vol. 8, pp. 146-151.

Twist, P. 1997, *Complete conditioning for ice hockey* Human Kinetics, Champaign, Illinois.

Verhulst, J. 1992, "Seasonal birth distribution of West European soccer players: A possible explanation", *Medical Hypotheses*, vol. 38, pp. 346-348.

Wacharasindhu, S., Pri-ngam, P., & Kongchonrak, T. 2002, "Self-assessment of sexual maturation in Thai children by Tanner photograph", *Journal of the Medical Association Thailand*, vol. 85, no. 3, pp. 308-319.

Warren, M. P. 1980, "The effects of exercise on pubertal progression and reproductive function in girls", *Journal of Clinical Endocrinology and Metabolism*, vol. 51, pp. 1150-1157.

Welch, Q. B. 1970, "Fitting growth and research data", *Growth*, vol. 34, pp. 293-312.

Wellens, R., Malina, R. M., Roche, A. F., Chumlea, W. C., Guo, S., & Siervogel, R. M. 2003, "Body size and fatness in young adults in relation to age of menarche", *American Journal of Human Biology*, vol. 4, no. 6, pp. 783-787.

Welon, Z. & Bielicki, T. 1971, "Further investigations of parent-child similarity in stature, as assessed from longitudinal data", *Human Biology,* vol. 43, pp. 517-525. Abstract

Whieldon, D. 1978, "Maturity sorting: new balance for young athletes", *The Physician and Sportsmedicine*, vol. 6, pp. 127-132.

Williams, R. L., Cheyne, K. L., Houtkooper, L. K., & Lohman, T. G. 2003, "Adolescent self-assessment of sexual maturation: Effects of fatness classification and actual maturation stage", *Journal of Adolescent Health Care*, vol. 9, pp. 480-482.

van Lenthe, F. J., Kemper, H. C. G., & Van Mechelen, W. 1996, "Rapid maturation in adolescence results in greater obesity in Adulthood: The Amsterdam Growth and Health Study", *American Journal of Clinical Nutrition.*, vol. 64, pp. 18-24.

Yoneyama, K., Nagata, H., & Sakamoto, Y. 1988, "A comparison of height growth curves among girls with different ages of menarche", *Human Biology*, vol. 60, no. 1, pp. 33-41.

Zacharias, L. & Rand, W. M. 1986, "Adolescent growth in weight and its relation to menarche in contemporary American girls", *Annals of Human Biology*, vol. 13, no. 4, pp. 369-386.

8. APPENDIX A: Ethics Approval

UNIVERSITY OF SASKATCHEWAN

BEHAVIOURAL RESEARCH ETHICS BOARD

http://www.usask.ca/research/ethics.shtml

NAME: Adam Baxter-Jones (Lauren Sherar) **BSC#:** 03-1128

College of Kinesiology

DATE: September 16, 2003

The University of Saskatchewan Behavioural Research Ethics Board has reviewed the Application for Ethics Approval for your study "Relationship Between Maturational Status and Talent Identification in Youth Sports" (03-1128).

1. Your study has been APPROVED.

2. Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair for Committee consideration in advance of its implementation.

3. The term of this approval is for 5 years.

4. This approval is valid for five years on the condition that a status report form is submitted annually to the Chair of the Committee. This certificate will automatically be invalidated if a status report form is not received within one month of the anniversary date. Please refer to the website for further instructions: http://www.usask.ca/research/behavrsc.shtml

I wish you a successful and informative study.

Dr. David Hay, Acting Chair
University of Saskatchewan
Behavioural Research Ethics Board

DH/ck

9. APPENDIX B: Youth/hockey player consent form

UNIVERSITY OF SASKATCHEWAN
Youth/Participant Consent Form

You are invited to participate in a study entitled*: The relationship between maturational status and talent identification in youth sports*. You do not have to take part in this study unless you want to and it will not affect your chances of making the team. Please read this form carefully and feel free to ask any questions.

Researcher: Adam Baxter-Jones, College of Kinesiology, University of Saskatchewan, 966-1078
Research Assistant: Lauren Sherar, College of Kinesiology, University of Saskatchewan, 966-1123

Purpose of the study

Most 'try-outs' for sporting teams involve young people of the same age playing against each other. It is believed that the best players will 'shine out' because against people of the same age they will play the best. However, many people believe that this is not the fairest method of spotting the best players.

