The role of growth, physical activity, and sport involvement on fundamental movement skills performance

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By

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Abstract

Background: Fundamental Movement Skills (FMS) consist of locomotor skills that are used to propel a human body through space and object control skills that include manipulating an object in action situations. It is known that FMS are imbedded by 8 years of age, less is known about their development through adolescence. This is of particularly interest given the suggestion that during adolescence there is a perceived period of physical awkwardness. Both sports participation (SP) and habitual physical activity (PA) have been shown to improve FMS. The purpose for this study was to identify the effect growth had on FMS development, whilst controlling for PA and SP. **Methods:** Eighty-four individuals (23 male, 61 female) were recruited from sports camps and teams. Age, height, sitting height and weight were measured and a biological age (BA) (years from peak height velocity [PHV]) predicted. Three maturity groups were identified: pre-PHV (n=21), peri-PHV (n=12) and post-PHV (n=51). SP and PA were assessed by questionnaire. The Test of Gross Motor Development 2 (TGMD-2) was used to assess the quality of FMS performance. Mean differences between groups were tested with an ANOVA and ANCOVA. **Results:** Significant differences were found between BA groups and FMS scores, with post-PHV having significantly greater FMS Scores (82±6) than pre-PHV (74±6) and peri-PHV (74±11) ($p<0.05$). Physical activity was only significantly different between pre-PHV (3.2±0.7) and post-PHV (2.6±0.4) ($p<0.05$). Sports participation was not significantly different between groups ($p>0.05$). A regression analysis found that sex, age, and SP ($p<0.05$) were significant predictors of FMS scores. **Discussion:** There was no observable decline in performance during rapid growth, the period of potential physical awkwardness. It was found that the most mature individuals performed the best. This is not unexpected as post-PHV participants were significantly older and therefore would have had more time to be taught, learn and practice their FMS through PA and sports participation. Interestingly, males outperformed females when adjustments were made for age and sports participation. These results do not support the contention that FMS are negatively impacted during the period of rapid adolescent growth.

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1. Introduction

Physical activity is an important part of healthy living at any age but is of particular importance during childhood when lifelong habits are started. Physical activity is important as it has been linked to reducing risks of many chronic diseases. It has also been linked to reducing the usage of tobacco, alcohol and drugs. It helps develop cardiovascular fitness, strength, flexibility and bone density. Physical activity comprises two components: (i) habitual physical activity and (ii) exercise or sport. One of the key components of sport is the development of fundamental movement skills (FMS). FMS have been holistically and comprehensively defined by Holfelder and Schott (2014), as

> "Consisting of locomotor skills that are used to propel a human body through space (e.g. running, jumping, and hopping) and object control skills that include manipulating an object in action situations (e.g. throwing, catching, kicking) … [That] are the building blocks for more complex and sport-specific skills" (Holfelder and Schott, 2014).

Fully developed FMS allow individuals to participate in varying sports with ease, whereas, a lack of skill development could lead to a lifelong disconnect from organized or unorganized recreation and sport (CS4L, 2015). The development of FMS follows a systematic and continuous process.

FMS milestones are attained throughout childhood and should be established into a person's physical ability by around the age of eight (Haywood and Getchell, 2009). The milestones start with crawling (around 8.5 months old) and finish with catching (around 8 years old) (Adolph *et* al, 2011; Haywood and Getchell, 2009). Catching is one of the last FMS developed due to the varying situations and objects to be caught, which makes evaluation of catching difficult due to the proficiency required to excel in various situations (Haywood and Getchell, 2009). Although FMS are attained at similar times and in a structured pattern, in different individuals, they need to be continually practiced in order to maintain proficiency (Haywood and Getchell, 2009). Failure to have FMS taught and developed properly, as well as not maintaining skills throughout the lifespan, can result in apprehension to participate in sport; this is especially crucial during the adolescent years where the formation of adult habituations occur (CS4L, 2015; Ford *et al*, 2011; Haywood and Getchell, 2009).

During the adolescent growth spurt (indexed by peak height velocity [PHV]) performance declines have been documented and a possible reason for this could be a decline in the ability to perform fundamental movement skills (Beunen & Malina, 1988; Butterfield *et al*, 2004; Davies & Rose, 2000; Isaacs *et al*, 2003; Lloyd & Oliver, 2012; Philippaerts *et al*, 2006; Quatman-Yates *et al.*, 2012; Tanner, 1978; Visser *et al.*, 1998). "Adolescent Awkwardness" (AA) is a term used to describe the phase of development characterized by clumsiness occurring during the adolescent growth spurt (Van der Kamp, 2015). Previous studies have been inconclusive on the existence of AA, through outcome-based performance have been shown to decline in repeatedly measured fitness tests (Beunen & Malina, 1988; Quatman-Yates *et al.*, 2012). In the study by Philippaerts *et al* (2006) measures of performance were the resultants of outcome measures achieved by participants and not the measure of their ability to move. For example: the participants' ability to perform a number of repetitions in a set amount of time or completing a task as quickly as possible. Declines in 30m-dash performance (taking longer to complete the task) were attributed to AA (Philippaerts *et al*, 2006). It is important to note that a decline in performance has been used as the indication of AA but this is not an indication of poor motor performance (MP) just a poor performance outcome on the day of testing.

Motor Performance is defined as "the observable production of a voluntary action, or a motor skill" (Schmidt and Wrisberg, 2008). The level to which a person is able to perform may be affected by temporary factors such as motivation, arousal, fatigue, and physical condition (Schmidt and Wrisberg, 2008). Analyzing motor performance provides the ability to monitor a person's motor learning (current capability for producing a particular movement) by observing the changes that occur systematically with additional practice (Schmidt and Wrisberg, 2008). If fatigue and physical condition are not optimal at the time of testing, the analysis of motor performance can be a better indicator of learning than performance based outcome measures. Analysis of the performance quality of FMS could give a better indication of skill development than motor performance outcome measures. What is less understood is the effects of growth and maturation on FMS development.

Growth and maturation are dynamic biological processes that interact with each other as well as with behavioral development which occur simultaneously and are particularly prevalent during adolescence (Sherar *et al.,* 2010). As indicated previously, FMS need to be learned in an appropriate timing and order as they are considered to be the building blocks for more specialized movement patterns (Balyi, 2001; CS4L, 2016). As humans develop, a certain amount of maturity (progression towards the adult state) is required in order to learn and perform varying skills, otherwise the individual is not strong enough to learn, perform, and practice consistently (CS4L, 2016). Due to the individual variability in timing and tempo of maturation it is essential to align individuals using an indicator of biological age (BA) rather than chronological age (CA). An example of a measure of BA is years from attainment of a sexual millstone such as PHV (Mirwald *et al.,* 2002; Moore *et al.*, 2014; Sherar *et al.,* 2005; Sherar *et al.*, 2010). Levels of physical activity have been associated with FMS development (Cohen *et al.,* 2015), however it has been found that physical activity levels decrease as a child's biological age increases (Sherar *et al.*, 2010). In addition to affecting FMS development, this age-related decline in physical activity during adolescence is problematic because a positive caloric balance is created, that can lead to excessive fat accumulation (Rowland, 1998).

The promotion of regular physical activity serves as a sound preventative health strategy (Rowland, 1998). Habitual physical activity levels have been shown to reduce the incidence of coronary artery disease, obesity, osteoporosis, and other significant contributors to morbidity and mortality in the general population (Rowland, 1998). Involvement in sports has also been shown to have substantial health benefits, including but not limited to: a healthy weight status, higher physical fitness, and improved cognitive functioning (Lubans *et al,* 2010; Okely *et al,* 2004; Sibley and Etnier, 2003). In order to set individuals up for lifelong participation in physical activity, the attainment of FMS needs to be promoted during developmental years and maintained throughout the lifespan (Hardy *et al.*, 2010; Quatman-Yates *et al.*, 2012). This is important because a greater mastery of FMS correlates with higher levels of physical activity (Cohen *et al.,* 2015).

The effects that fully and partially developed FMS have on physical activity levels have been well documented. A positive correlation between object control proficiency and time spent in daily physical activity has been found (Barnett *et al.*, 2009). School based FMS interventions have been proven to maintain physical activity, improve FMS competency, and increased cardiorespiratory fitness in children (Cohen *et al.*, 2014). Mastery of FMS is assumed in individuals in order for them to participate in or show interest in participation of varying sports and activities (Holfelder & Schott, 2014).

FMS also play an important role in setting the foundation for sport performance (CS4L, 2016). Sport performance is the execution of a sport-specific action or actions within the domain of the sport in order to obtain advantage over opposition (Merriam-Webster, 2016; Oxford Dictionaries, 2016). These skills are more complex in their application and/or the environment is more complex than the basics of FMS (Holfelder and Schott, 2014). FMS are considered to be the building blocks for more specialized movement patterns required for sport participation (Lubans *et al,* 2010). FMS and sport skills need to be learned in an appropriate timing and order (Balyi, 2001; CS4L, 2016). FMS should be mastered prior to the introduction of sport-specific skills (Balyi, 2001). Proper development of skills can be affected by sports participation (Cote *et al,* 2009; Myer *et al,* 2016; Post *et al,* 2017). Single sport participation could have negative implications on proper skill and physical development (Cote *et al,* 2009; Myer *et al,* 2016; Post *et al,* 2017). An emphasis on motor development will produce athletes with better trainability for long-term sport specific development and allow for appropriate and full development of skills (Balyi, 2001).

Generally, organized sports have seen an increase in rates of participation and decrease in ages of participants, although it has been suggested that organized sport participation is remaining steady (Baxter-Jones, 1995; Eime *et al*, 2015). Interestingly, the variance in age at onset of the adolescent growth spurt (PHV) can result in an athletic advantage to those maturing earlier than their peers due to their greater size and strength (Malina *et al,* 2004b; Malina *et al,* 2015). This size and maturity advantage increases the likelihood that early maturers will be selected for sports teams over their later maturing counterparts (Malina *et al,* 2004b; Malina *et al,* 2015). Even though athletes are selected based on skill it has been suggested that apparent skill may be based on physical characteristics that in turn are reliant on maturational changes (Baxter-Jones, 1995). Selection bias due to physical characteristics favors early maturing individuals as they are more physically developed at all chronological ages (Baxter-Jones, 1995). This observation would suggest that maturity could also be effecting FMS acquisition, which in turn would advantage the early maturers to be successful in CA banded competition.

Currently, there has been a lack of studies that have analyzed the impact of growth and maturation has on FMS performance. There is a need for a novel research design which incorporates measures of growth and maturation as well as movement quality (FMS performance quality), whilst controlling for physical activity, in order to provide a more accurate and informed understanding of the relationships between FMS, physical activity, sports involvement and growth, and maturation (Rowland, 1998; Sherar *et al*., 2010). This suggests there is a need for studies to investigate interactions that occur between physical activity, sport involvement, growth, and performance of FMS.

The purposes of this study are twofold: (i) To identify the effect growth and maturation has on the performance of fundamental movement skills; and (ii) Identify the effect physical activity levels and sport participation will have on fundamental movement skills. It is hypothesized that: (i) growth and maturation will have a positive effect on the quality in performance of fundamental movement skills; and (ii) physical activity and sport participation will positively affect fundamental movement skills performance.

2. Review of the Literature

2.1 Growth, Maturation and Development

It is common for the terms maturation and development to be used interchangeably. However, for the purpose of this study: maturation is in reference to an individual's biological age (BA) (Baxter-Jones, 1995); and development refers to the timing and tempo of progress toward the mature state (Baxter-Jones, 1995).

Growth is defined as a quantitative increase in size of a body or its parts (Baxter-Jones, 1995; Haywood and Getchell, 2009). All living organisms experience a period of growth in physical size (Haywood and Getchell, 2009). For humans, this growth period starts with conception and ends during the period of emerging adulthood (Haywood and Getchell, 2009). Human growth occurs through three major processes: 1) Hyperplasia – increases in cellular number, 2) Hypertrophy – increases in cellular size, and 3) Accretion – increase in intracellular substances. (Malina *et al*, 2004a). The process of growth is a dominant biological activity during the first two decades of human life (Malina *et al*, 2004a).