There is much difference in the growth and development of boys and girls as they enter puberty. As you may have seen among your friends there are age early, average and late maturers. For example, take two girls of the same age; one girl could have her growth spurt at 12 years of age and the other girl at 15 years of age. They might both end up the same height but the first girl (the early maturer) is taller than her friend for 3 years. It has been suggested that an early maturer might get picked for sports teams over a late maturer simply because he/she is bigger and stronger.

The aim of this study is to see whether early, average or late maturing individuals are more likely to be selected during try-out for sports teams. Age, sitting height, standing height, weight will be used to predict if an individual is an early, average or late maturer. Furthermore information on your parent's height and your weight at birth will be used to assess maturity.

Procedures

At the try-outs there will be research assistants present who will measure your weight (if you choose to participate in the study). Then you will sit with your back against a wall and your sitting height will be measured. Lastly you will stand next to a wall and your full height will be measured. Measurements are very quick and easy to take so shouldn't hold up the try-outs. Your parents will be asked on their consent form to note your birth weight and their heights.

The results from this study will be published and presented at conferences; however, your name will be kept confidential. You may leave the study for any reason, at any time. Furthermore, taking part in this study will not have any affect on your chance of making the team and your predicted maturational status (early, average or late) will remain confidential. If you have any questions you can call collect either Adam Baxter-Jones or Lauren Sherar (telephone number at the top of the page) or the Office of Research Services on 966-2084.

Consent Form

Signing this form shows that I__________________________ agree to take part in the study *The relationship between maturational status and talent identification in youth sports.* It shows that I understand the following,

1. I understand the reason for this study and what will be asked of me if I take part
2. Taking part in this study is totally up to me. If I don't want to I don't have to answer the questions and/or have the measurements taken. I can leave the study at any time. My decision (taking part in the study/not taking part in the study) will have no effect on my chance of making the team.
3. There are no risks involved with taking part in this study
4. All data on individuals will be kept unknown from anyone outside of the study
5. If I withdraw from the study then my data will be deleted
6. I have read and understood the information provided in this letter, and have been given a copy of that letter and the consent form for myself.

I ________________________ have read the above statements about the study and I what is required of me if I choose to participate in the study.

_________________	________________________
My Name	My Signature
___________________	________________________
Researcher's Name	Researcher's Signature

Lauren Sherar, MSc (306) 966-1123
Adam Baxter- Jones, PhD (306) 966- 1078
College of Kinesiology
University of Saskatchewan

10. APPENDIX C: Parental consent form

UNIVERSITY OF SASKATCHEWAN
Parental Informed Consent

Your child is invited to participate in a study entitled: *The relationship between maturational status and talent identification in youth sports.* This is an optional activity and is not part of the selection process for the team that your child is trying out for. Please read this form carefully and feel free to ask any questions.

Researcher: Adam Baxter-Jones, College of Kinesiology, University of Saskatchewan, 966- 1078
Research Assistant: Lauren Sherar, College of Kinesiology, University of Saskatchewan, 652-1123

Purpose of the study

The majority of 'try-outs' for sporting teams involve children of the same age competing against each other. It is believed that the best players will 'shine out' because against children of the same age they will be the best performers. However, many people believe this is not the fairest method of spotting the most talented players, or predicting promising players for the future.

As children enter the years between childhood into puberty, there is much variation in the growth and development of individuals of the same sex and age (i.e. early, average and late maturers can be seen). A child with advanced maturity may succeed in chronological grouped competition because he/she is structurally more advanced (i.e. bigger and stronger) whilst a late maturer may not 'shine' in try-outs purely because they are yet to fulfill their true potential ('late bloomer'). Ignoring the late maturer may have a negative impact on the child's future, as well as their current success in the sport. This is because he/she will not be exposed to the same top level coaching, become known to selectors or experience international competitions and tournaments from an early age. Therefore, to reduce the size, strength and skill mismatches in youth sport, some researchers have suggested matching youths by biological maturity status.