Individuals' follow a similar growth pattern but the timing and magnitude varies considerably. Due to individual variability in biological and somatic growth there is a large range in timing when individuals start and finish maturity and this is most apparent during adolescent growth, typically occurring around ages 10-14 in females and 12-16 in males (Mirwald *et al*, 2002; Moore *et al*, 2014; Tanner, 1978). This time period is also known as the period of puberty. One of the major pubertal events is the occurrence of somatic maturation, a milestone occurring in both sexes when the velocity of statural growth is at its peak (peak height velocity (PHV)) Individuals can reach peak height velocity over a four-year window (Figure 2.1); thus when comparing individuals it is more conducive to align them by years around attainment of PHV rather than by chronological age (Baxter-Jones, 1995; Baxter-Jones *et al,* 2005; *Mirwald et al*, 2002; Moore *et al*, 2014). The PHV is described in more detail in the adolescent growth spurt section.

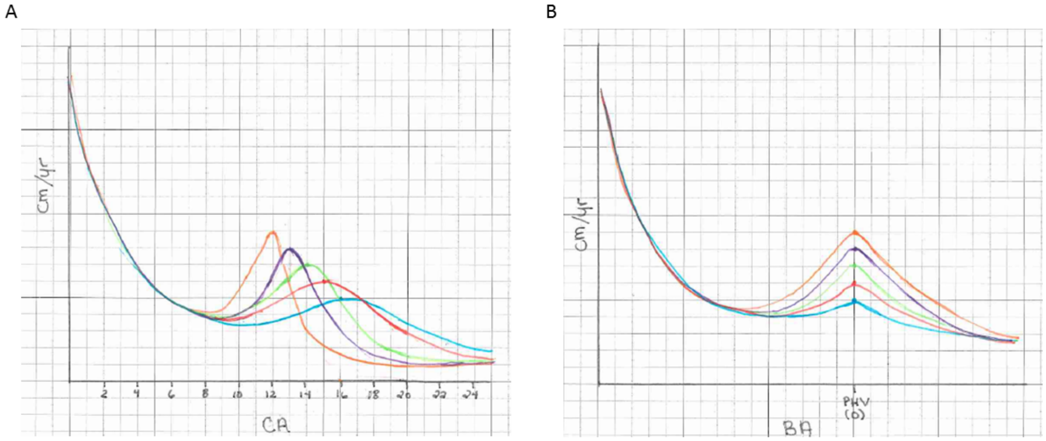

Figure 2.1. Comparison of individual mean velocities during the adolescent growth spurt (A). The same curves plotted aligned by PHV (B).
Modified from Foetus into Man by Tanner, 1978.

Stature and weight follow a four-phase pattern of growth: rapid gains are made during infancy (0-2 years old) and early childhood (3-8 years old), steady growth during middle childhood (9-11 years), rapid adolescent growth (12-18 years), and finally a slow increase until the cessation of growth once adult stature is attained, these events are for the most part genetically determined (Figure 2.2) (AAAS, 2017; Malina *et al,* 2004a). The stature of individuals reaches a genetically determined end point, (approximately 18 years in females and 20 years in males) however, body weight typically continues to increase into adult life (Figure 2.3) (Malina *et al,* 2004a; Tanner *et al,* 1976).

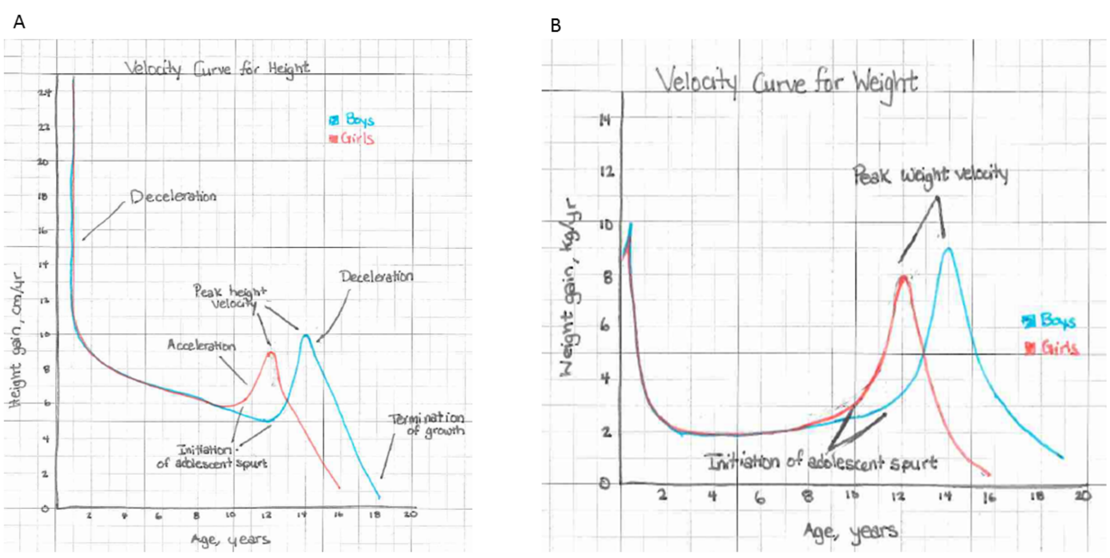

Figure 2.2. Comparison of Peak Height Velocity (A) and Peak Weight velocity (B) of typical Males and Females.
Modified from Growth, Maturation, and Physical activity by Malina *et al*, 2004.

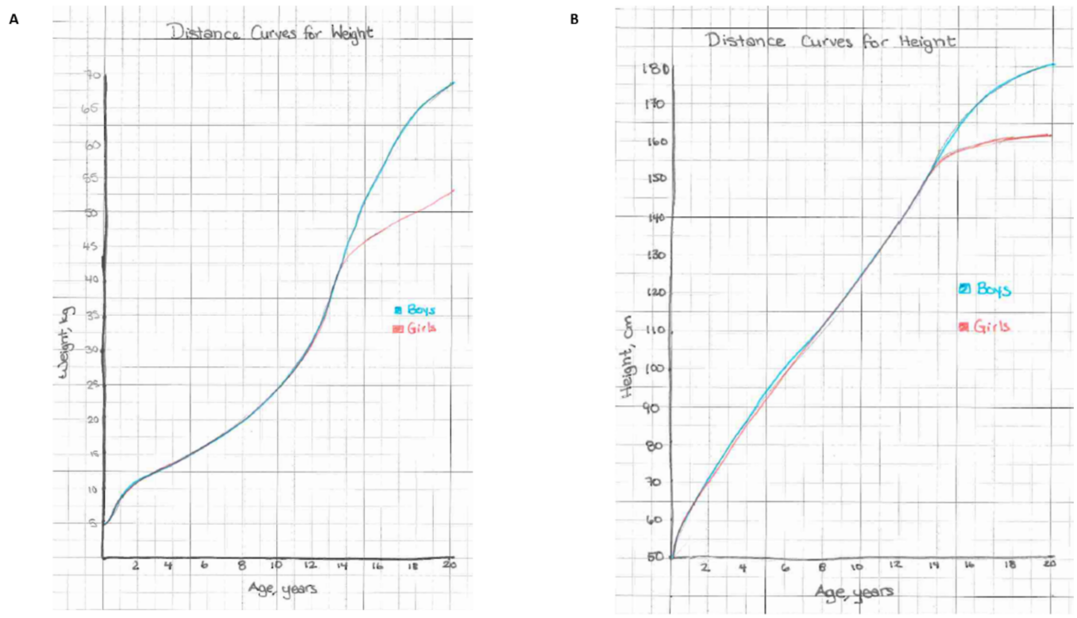

Figure 2.3. Distance Curves of Weight (A) and Stature (B) of typical Males and Females.
Modified from Growth, Maturation, and Physical activity by Malina *et al*, 2004.

Increases in height and weight are the result of growth in different tissues of the body. Growth in stature is a direct result of the growth in long bone tissue (Malina *et al,* 2004a). From infancy to adulthood bones grow in length and width while maintaining their shape through constant remodeling (Malina *et al,* 2004a; Tandon *et al,* 2012). Body weight is a gross measure of the body composition and therefore the measure of all the tissues of the body (Malina *et al,* 2004a). The primary tissues of the body are skeletal muscle, adipose, bone, blood, the viscera, and brain (Malina *et al,* 2004a). Typically a two or three component measure of weight is used for measures of body weight. The two component measure divides the body into fat mass (FM) and fat free mass (FFM) whereas the three component measures divide the body into fat, water, and fat free dry tissues (muscle, bone, and other dry materials) (Wells and Fewtrell, 2006). Although growth of all these tissues varies within and between individuals, despite age and sex, they do follow similar patterns within age groups and sexes (Figure 2.4).

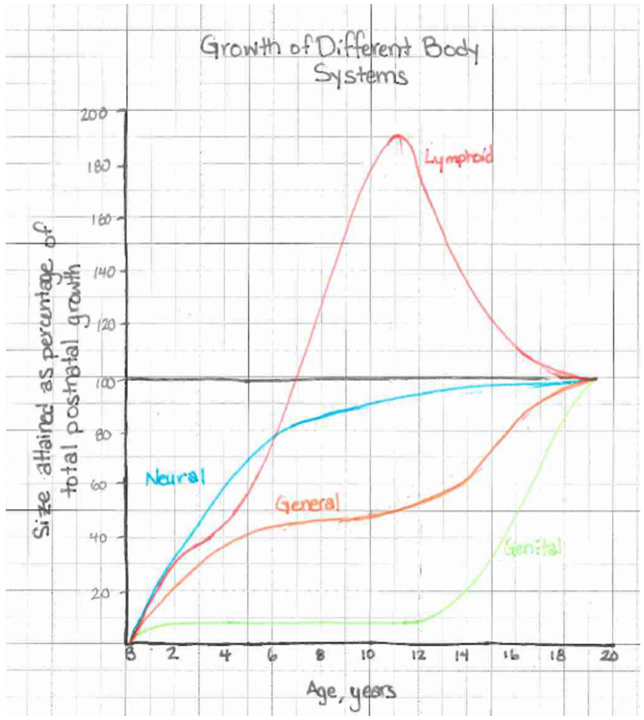

Figure 2.4. Growth of Different Body Systems.
Modified from Growth, Maturation, and Physical activity by Malina *et al*, 2004.

Development refers to the process of advancing or growing. Human development refers to the advancing or growing of the individual either biologically and/or behaviorally (Malina *et al*, 2004a). Biological development is the differentiation and specialization of embryonic cells into their specific cell types (Malina *et al*, 2004a). Whereas, behavioral development is the acquisition and refinement of expected and acceptable behaviors or skills (Malina *et al*, 2004a). Development is defined by several characteristics (Haywood and Getchell, 2009). First, it is a continuous process of change in functional capacity (Haywood and Getchell, 2009). Second, development is related to age, as age advances so does development (Haywood and Getchell, 2009). However, biological development can be faster or slower at different times and rates of development can differ among individuals of the same age, similar to statural growth (Figure 2.1) (Haywood and Getchell, 2009). Third, development involves sequential change; one step leads to the next in an orderly and irreversible fashion (Haywood and Getchell, 2009). Biological development can also be referred to as biological maturation and is the process of reaching adult maturity (Baxter-Jones, 1995; Malina *et al,* 2004a). Maturation is attained at different chronological and biological stages, dependent upon the body system in question (Malina *et al,* 2004a). During childhood and adolescences, individuals vary in the timing and tempo to which they progress towards the adult state, however, the pattern of maturation is similar (Malina *et al,* 2004a). Due to the variability in the timing and tempo of maturation, biological maturity (sometimes referred to as BA) is a better measure for comparing individuals as opposed to assessing them based on their chronological age (CA) (Malina *et al,* 2004a; Mirwald *et al*, 2001).

Growth, maturation, and development play important roles in the improvement of fundamental movement skills (FMS) (Bailey *et al,* 2010; CS4L, 2016; Ford *et al*, 2011). As a person grows and develops biologically they become bigger, stronger, and through learning have more developed neural pathways. All these attributes contribute to the person's ability to effectively and efficiently move their body in space and manipulate objects (CS4L, 2016). As a person moves through the different stages from infancy to maturity they become more able to connect simple movements (i.e. walking and running) together to form complex actions (i.e. running while dribbling a basketball) and once they are proficient with performing these skills they can then be applied to complex situations (PA and sport) (CS4L, 2016).

2.2 Adolescent Growth Spurt

Growth, maturation, and development are characterized by changes physically, mentally and socially and the changes surrounding puberty are quite dramatic. Puberty is the time of greatest change in reproductive organs, secondary sex characteristics, body size and shape, muscle, fat, bone, and other physiological functions (Tanner, 1978). The majority of the adolescent height growth spurt (PHV) (Figure 2a) is due to acceleration in trunk growth (Tanner, 1978). The rate at which individuals grow continuously declines from birth until just prior to puberty (Tanner, 1978). Growth differs significantly between males, females, as well as between individuals of the same sex (Tanner, 1978).

Females typically reach their PHV chronologically earlier, and at a lower velocity compared to their male counterparts (Tanner, 1978). PHV occurs at about 12.0 years of age in females (Tanner, 1978). On top of statural growth females also experience more growth in their hips than males (Tanner, 1978).

Males reach their PHV at a later chronological age, but at a greater velocity than females (Tanner, 1978). The later age of PHV, 14.0 years of age, allows for greater pre-pubertal growth, which accounts in part for the larger average stature of males compared to females (Tanner, 1978). Puberty also increases the shoulder width and muscle mass to a greater degree in males (Tanner, 1978).

The majority of individuals fall into the average maturer category, reaching PHV at approximately 12.0 and 14.0, for females and males respectively (Tanner, 1978). The variation to which the timing of PHV occurs is within ±2.0 years (Tanner, 1978). This means that females can potentially, reach PHV between the ages of 10 and 14 while males reach it is between 12 and 16 (Tanner, 1978). Even though the timing of the adolescent growth spurt occurs at an average age, it does vary between individuals (Tanner, 1978).

2.3 Assessing Biological Maturity

It is known that individuals follow a similar pattern of growth but the timing and magnitude varies. Due to individual variability, genetically determined, in biological and somatic growth there is a large range to which individuals can mature. The variability between sexes and ages is very apparent during the adolescent growth period (Mirwald *et al*, 2002; Moore *et al*, 2014). For example, individuals can reach their PHV within a four-year window, which allows those developing earlier than their peers to have a perceived advantage. As previously indicated PHV is the point of greatest growth during the adolescent years (Haywood and Getchell, 2009; Malina *et al,* 2004a). In order to more accurately assess individuals during the adolescent growth period it is best to equalize results based upon a measure of biological maturity, or BA , opposed to just CA (Mirwald *et al*, 2002; Moore *et al*, 2014). There are a number of different ways to assess biological maturity.

Skeletal maturity has been classified as the gold standard method to assess the status of an individual's biological maturity (Malina *et al,* 2004a). Skeletal maturity is an effective method because it is a continuous process across the whole growth period. All children start with a skeleton of cartilage and end with a fully developed skeleton of bone in adulthood (Malina *et al,* 2004a). Thus the only variability is within the timing of this progression to adulthood among individuals (Malina *et al,* 2004a). Progress in skeletal maturation can be evaluated using standardized X-rays, typically of the hand-wrist area, as this area is representative of the age of whole skeleton (Malina *et al,* 2004a). Changes in bone due to ossification are fairly uniform and provide the bases of skeletal maturity assessment (Malina *et al,* 2004a). Three types of information are used to determine skeletal maturity: 1) initial appearance of bone centres, indicating the replacement of cartilage by bone tissue, 2) the definition and characterization towards the gradual shape of the adult form, and 3) the fusion of the epiphyses with respective diaphysis. (Malina *et al,* 2004a) The estimation of skeletal maturity provides a measure of skeletal age (SA) for a child relative to a reference sample, this can be problematic depend on the similarity of the demographics of the participant to the reference sample (Malina *et al,* 2004a). SA can then be compared to CA to provide an indication as to maturity status, i.e. SA < CA indicates late maturation, SA=CA average maturation and SA > CA early maturation. This information provides an insight as to how an individual is developing towards adulthood (Malina *et al,* 2004a). SA assessment can be expensive due to the need for X-rays, reference images are required to assess SA, and there can be parental and ethical issues with exposing children to the radiation. These cost and ethical issues make this assessment problematic for field studies.

Dental maturity is a similar assessment tool to skeletal assessment except that it requires an X-ray of two incisors, the cuspid, two premolar or bicuspids, and the first and second molars (Malina *et al,* 2004a). The criteria for assessment are based on features common to a tooth (Malina *et al,* 2004a). Specific stages are described for each tooth from the beginning of calcification until closure of the root (Malina *et al,* 2004a). Recent studies have shown that dental aging tends to under-estimate maturity (AlQahtani *et al*, 2014). Similar to assessing SA, the constraints for this type of assessment include cost due to the need for X-rays, reference images are required, and there can be parental and ethical issues with exposing children to the radiation of X-rays.

Sexual maturation is a continuous process from the embryo through to puberty and then into full maturity and fertility (Malina *et al,* 2004a). Puberty is the transitional period between childhood and adulthood and includes the adolescent growth spurt (PHV), maturation of the reproductive system, and the appearance of secondary sex characteristics (Malina *et al,* 2004a). Assessment of secondary sexual characteristics includes assessment of breast and pubic hair development in females, penis and teste development and pubic hair in males (Malina *et al,* 2004a). The use of secondary sex characteristics is limited to the puberty phase of growth and therefore has limited applicability over the course of total growth and development, which is in direct in contrast to the previous described methods (Malina *et al,* 2004a). Sexual maturity is the ability to reproduce, which is more difficult to assess, therefore outward signs of pubertal development and secondary sex characteristics are the outward indicators of the level of maturity at a given point in time (Malina *et al,* 2004a). Progress in the development of secondary sex characteristics in ordinarily summarized into five or six stages (Malina *et al*, 2004a). Stage one indicates a pre-pubertal state where as stage five is indicative of the mature state (stage six exists in some pubic hair assessment tools) (Malina *et al*, 2004a). Ratings of the stages of sexual maturation are typically made by direct observation at clinical examinations and have beneficial application in this setting but this method requires invasion of individual privacy (Malina *et al*, 2004a). Self-assessment of pubertal maturation has been used in prior studies but it has been found that females tend to underestimate and males overestimate their pubertal stage (Rasmussen *et al,* 2014). Even though the development of secondary sex characteristics is a continuous process it can vary in tempo (Malina *et al*, 2004a). There is considerable variability among adolescents. Some may show a period of minimal change followed by rapid progress, while others will have a more continuous process of development (Malina *et al*, 2004a). This process of assessing maturation also requires multiple observations (Malina *et al*, 2004a).

Age at menarche refers to the age at which the first menstrual period occurs and is a common maturity indicator of females, no corresponding event occurs in males although enlargement of the larynx and elongation of the vocal cords has been indicated as a similar developmental achievement (it is not a reliable criteria) (Malina *et al*, 2004a; Tanner, 1978). These sex dependent methods of assessing maturity are very invasive to the individuals' privacy, impractical, limiting due to time commitments and assessment time, as well as subjective because they depend on the person rating the stages.

Somatic maturation is used to evaluate maturity status using the analysis of growth of anthropometric measures (Baxter-Jones *et al*, 2005; Miranda *et* al, 2013). Somatic maturity can be predicted by calculating the age at which an individual will reach their PHV (Mirwald *et al*, 2002). The actual measure of PHV requires serial measures of height during the adolescent growth spurt and is used in longitudinal studies. For a definitive measure of PHV, serial measures are needed in order to see when the greatest statural growth rate is occurring. For cross-sectional studies Mirwald et al. developed a predictive model based on anthropometric assessments, it is based on the theoretic model of growth that peak velocity of leg growth occurs prior to the peak velocity in trunk growth. The prediction model utilizes the measures of sex, age, weight, height, and seated height to predict leg length and trunk length. The outcome variable is a measure in years with regards to the attainment of PHV (error ±0.5 yrs.). Growth differences between males and females are very different and therefore two prediction equations were developed based on the sex of the individual. The equations are as follows:

The BM equation for males: Maturity Offset = -9.236 + 0.0002708·Leg Length and Sitting Height interaction - 0.001663·Age and Leg Length interaction + 0.007216·Age and Sitting Height interaction + 0.02292·weight by height ratio.

The BM equation for females: Maturity Offset = -9.376 + 0.0001882·Leg Length and Sitting Height interaction + 0.0022·Age and Leg Length interaction + 0.005841·Age and Sitting Height interaction - 0.002658·Age and Weight interaction + 0.07693·Weight by Height ratio.

These equations were used in the present study to assess the participants' maturity status (pre-pubertal > 1 year pre PHV, peri-pubertal with 1 year of PHV attainment and post-pubertal > 1 year post PHV). Other equations have been developed to simplify the data collection process for researchers (Moore *et al,* 2014).

Concerns about the deviation between predicted age at PHV and actual age at PHV, especially in short statured athletic populations, have been raised (Malina *et al,* 2006). The prediction of the age of PHV is based on anthropometric measures prior to the attainment of PHV and it may not be reflective of the variations that could be observed at PHV (Malina *et al,* 2006). Despite criticism, the merit of the noninvasive procedure of predicting the age to which PHV could be attained is recognized (Malina *et al,* 2006). All prediction equations have errors associated with them due to the individual differences in the timing and tempo of adolescent growth (Malina *et al,* 2006).

In summary, a variety of methods can be used to assess biological maturity. The various assessment methods include but are not limited to: skeletal age assessment, dental age, morphological age, assessing secondary sex characteristics, and using a prediction model (Mirwald *et al*, 2002; Moore *et al*, 2014). Due to the invasive nature (radiation or personal comfort), and the cost of most of the assessment methods, the use of a prediction model was utilized during this study.

2.4 Motor Performance

Motor development (MD) refers to the development of movement abilities (Haywood and Getchell, 2009). Motor learning refers to movement changes that are relatively permanent but related to experience rather than age. MD, which refers to the development of movement abilities (Haywood and Getchell, 2009). Motor performance (MP) is defined as "the observable production of a voluntary action, or a motor skill" (Schmidt and Wrisberg, 2008). ML is the process of figuring motor skills out, MD is the overall change over time of a skill, and MP is the proper execution of a skill. The level to which a person is able to successfully achieve ideal MP is susceptible to fluctuations in temporary factors such as motivation, arousal, fatigue, and physical condition (Schmidt and Wrisberg, 2008). Analyzing MP allows for the ability to reflect on a person's ML (current capability for producing a particular movement) by noting the changes that occur systematically with additional practice and assess where on the MD spectrum they are (Schmidt and Wrisberg, 2008). Motor performance is the description of and quality to which a person can perform FMS.

2.5 Fundamental Movement Skills

Fundamental movement skills (FMS), as defined by Holfelder and Schott (2014):

> "Consist of locomotor skills that are used to propel a human body through space and object control skills which include manipulating an object in action situations… [And these] are the building blocks for more complex sport-specific skills."

It has been acknowledged that by mastering FMS, children will find it easier to learn fundamental sport skills. A child's acquisition of FMS and sport skills allows access to infinite possibilities in sport and physical activity, and without these skills, children will struggle to participate in some types of activities (CS4L, 2016; Hardy *et al*, 2013).