The aim of this study is to observe the relationship between maturational status of a child (i.e. early, average, late maturer) and how successful he is in trying out for a team. In doing this we will be able to see if the 'late bloomer' is being neglected during try-outs for sporting teams. Information on chronological age, standing height, sitting height, weight, youth's weight at birth and parental heights will be used to predict a child's maturational status.

Procedures

At the try-outs a research assistant will measure your child's weight (if you and your child agree to participate in the study) on a digital scale. Then he will sit with his back against a wall and his sitting height will be measured. Lastly he will stand next to a wall and full height will be measured. Measurements are very quick and easy to take and there will be two research assistants working simultaneously so as not to hold-up the selection process. The selection committee will inform the researchers of the results of the try-outs at a later date. Attached to the back of this consent form is a place for you to document your child's weight at birth and parental heights.

Participation of your youth in this study may help researchers to better understand the link between maturational status and success in achieving places in sporting teams. This may help to create awareness and promote a better system of talent identification. Hopefully the new system will be more accurate thus promoting a fairer selection process, safer participation in sport and ultimately enhancing future enjoyment in youth sports.

The data from this study will be published and presented at conferences; however, your child's identity will be kept confidential. You/or your child may withdraw from the study for any reason, at any time, without penalty of any sort, including current or future participation in this or any other program. Furthermore, taking part in this study will not have any enhancing or detrimental affect on your child's chance of making the team and your child's predicted maturational status will remain confidential.

If you have any questions concerning the study, please feel free to ask them at any time; you are also free to contact the researcher (call collect) at the number provided above if you have any questions at a later date. Any questions regarding your child's rights as a participant may be addressed to the University of Saskatchewan Behavioural Sciences Research Ethics Board through the office of Research services call collect on 966-2084. You may contact the researcher to find out the results of the study and a copy of the published manuscript can also be requested.

Consent Form

My signature on this sheet indicates that I have received information regarding the nature of the study, its purpose, and procedure, and I will allow my son, ______________________, to participate in the study *The relationship between maturational status and talent identification in youth sports.* It indicates that I understand the following,

1. I received information regarding the nature of the study, its purpose, and procedures. This research project was reviewed and approved on ethical grounds by the University of Saskatchewan Advisory Committee on Ethics in Behavioral Science Research on Dec 4, 2003
2. Participation is totally voluntary; the participant (my son) has the right not to answer any or all of the questions, refuse any or all of the measurements and can withdraw from the study at any time without any fear of penalty. The decision to refuse consent, withdraw from the study or take part in the study will have no effect on the selection process i.e. it will have no enhancing or detrimental effects on my child's chance of making the team.
3. If my child withdraws from the study then his data will be deleted
4. There are no risks of psychological or physiological harm
5. All individual data that is provided will remain confidential from sources outside of the study (including the selection committee).
6. I will receive a summary of the project, upon request, following completion of the project.
7. I have read and understood the information provided in the cover letter, and have received a copy of that letter and the consent form for my records.

I ________________________ have read the above statements regarding the study and

understand the conditions of ________________(my child's) participation in this study.

Parent/Guardian's Signature____________________ Date:_____________

Researcher's Signature ____________________ Date:_____________

Lauren Sherar, MSc (306) 966-1123
Adam Baxter- Jones, PhD (306) 966- 1078
College of Kinesiology
University of Saskatchewan

please turn over

I would appreciate if you could provide in the spaces below information concerning your child. Please indicate the weights and heights in the units you are most familiar (i.e. feet and inches or centimeters and meters)

Child's birth weight ____________________

Mother's height ____________________

Father's height ____________________

Thank you

11. APPENDIX D: Testing form (female)

Date: Jan 16th, 2004
Camp: Zone: 4
Location: Kamsack

Subject name: ______________________________

Telephone number: ______________________________

D.O.B: ______________________________

Height (cm):
1) ______________________________
2) ______________________________
3) ______________________________

Sitting height (cm):
1) ______________________________
2) ______________________________
3) ______________________________

Weight (kg):
1) ______________________________
2) ______________________________
3) ______________________________

Age of menarche: month ____________ **Year** ____________