There is a positive correlation between FMS and physical activities (Capio *et al*, 2012; Jaakkola *et al,* 2014; Okely *et al*, 2001). Physical activity is defined as any bodily movement or action that results in energy expenditure and has shown to be beneficial for health (Butte *et al,* 2012; Caspersen *et al*, 1985; Reiner *et al,* 2013). Children who demonstrate higher proficiency levels in FMS spend more time in vigorous PA, not only during childhood but also into their adolescent years (Jaakkola *et al,* 2014). FMS scores are positively correlated with, and predictive of, PA levels from early adolescence to late adolescence (Jaakkola *et al,* 2014). Although not an ultimate solution, if there is one, to current societal health issues (as this is a very complex issue that requires individualized approaches), regular participation in physical activity is associated with substantial health benefits, including but not limited to increased bone mass, maintenance of a healthy weight, reduction of high blood pressure, and improved psychosocial outcomes (Cairney *et al,* 2012; *Hardy et al*, 2013; Okely *et al*, 2001). The positive correlation between PA and FMS solidify the idea that in order for individuals to be motivated and benefit from PA they should have a foundation in the ability to move competently.

2.6 Assessing Fundamental Movement Skills

FMS as previously described consist of the foundation of human movement and complex sports skills. Assessing FMS can be done using a number of available tools; some of these tools (Movement Assessment Battery for Children, Peabody Development Scales, TGMD, and others) are specific for the population in question and are typically used to assess impairments or deficiencies (Cools *et al,* 2009). These tools are, typically, norm-referenced (participants are compared to a normative group) or criterion-referenced (participants are compared to performance criteria of a skill) (Cools *et al,* 2009). For this research the Test of Gross Motor Development-2 (TGMD-2) was used as the assessment tool due to its practicality for the researchers. The TGMD-2 is a valid and reliable (test–retest reliability=0.88–0.96) criteria/norm based instrument designed to assess children aged three to 10 years old (Hardy *et al,* 2010). The TGMD-2 assess whether the form of a skill includes observable performance criteria and more accurately identifies specific characteristics of the movement reflective of the skill level, not the maturational level of the child (Hardy *et al,* 2010). The TGMD-2 assesses 12 gross motor skills divided into two focuses: 1.Locomotor (run, hop, gallop, leap, horizontal jump, and slide), 2. Object Control (striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll) (Ulrich, 1985). Each skill is scored based no how many of the three to five criteria are met (depending upon the skill), the score of two trials of each skill is added up, and the total can be compared to normative data (Ulrich, 2000). Strengths of the TGMD-2 include: Test items are familiar activities and easy to explain, short administration time, commonly available materials, detailed performance criteria, each skill component is analyzed, and test items are a good composite of gross motor skills (Ulrich & Sanford, 1985). Limitations include: a Needs a lot of room and a wall**,** Test reliability (has a coefficient of .95 but there is still a 15% error built in), Need to be cautious about making a judgment solely on the test results as they do not tell the whole story of performance (Ulrich & Sanford, 1985).

2.7 Physical Activity

Physical activity (PA) is defined as any bodily movement or action that results in energy expenditure (Butte *et al,* 2012; Caspersen *et al*, 1985). PA has shown to be beneficial in counteracting and negatively affecting the attainment of and reducing the effect of noncommunicable diseases (Reiner *et al,* 2013). The western world has had obesity, cardiovascular disease, and type 2 diabetes identified as major noncommunicable diseases that are the resultants of an unhealthy lifestyles (overconsumption and physical inactivity) (Reiner *et al,* 2013). On top of the positive health effects from participating in PA it has also been shown that PA has a positive effect on FMS and vice versa (Cohen *et al.,* 2015).

PA has many physical and mental health benefits such as a healthy weight status, higher physical fitness, and improved cognitive functioning (Lubans *et al,* 2010; Okely *et al,* 2004; Sibley and Etnier, 2003; Silvestri, 1997; Warburton *et al,* 2006). PA is a modifiable behavior that can reduce the risk factors associated with cardiovascular disease, diabetes mellitus, cancer, obesity, hypertension, bone and joint diseases, and depression (Silvestri, 1997; Warburton *et al,* 2006). There appears to be a linear relationship between PA and health status; the more physically active people are the lower their risk of health issues (Warburton *et al,* 2006).

On top of the health benefits of PA there are also benefits to FMS that come with being physically active. Positive correlations between a person's ability to perform FMS and their participation in PA, especially organized PA, have been found (Okely *et al,* 2001). FMS and organized PA may be dependent upon each other in that having more competencies with movement skills may increase options for PA and more time participating in organized PA may also lead to improved FMS abilities (Okely *et al,* 2001). Although a positive relationship is evident the extent to which each depends on the other isn't understood fully (Capio *et al,* 2015; Okely *et al,* 2001).

PA is a complex construct that can be classified qualitatively, quantitatively, and contextually (Butte *et al,* 2012). Qualitatively PA can be categorized by sedentary behavior, locomotion, work, leisure activities, and exercise (i.e. sport) (Butte *et al,* 2012). Quantitatively PA can be classified based on frequency, duration, and intensity (Butte *et al,* 2012). Contextually PA can be classified by the dimensions of time and space, position, or posture (Butte *et al,* 2012). It is difficult to assess PA because a gold standard does not exist (Kowalski *et al,* 2004). Instruments used to assess PA have included, direct observation, motion sensors, and self-report (Kowalski *et al,* 2004). Each method, as with all research, has pro and cons that need to be addressed.

Direct observation of PA behavior tends to be well suited for studies involving children (Welk *et al*, 2000). The benefits of performing direct observations of the PA of children is that it can be easily categorized, measured and detailed in order to give the most accurate measures (Welk *et al*, 2000). Unfortunately direct observation is very time consuming and resource dependent for researchers (Welk *et al*, 2000). Due to the time and energy required in order to directly observe the PA of many participants it is not typically utilized unless to validate other assessment tools (Welk *et al*, 2000).

Self-report measures, or questionnaires, are frequently used to assess the PA levels in children and adolescents due to the low cost and ease of administration, especially for large populations (Kowalski *et al,* 2004). However, a small number of the recall questionnaires have strong validity and feasibility for large-scale research (Kowalski *et al,* 2004). There are several types of information sought after through physical activity questionnaires, this information includes type of activities, intensity, frequency of activity, duration participating in activities, and seasonal variation in activity (Booth *et al,* 2002). Different PA questionnaires can be utilized depending upon the needs of the researcher; one such questionnaire is the Physical Activity Questionnaire (PAQ) and the Adolescent Physical Activity Recall Questionnaire (APARQ). The PAQ has a few strengths and limitations. The strengths of PAQ is that it has been shown to be valid and reliable measures of general PA, it utilize memory cues to enhance recall, and has been found to be a cost and time efficient tool (Kowalski *et al,* 2004). The limitations of PAQ is that it does not provide estimates of caloric expenditure, does not discriminate between the intensities of the activities, and is most appropriate for assessing PA during the school year (Kowalski *et al,* 2004). The APARQ assesses participation in organized sports, games, and activities as well as nonorganized PA during both the summer and winter school terms (Booth *et al,* 2002). The APARQ has shown to be valid and reliable measure of how many and the duration of physical activities participated in during the past year (Booth *et al,* 2002). Good reliability and validity, utilization of memory cues, and the cost and time efficiency of these questionnaires make them a good tool for assessing PA levels and specific sports participation.

Increased efforts to track PA are being made internationally (Pedisic and Bauman, 2016). Questionnaires are the current trend in estimating PA behavior but with technological improvements accelerometer use has gained popularity (Pedisic and Bauman, 2016). Use of accelerometers has shown to be more reliable because questionnaires have been tending to underestimate PA time and energy expenditures (Pedisic and Bauman, 2016). The issues with the use of accelerometers include: ongoing debate on length of monitoring, poor adherence to monitoring standards, and questions of generalizability (Pedisic and Bauman, 2016). Accelerometer reliability is dependent upon technical and human-related sources of error (Pedisic and Bauman, 2016). The validity of accelerometer-based estimates of PA and sedentary behaviour can be compromised by: technical shortcomings, significant amounts of non-wearing time, possible interference with the results, and use of intensity cut-off points (Pedisic and Bauman, 2016). Due to the potential for participant influence, invasion of day-to-day life, the time commitments, and the cost of accelerometer use it is not always feasible or advised for PA monitoring.

2.8 Sport Performance

Performance is defined as "the execution of an action" (Merriam-Webster, 2016). Sport is defined as "any activity involving physical exertion and skill in which an individual or team competes against another or others for entertainment" (Oxford Dictionaries, 2016). Sport performance would then be the execution of a sport-specific action or actions within the domain of the sport in order to obtain advantage over opposition. These skills are more complex in their application and/or the environment is more complex than the basics of FMS (Holfelder and Schott, 2014). Sports are a complex interaction between the environment, rules, and participants. In the context of this research the interest lies in an individual's ability to perform tasks in an isolated environment.

FMS play an important role in setting the foundation for sport performance (CS4L, 2016). FMS are considered to be the building blocks for more specialized movement patterns required for sport participation (Lubans *et al,* 2010). FMS and sport skills need to be learned in an appropriate timing and order (Balyi, 2001; CS4L, 2016). As humans develop a certain amount of maturity is required in order learn and perform varying skills, otherwise the individual is not strong enough (CS4L, 2016; Ford *et al,* 2011). FMS should be mastered prior to the introduction of sport-specific skills (Balyi, 2001). The development of FMS and sport-specific skills should be done in a positive environment, with a variety of sports, to contribute to future athletic achievements (Balyi, 2001). An emphasis on motor development will produce athletes with better trainability for long-term sport specific development and allow for appropriate and full development of skills that cannot be recaptured later in life (Balyi, 2001). This proper development of skills can be affected by sports participation (Cote *et al,* 2009; Myer *et al,* 2016; Post *et al,* 2017). Single sport participation could have negative implications on proper skill and physical development (Cote *et al,* 2009; Myer *et al,* 2016; Post *et al,* 2017). On top of the potential of skill impairment early specialization can lead to burnout, overuse injuries, and performance declines (Myer *et al*, 2016). Individuals should be exposed to multiple activities, especially during childhood, to ensure exposure to and practice of the wide variety of movement skills (Cote *et al,* 2016). Without the proper building blocks athletes (and all humans) will not have the foundation needed for competent movement allowing more advanced skills to be acquired, or continued participation in a variety of activities. A specific and well-planned practice, training, recovery and competition plan will help to optimize the development of an athlete (Balyi, 2004). Consistent and sustainable success comes from good training and performance over the long-term of any athletes' career and not in short sighted pushes to win (Balyi, 2004). There are no short cuts to athletic success and an overemphasis on competition will cause shortcomings in athletic abilities (Balyi, 2004).

2.9 Sport Performance and Growth

The adolescent period is characterized by rapid increases in anthropometric measures of height, weight, muscle mass and fat mass. The variability in the timing of adolescent growth between individuals has been described previously. The variance in age at onset of the adolescent growth spurt can result in an athletic advantage to those maturing earlier than their peers due to their greater size and strength (Malina *et al,* 2004b; Malina *et al,* 2015). This size and maturity advantage increases the likelihood that early maturers will be selected for sports teams over their later maturing counterparts (Malina *et al,* 2004b; Malina *et al,* 2015). Biased selection leads to early maturers receiving higher levels of coaching, more practice time with a focus on improving both FMS and sport specific skills. This advantageous exposure increases the gap in the abilities from less mature athletes and could result in decreased participation in this later maturing population.

Organized sports have seen an increase in rates of participation and decrease in ages of participants, although it has been suggested that organized sport participation is remaining steady (Baxter-Jones, 1995; Eime *et al*, 2015). As such, individuals entering puberty may have already accumulated several years of intensive sport specific training (Baxter-Jones, 1995). This is problematic for team selection that is based on chronological age categories (Baxter-Jones, 1995). The problem occurs because maturity based selection bias could lead to decreased motivation to participate in sport and a continued increase in the use of performance criteria as talent identifiers (Baxter-Jones, 1995). Even though athletes are selected based on skill it has been suggested that apparent skill may be based on physical characteristics, which in turn are reliant on maturation and pubertal changes. (Baxter-Jones, 1995). Selection bias due to physical characteristics favours early maturing individuals as they are more physically developed at all CA (Baxter-Jones, 1995).

2.10 Summary

Fundamental Movement Skills (FMS) "are the building blocks for more complex and sport-specific skills" and when fully developed may allow individuals to participate in varying sports with ease (CS4L, 2015; Holfelder and Schott, 2014). FMS milestones are attained throughout childhood at similar times and in a structured pattern but need to be continually practiced in order to maintain proficiency (Adolph *et* al, 2011; CS4L, 2015; Haywood and Getchell, 2009). During the adolescent growth spurt (termed peak height velocity [PHV]) performance declines have been documented and a possible reason for this could be a decline in the ability to perform fundamental movement skills (Beunen & Malina, 1988; Butterfield *et al*, 2004; Davies & Rose, 2000; Isaacs *et al*, 2003; Lloyd & Oliver, 2012; Philippaerts *et al*, 2006; Quatman-Yates *et al.*, 2012; Tanner, 1978; Visser *et al.*, 1998). The level to which a person is able to perform movement skills may be affected by temporary factors such as motivation, arousal, fatigue, and physical condition (Schmidt and Wrisberg, 2008) while the effects of growth and maturation are unknown. Growth and maturation are dynamic biological processes that interact with each other as well as with behavioral development which occur simultaneously during adolescence (Sherar *et al.,* 2010). As humans develop, a certain amount of maturity is required in order learn and perform varying movement skills, otherwise the individual is not strong enough (CS4L, 2016). In order to promote an individual's lifelong participation in PA, the attainment of FMS needs to be promoted during developmental years and maintained throughout the lifespan (Hardy *et al.*, 2010; Quatman-Yates *et al.*, 2012). By analyzing the impact that growth and maturation have on FMS performance a better understanding of possible reasons for PA declines can be understood.

2.11 Purpose and hypotheses:

2.11.1 Purpose

The purposes of this study are twofold:
Primary: To identify the effect growth and maturation has on the performance of fundamental performance skills.
Secondary: Identify the effect of physical activity levels and sport participation will have on fundamental movement skills.

2.11.2 Hypotheses

It was hypothesized that:
1) Growth and maturation will have a positive effect on the quality in performance of fundamental movement skills.
2) Physical activity and sport participation will positively affect fundamental movement skills performance.

3. Methods

3.1 Study Design

The study used an observational cross-sectional study design with participants being measured between June and December 2016.
Pilot test: Four children from the community of Saskatoon were recruited for pilot testing in order to estimate the time requirements for participants in order to more accurately inform potential participants as to what would be required of them. These children represented the younger end of the spectrum based on the idea that this age group would require the most amount of time to organize and have them complete all requirements of testing. A testing time was determined and participants arrived with consent forms filled out by legal guardians. The participants were informed of what they would be required to do and informed of their rights to withdraw or not participate without repercussion. Once participants agreed to participate they were given their questionnaires to fill out, clarification on questions were given if needed.

Data collection: Following testing the TGMD-2 was administered. Following the pilot test, recruitment was done during the University of Saskatchewan Summer Activity Camps and University of Saskatchewan Huskies Volleyball camps. From these camps approximately 200/800 children (within the desired age range) were invited to participate from the summer activity camps, another 120 from the volleyball summer camp were invited. Sports programs from around the City of Saskatoon were approached, as well. Directors of sports programs were contacted for approval to talk with coaches, coaches then gave approval to approach athletes, and athletes and their guardians were given the details of the study. Eight different sporting organizations were approached; four of these organizations responded and distributed the studies information to over 100 potential participants.

Recruitment lead to a sample of 84 participants (23 male, 61 female) (children/adolescents) between the ages of eight and 17. In addition to being within the 8-17 age range participants had no history of mental and/or physical conditions that would impair their performance of the tasks required. Mental/physical ability was self-assessed through self-selection based on the description from the "Who can participate in this study" on the consent forms (Appendices B and C). As previously mentioned data collection took place in gyms, open areas, or fields during lunchtime and after hour's activity time as to not disrupt camp activities or practices.

Ethics approval was obtained through the University of Saskatchewan Behavioral Research Ethics Board, BEH#: 16-160 (Appendix A). Parents were informed about the study before potential participants were approached. Consent and assent forms were given to potential participants and their parents prior to data collection. Potential participants who wished to participate signed assent forms and their parents signed consent forms before any data was collected. All procedures were explained carefully to participants and their parents. Individual results were kept confidential; participants' scores were not given to participants or their parents. In addition, participants were assigned ID codes for analysis of their results so they cannot be identified by name and connected to their individual results.

3.2 Measurement Procedures

2.2.1 Chronological Age

Using their date of birth and subtracting it from the date of testing calculated the chronological age (CA) of each participant (Microsoft Excel, Version 14.7.2).

3.2.2 Anthropometry

Body Weight and height measurements were performed based on the 2013 Canadian Society for Exercise Physiology – Physical Activity Training for Health (CSEP-PATH) manual protocol. Height and sitting height were measured to the nearest 0.1 cm while weight was measured to the nearest 0.1 kg. Height, sitting height, and weight were measured twice and had to be within 0.5 cm or 0.1 kg or a third measurement would be taken; the mean of the two closet measurements were used for analysis. Height was measured using a SECA brand portable stadiometer and the box used for sitting height was measured each day in order to achieve consistent results. Leg length was calculated by subtracting sitting height from standing height. Weight was measured using a Tanita brand weight scale (Model 1631, Tanita Corp, Tokyo, Japan).

3.2.3 Biological Maturity

Biological maturity was assessed using a sex-specific multiple regression equation, developed by Mirwald *et al* (2002), which predicted when APHV would/had occurred; a measure of somatic maturity. Using CA, weight, height, sitting height, and leg length measurements, the equation provides an estimate of the timing, termed maturity offset age, of APHV within ±6 months. The Mirwald equation has proven to be valid and reliable in a nonintrusive way for predicting the age at PHV (Mirwald *et al,* 2002; Sherar *et al,* 2005). The specific regression equations used were:

(i) **The biological maturity equation for males:** Biological age = -9.236 + 0.0002708·Leg Length and Sitting Height interaction - 0.001663·Age and Leg Length interaction + 0.007216·Age and Sitting Height interaction + 0.02292·Weight by Height ratio.

(ii) **The biological maturity equation for females:** Biological age = -9.376 + 0.0001882·Leg Length and Sitting Height interaction + 0.0022·Age and Leg Length interaction + 0.005841·Age and Sitting Height interaction - 0.002658·Age and Weight interaction + 0.07693·Weight by Height ratio.

Participants were assigned to one of three maturity groups, by sex: (i) Pre-PHV, BA < 1 year from the average age at PHV; (ii) Peri-PHV, BA is > 1 year from average PHV and BA < 1 year after average age of PHV; Post-PHV, BA is > 1 year after the average age of PHV.

2.2.4 Physical Activity levels

Physical activity levels were assessed using the Physical Activity Questionnaire for Children (ages 8-14) or Adolescents (ages 12-18), based on age appropriateness (Crocker *et al*., 2001, Kowalski *et al.*, 1997a; Kowalski *et al.*, 1997b). This one-week recall self-report questionnaire provides information regarding sports participation as well as General PA. The questionnaires use a 5-point Likert scale with a rating of one being low levels of PA and five being high levels of PA. The Physical Activity Questionnaires have demonstrated good internal validity and reliability with moderate relations with 7-day activity recalls, teacher evaluations, and motion sensors (Copeland *et al,* 2005; Kowalski *et al,* 2005; Manchola-Gonzales *et al,* 2015) The questionnaires can be found in Appendix E.

3.2.5 Sport Participation

Sports involvement was determined using the Adolescent Physical Activity Recall Questionnaire, (APARQ), developed by Booth *et al* and found valid and reliable in 2002. The APARQ is a questionnaire that has participants recall both organized and non-organized activity during a typical week during both summer and winter school terms (Booth, *et al.*, 2002). Participants were divided into two group: (i) a single (or less) sport athlete; or a (ii) multisport athlete. Categories were assigned a score of zero or one, respectively, depending on the number of different sports they were involved in within the past year, this is represented in the analysis as "athletic status". In order to determine sports participation the participants were evaluated based on how many different coached sports they had or were participating in. The APARQ has shown to be reliable and valid when in measuring caloric expenditure (Booth *et al,* 2002); for the purposes of this study the APARQ provided the appropriate information about sports participation. The questionnaire can be found in Appendix E.

3.2.6 Fundamental Movement Score

Fundamental movement was scored based on the Test of Gross Motor Development 2 (TGMD-2). The TGMD-2 is composed of two subtests (locomotor and object control) that measure the gross motor abilities that are developed early in life (Ulrich, 2000). The locomotor skills assessed by the TGMD-2 include the participants' ability to run, gallop, hop, leap, and horizontal jump. The object control skills assessed include striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll. Each skill had two attempts and are marked individually giving a score based on the number of performance criteria that were met. The individual skill scores are then added together to form the Gross Motor Quotient, (GMQ) which is the overall measure of the individuals' gross motor ability. Age equivalents can be used in order to assess the developmental progress of participants (Ulrich, 2000). Age equivalents were not the focus of this study and therefore of the total of the GMQ were used for comparisons. Required sporting equipment, as outlined in the Test of Gross Motor Development 2nd Edition – Examiner's Manual (Ulrich, 2000), was obtained from the University of Saskatchewan Recreation Services. As per the TGMD-2 space requirements a tape measure was used in order to place cones the proper distance from one another (Ulrich, 2000). Two cones represented the start position and distance intervals were marked off, with more cones, at the necessary intervals better described in the TGMD-2 Manual (Ulrich, 2000). Cones were used, opposed to tape, as they can be easily transported and some of the testing would be conducted outdoors (in grassy fields) due to where participants could be recruited. To reduce the time commitments of participants the researcher would travel to the location where the participants would be and this required adapting where the different skills could be tested. The set-up for the TGMD-2 testing was, as much as possible, similarly replicated based on the environment available for testing (safety and amount of space were taken into account). As per the TGMD-2 manual (Ulrich, 2000), participants were told what skill they would be demonstrating, provided a demonstration, and were allowed their practice if desired. Participants would then be filmed performing their two attempts at each skill. If multiple participants were present for testing they would alternate demonstrating skills, in order to expedite the process and allow the Skill Grader to be able to complete a participants grading without confusion. Coders familiar with the TGMD-2 protocol and scoring criteria as well as the researcher did analysis. Inter-rater reliability (IRR) was tested on the four participants (equating to 48 different variables being compared). The IIR=.71 which falls within the acceptable range (Ulrich, 1985). Coders filled out the scoring rubric found in Appendix F with descriptions of the scoring criteria.

3.3 Statistical analysis

IBM SPSS Statistics (Version 24, IBM Corp.) was used to analyze the data with an $\alpha=0.05$. Participants were divided by sex and the chronological ages (CA), biological ages (BA; pre-, peri- or post- PHV), height, weight, FMS scores, physical activity, and sports participation (athletic status) for each stage of PHV (pre-, peri- and post) were compared to one another using ANOVA analysis. Participants were divided into multi-sport athletes and non-multisport athletes and the groups were compared, within sexes, by Tests with a Bonferroni correction. All Participants were tertiled based on PA levels and compared using an ANOVA. An ANCOVA test was ran in order to control for differences in exposures to varying sports/activities and well as any effects sex, CA, maturity status, height weight might have.

4. Results

Table 4.1 contains the information on where participants were recruited from demonstrating the availability of participants from each group and number of participants that took part in the study

Table 4.1. Recruitment Information

Program	Pilot	UofS Activity Camps	UofS Varsity Sports Camps	Soccer Program	Swim Program	Synchronized Swim Program	Hockey Program
Population	4	800	120	40	100	90	14
Available Participants	4	200	120	36	80	60	14
Participants Recruited	4	11	6	36	7	8	12

Table 4.2 shows female demographics (mean ±SD). From the 61 female participants three different maturity groups were identified. The Pre-PHV group consisted of 12 participants with a mean chronological age (CA) of 9.26 ± 1.18 years, biological age (BA) of -2.63 ± 0.88 years from PHV; the Peri-PHV group consisted of 9 participants with a mean CA of 12.14 ± 0.71 years, BA of -0.25 ± 0.53 years from PHV; the Post-PHV group consisted of 40 participants with a mean CA of 13.86 ± 2.84 years, BA of 2.01 ± 0.53 years from PHV. These three groups had statistically different CA and BAs ($p<0.05$) falling within acceptable chronological and biological ranges for PHV grouping classification. The height and weight of all three groups were significantly different ($p<0.05$) with the Pre-PHV group having the lowest values (Height=137.29 ± 6.63cm, Weight= 33.3 ± 7.1 kg) and Post-PHV having the largest values (Height= 155.29 ± 4.7cm, Weight= 53.5±13.6). Physical activity was only significantly different ($p<0.05$) between Pre-PHV (3.00 ±. 59) and Post-PHV (2.58 ± 0.43). A significant difference was found with FMS scores and Post-hoc analysis revealed that Post-PHV had significantly higher ($p<0.05$) FMS Scores (81.28 ± 6.95) than Pre-PHV (72.58 ± 7.49) and Peri-PHV (70.78 ± 10.79), Pre-PHV and Peri-PHV groups were not significantly different ($p>0.05$).

Table 4.3 contains the demographics (mean ± SD) values for the male groups. From the 23 male participants three different maturity groups were identified. The Pre-PHV group consisted of 9 participants with a mean chronological age (CA) of 9.45 ± 1.35 years, biological age (BA) of -3.06 ± 1.16 years from PHV; the Peri-PHV group consisted of 3 participants with a mean CA of 13.26 ± 1.71 years, BA of -0.11 ± 0.79 years from PHV; the Post-PHV group consisted of 11 participants with a mean CA of 14.54 ± 0.93 years, BA of 2.01 ± 0.73 years from PHV. These three groups had statistically different CA and BAs ($p<0.05$) and fell within accepted chronological and biological ranges for grouping classification. The height and weight of all three groups were significantly different ($p<0.05$) with the Pre-PHV group having the lowest values (Height=134.50±5.4cm, Weight=

31.8±4.9 kg) and Post-PHV having the largest values (Height= 173.52±6.6cm, Weight= 65.2±9.3kg). Physical activity was only significantly different ($p<0.05$) between Pre-PHV (3.41±0.83) and Post-PHV (2.86±0.42).

Table 4.2. Female Demographics of Pre-PHV, Peri-PHV, and Post-PHV groups.

Female Participant Grouping Demographics								
Maturity Group	N	CA (years)	BA (years from PHV)	Height (cm)	Weight (kg)	PAQ Score	FMS Score (GMQ)	Athletic Status
Pre-PHV	12	9.26±1.18 ɨŦ	-2.63±0.88 ɨŦ	137.29±6.63 ɨŦ	33.3±7.1 ɨŦ	3.00±0.59 Ŧ	74.00±7.76Ŧ	.83±0.39
Peri-PHV	9	12.14±0.71* Ŧ	-.25±0.53 * Ŧ	155.29±4.76* Ŧ	46.2±7.6* Ŧ	3.13±0.29	72.00±10.30 Ŧ	.67±0.52
Post-PHV	40	13.86±2.84 *ɨ	2.01±0.53 *ɨ	158.80±12.25 *ɨ	53.5±13.6 *ɨ	2.58±0.43*	82.23±6.54	.48±0.51

* - Indicates values significantly different only from Pre-PHV ($p<0.05$).
ɨ - Indicates values significantly different only from Peri-PHV ($p<0.05$).
Ŧ - Indicates values significantly different only from Post-PHV ($p<0.05$).

Table 4.3 contains the demographics (mean ± SD) values for the male groups. From the 23 male participants three different maturity groups were identified. The Pre-PHV group consisted of 9 participants with a mean chronological age (CA) of 9.45 ± 1.35 years, biological age (BA) of -3.06 ± 1.16 years from PHV; the Peri-PHV group consisted of 3 participants with a mean CA of 13.26 ± 1.71 years, BA of -0.11 ± 0.79 years from PHV; the Post-PHV group consisted of 11 participants with a mean CA of 14.54 ± 0.93 years, BA of 2.01 ± 0.73 years from PHV. These three groups had statistically different CA and BAs ($p<0.05$) and fell within accepted chronological and biological ranges for grouping classification. The height and weight of all three groups were significantly different ($p<0.05$) with the Pre-PHV group having the lowest values (Height=134.50±5.4cm, Weight= 31.8±4.9 kg) and Post-PHV having the largest values (Height= 173.52±6.6cm, Weight= 65.2±9.3kg). Physical activity was only significantly different ($p<0.05$) between Pre-PHV (3.41±0.83) and Post-PHV (2.86±0.42). A significant difference was found with FMS scores and Post-hoc analysis found that Pre-PHV had significantly lower ($p<0.05$) FMS Scores (75.78±3.23) than Peri-PHV (85.33±4.04) and Post-PHV (84.18±3.46), Peri-PHV and Post-PHV groups were not significantly different.

Table 4.3. Male Demographics of Pre-PHV, Peri-PHV, and Post-PHV groups.

Male Participant Grouping Demographics								
Maturity Group	N	CA (years)	BA (years from PHV)	Height (cm)	Weight (kg)	PAQ Score	FMS Score (GMQ)	Athletic Status
Pre-PHV	9	9.45±1.35 ɨŦ	-3.06±1.16 ɨŦ	134.50 ±5.4 ɨŦ	31.8±4.9 ɨŦ	3.41±0.83	76.22±2.91 ɨŦ	.67±0.50
Peri-PHV	3	13.26±1.71	-.11±0.79 * Ŧ	149.60 ±2.8* Ŧ	43.5±0.96* Ŧ	2.68±0.15	85.33±4.93	.67±0.58
Post-PHV	11	14.54±0.93	2.01±0.73 *ɨ	173.52 ±6.6 *ɨ	65.2±9.3 *ɨ	2.86±0.42	85.91±3.30	.67±0.48

* - Indicates values significantly different only from Pre-PHV ($p<0.05$).
ɨ - Indicates values significantly different only from Peri-PHV ($p<0.05$).
Ŧ - Indicates values significantly different only from Post-PHV ($p<0.05$).

Figure 4.1 shows the FMS scores of each biological maturity group, split by sex. For females, the Pre-PHV and Peri-PHV groups had significantly lower scores than the Post-PHV group ($p<0.05$). For males, the Pre-PHV group had significantly lower scores than the Peri-PHV and Post-PHV group ($p<0.05$).

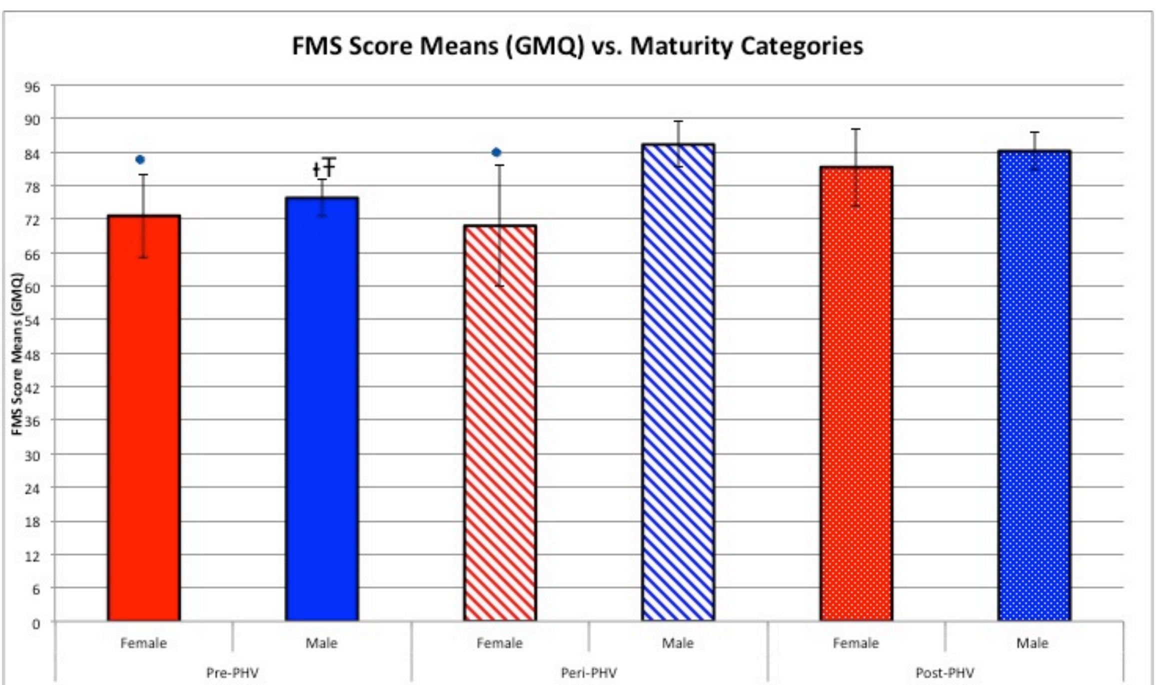

Figure 4.1. Bar Chart of the mean FMS Scores of Participants based on distance from Peak height velocity, split by sex. - * Indicates values significantly different from Post-PHV (within females) ($p<0.05$). ɨ - Indicates values significantly different from Post-PHV (within males) ($p<0.05$).

Figure 4.2 shows the FMS scores of participants separated by their sports participation (or athletic status) into multisport and non-multisport groups and split by sex. In both males and females the FMS score was not significantly different between multisport and non-multisport groups (p>0.05).

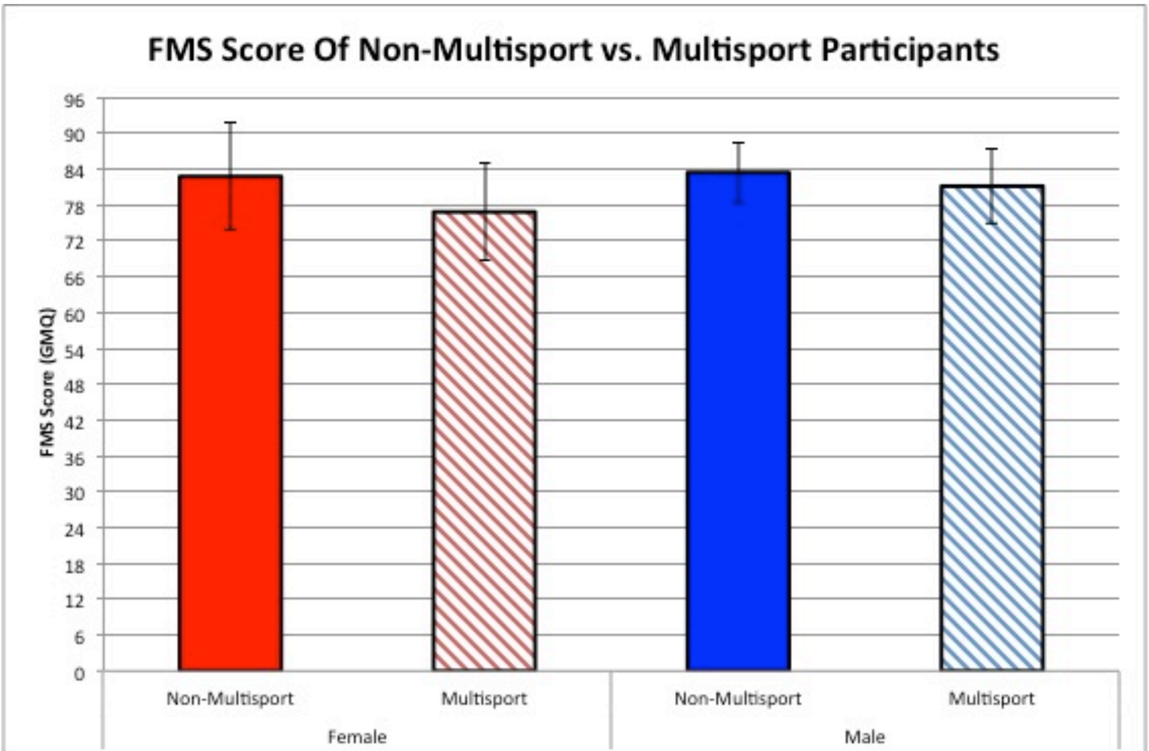

Figure 4.2. Bar Chart of the mean FMS Scores of Participants based on athletic status, split by sex.

Figure 4.3 shows the FMS Scores of participants tertiled based on physical activity scores within the population of participants. There was no significant difference between groups once separated by physical activity (p>0.05). The same comparison was done with participant split into males and females, again no significance was found (p>0.05).

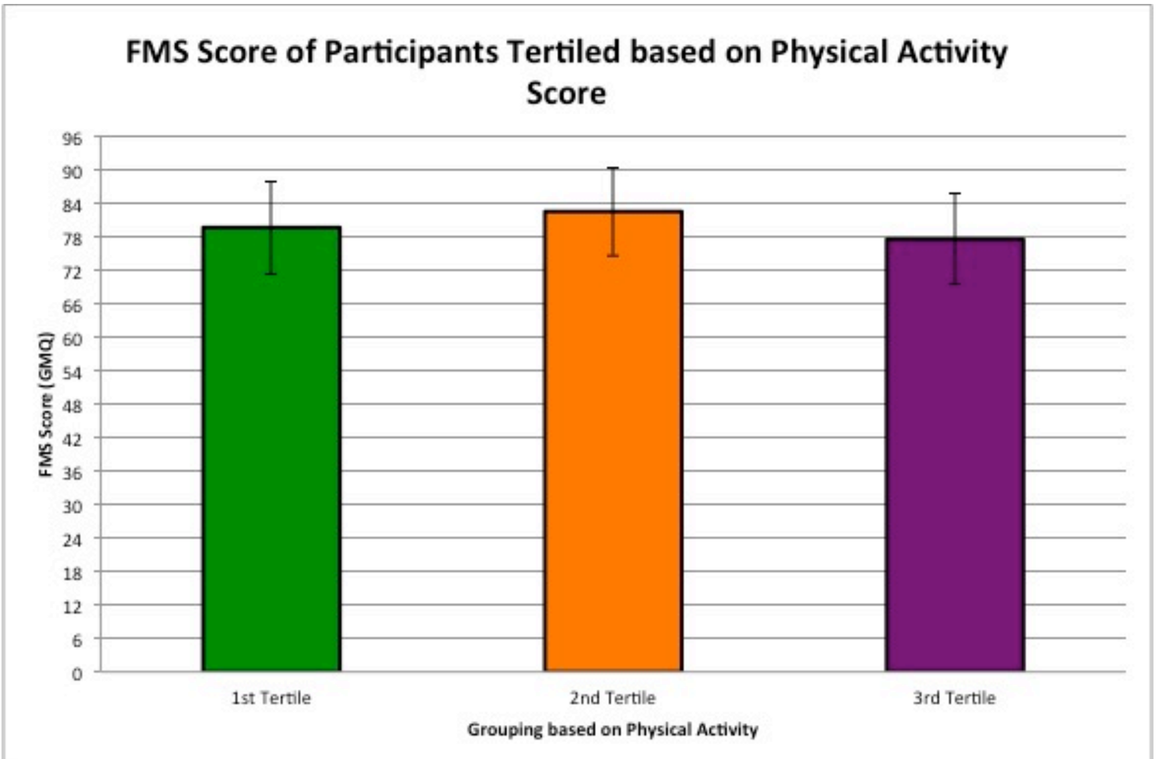

Figure 4.3. Bar Chart of the mean FMS Scores of Participants tertiled according to Physical activity score.

From analysis it was found that CA (r=0.465; Figure 4.4), BA(r=0.471; Figure 4.5) (split by sex [Figure 4.6]), Height (r=0.417; Figure 4.7) and Weight (r=0.366; Figure 4.8) were significantly and positively correlated with FMS Scores ($p<0.05$). In contrast physical activity was negatively correlated (r=-0.203) with FMS Scores but this was not significant ($p>0.05$) (Figure 4.9).

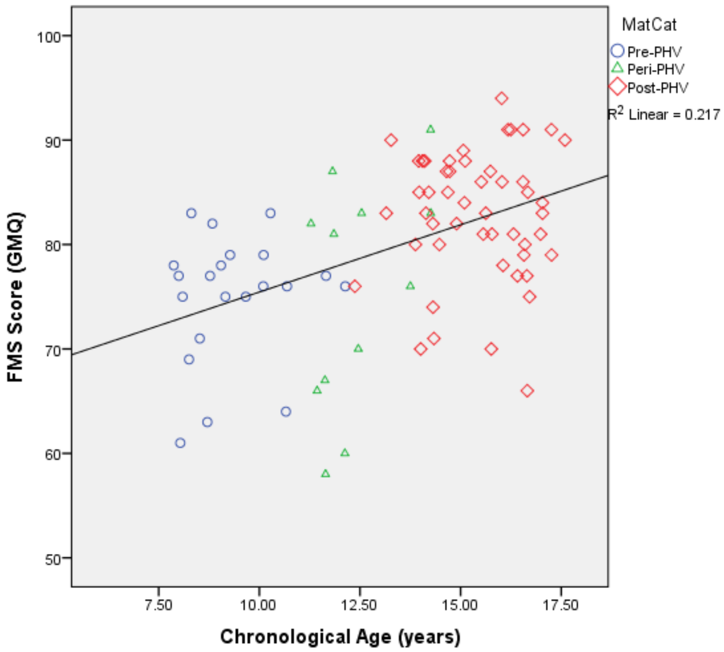

Figure 4.4. Scatter plot of individual FMS Scores and their respective CA, r=-0.465 (p<0.05).

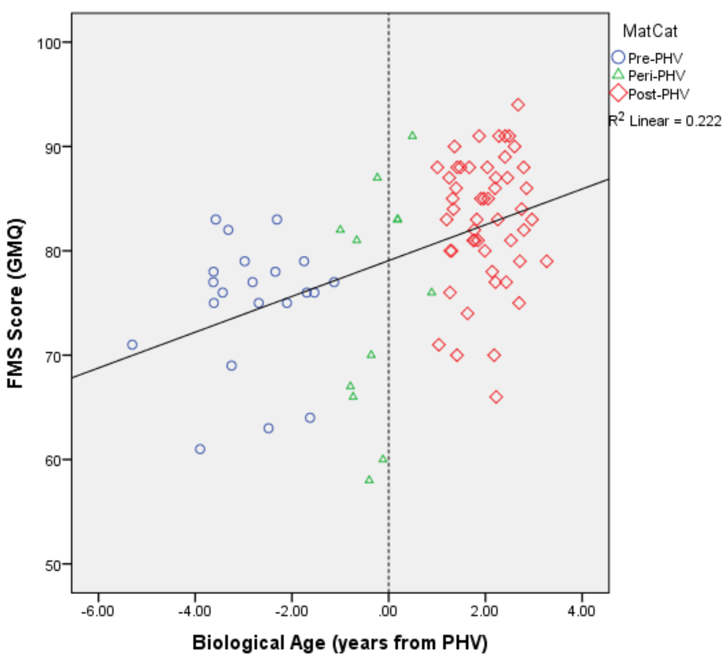

Figure 4.5. Scatter plot of individual FMS Scores and their respective BA, r=0.471 (p<0.05).

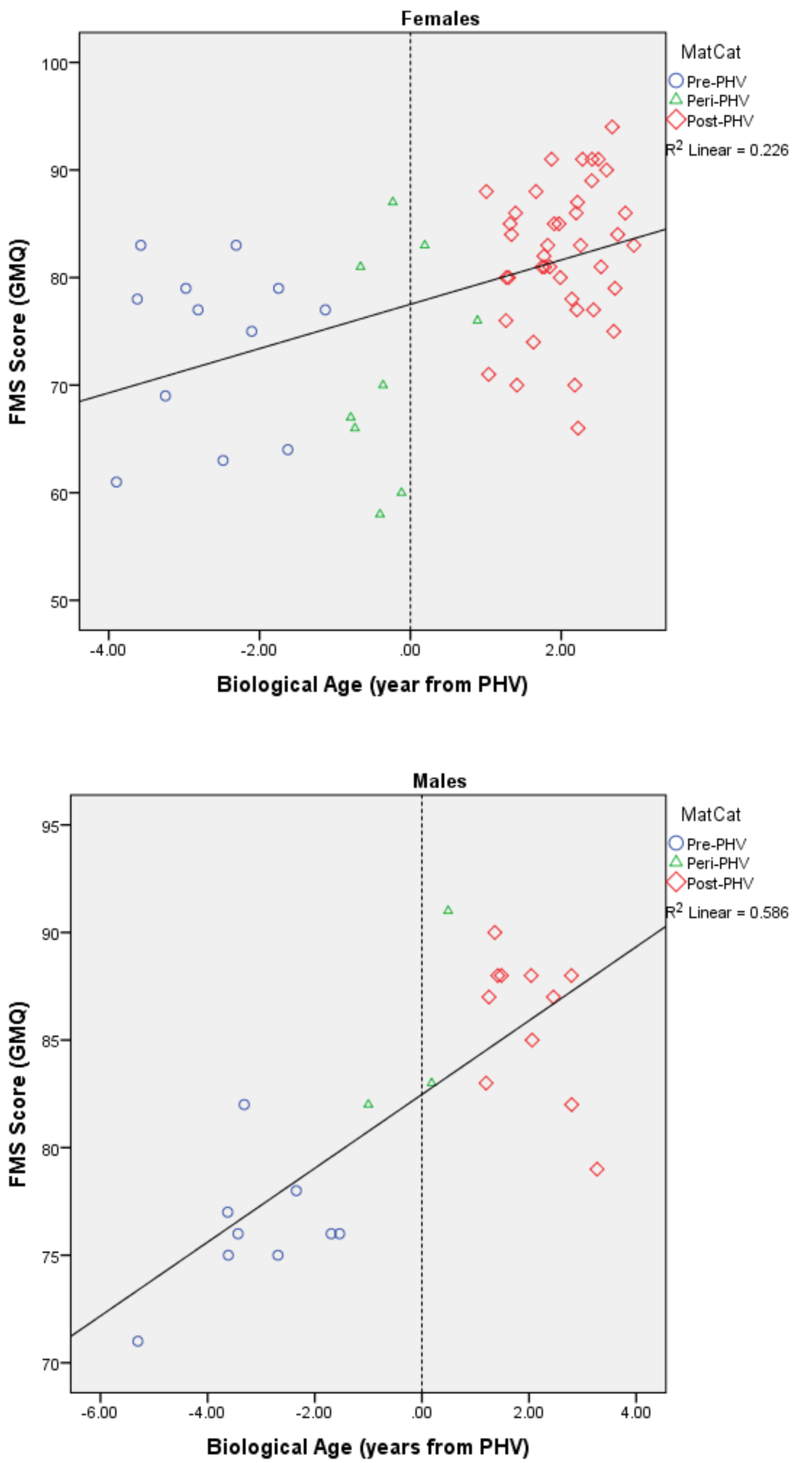

Figure 4.6. Scatter plot of individual FMS Scores and their respective BA for females and males.

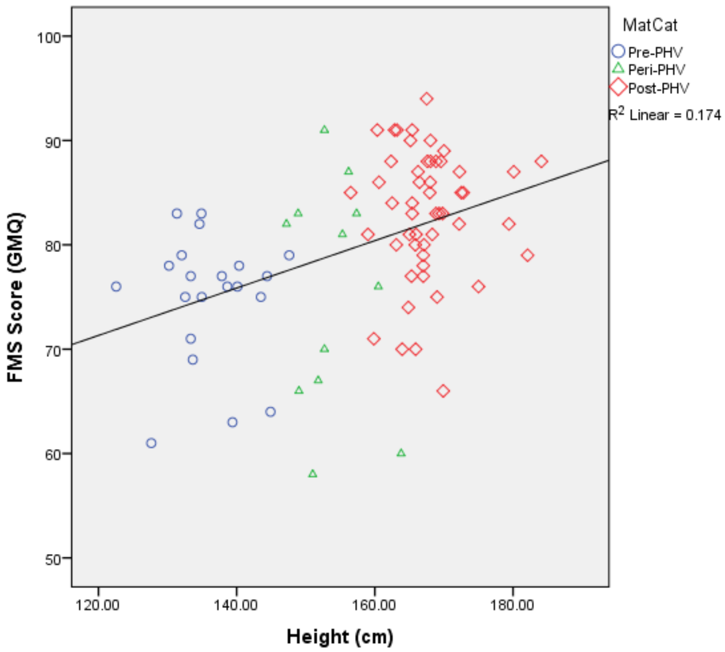

Figure 4.7. Scatter plot of individual FMS Scores and their respective height, r=0.417 ($p<0.05$).

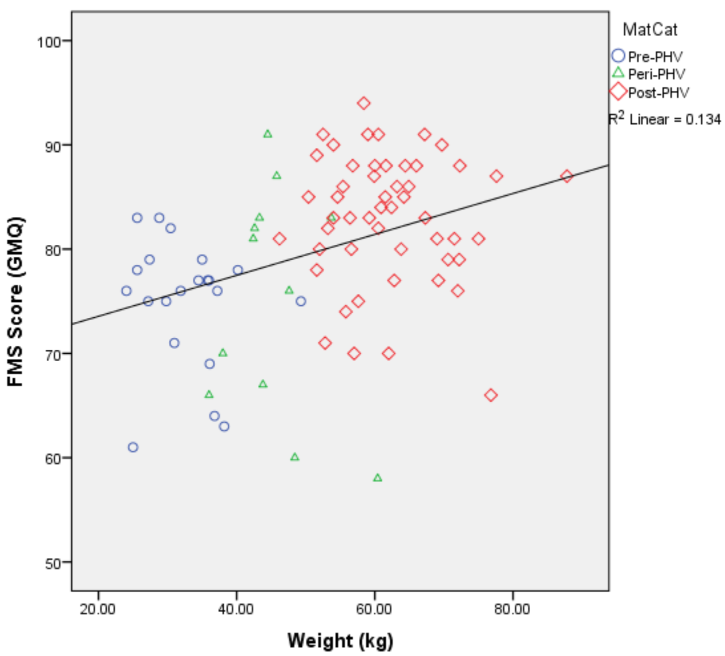

Figure 4.8. Scatter plot of individual FMS Scores and their respective weight, r=0.366 ($p<0.05$).

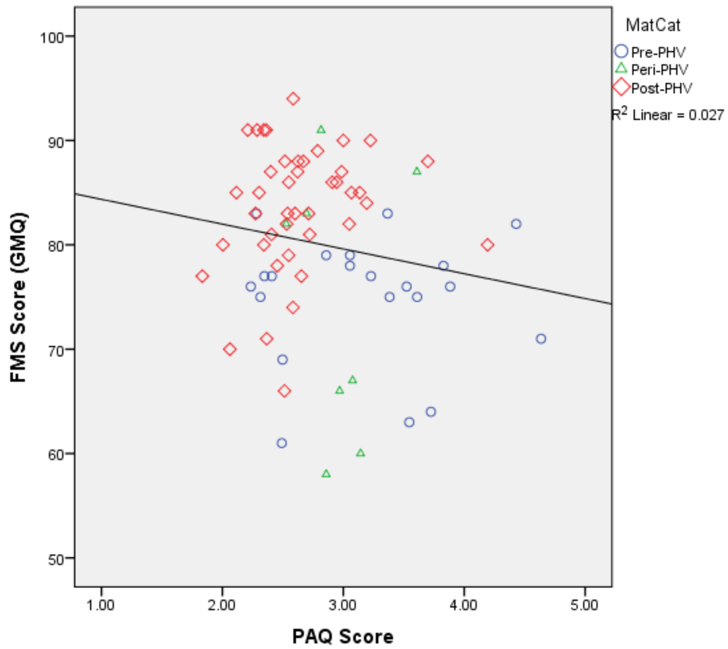

Figure 4.9. Scatter plot of individual FMS Scores and their respective PAQ Score, r=-0.164 (p>0.05)

Using the significant correlated variables ANCOVA analysis was performed and adjusted means identified (Table 4.4). It was found that that sex (p<0.05) and CA (p<0.05) were significant predictors of FMS Scores. Maturation, height and weight were not significant predictors of FMS scores in the model (p>0.05). Figure 17 shows the adjusted FMS scores of Participants based on distance from Peak height velocity, split by sex.

Table 4.4. FMS Score ANCOVA Analysis

FMS Score ANCOVA Analysis Results					
Source	Sum of Squares	df	Mean square	F	Significance
Corrected Model	1934.863a	7	276.409	6.095	.000
Intercept	337.583	1	337.583	7.444	.008
Sex	412.548	1	412.548	9.097	.004
Age	218.132	1	218.132	4.810	.032
Height	.227	1	.227	.005	.944
Weight	53.144	1	53.144	1.172	.283
PAQScore	10.834	1	10.834	.239	.627
MatCat	25.734	1	25.734	.567	.454
Athstat	159.261	1	159.261	3.512	.066
Error	2857.137	63	45.351		
Total	459192.000	71			
Corrected total	4792.000	70			
R Squared = .392 (Adjusted R Squared = .324)					

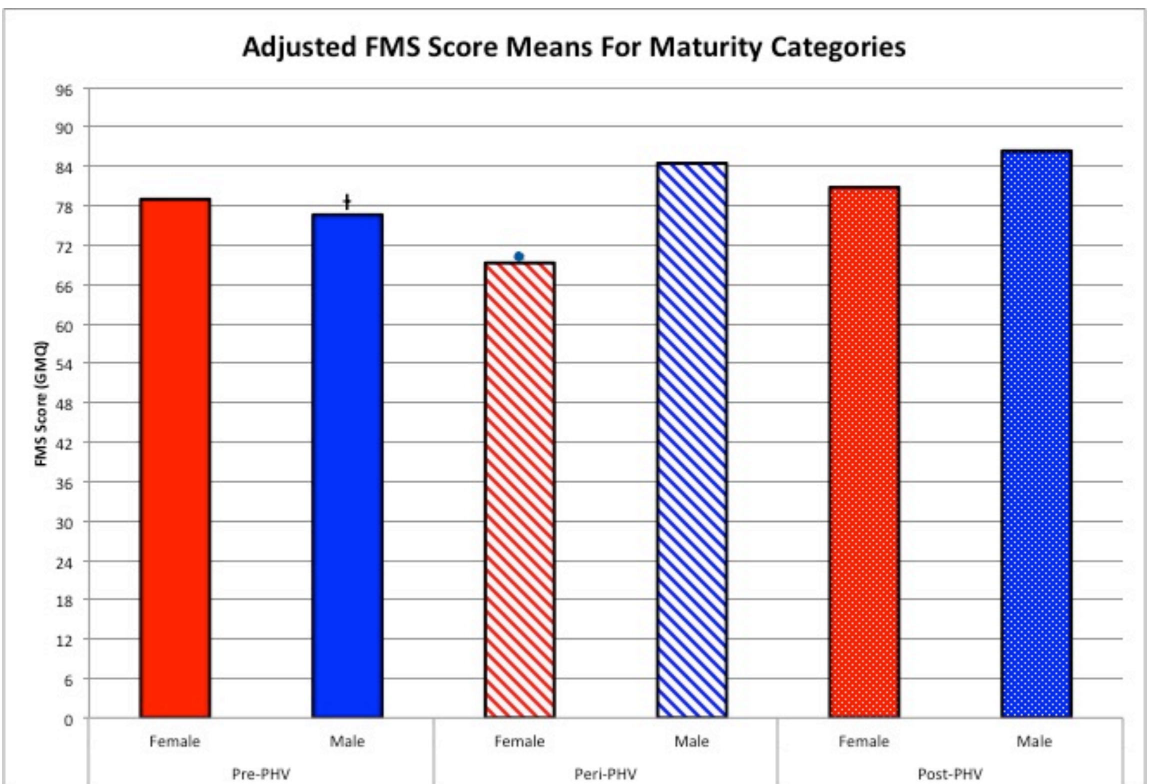

Figure 4.10. Bar Chart of the adjusted mean FMS Scores of Participants based on distance from Peak height velocity, split by sex. - * Indicates values significantly different from Post-PHV (within females) (p<0.05). ƚ - Indicates values significantly different from Peri-PHV (within males) (p<0.05)

5. Discussion

The aim of this study was to identify the effect growth and maturation has on the performance of fundamental movement scores (FMS) and the effect of physical activity (PA) levels and sport participation (SP) will have on fundamental movement scores. It was hypothesized that growth and maturation would have a positive effect on the quality in performance of FMS and that PA and SP will positively affect FMS performance. This study found that once all major factors were accounted for the significant predictors of fundamental movement skill performance were: sex and chronological age. Statistically, once other important factors were included, growth and maturation did not affect fundamental movement skills. PA levels and SP did not influence FMS performance.

The potential confounders to FMS performance during adolescents were identified as growth and maturation, PA, and SP. Once corrected for maturational staging it was found that growth and maturation did not measurably have an effect on FMS performance. The PA level of the participants had no statistical effect this can be attributed to the fact that the PA level was fairly homogenous across groups. SP did not show a statistically significant effect but the implications of this could be misleading due to the limitations of the SP recall only being from the part year of participation. These will be further explored in the following writing.

As a person moves through adolescences they increase in size and weight as well as mature physically, socially, neurologically, etc. (Baxter-Jones, 1995; Haywood and Getchell, 2009; Malina *et al,* 2004a; Mirwald *et al*, 2002; Moore *et al*, 2014; Tanner *et al,* 1976; Tanner, 1978). The increase in physical size corresponds to a greater amount of lean tissue mass (Malina *et al,* 2004a). More muscle mass correlates with increased strength and therefore a more biologically mature individual will be stronger than a less biologically mature individual (Beunen & Malina, 1988; Butterfield *et al*, 2004; Davies & Rose, 2000; Lloyd & Oliver, 2012; Philippaerts *et al*, 2006; Quatman-Yates *et al.*, 2012). Progressed maturity and increased strength allows an individual to readily manipulate their body, external objects, and their surrounding environment with greater ease (Lloyd & Oliver, 2012). Despite the beneficial aspects of growth, there was no measureable effect of growth on the performance of FMS. Individuals may follow a similar pattern of growth but the timing and magnitude varies and due to this variability is very apparent during the adolescent growth period (Mirwald *et al*, 2002; Moore *et al*, 2014). In order to more accurately assess individuals during the adolescent growth period participants were grouped based upon a measure of biological age (BA) opposed to just CA. The current study found results similar to other studies; as CA increases so does performance (Beunen & Malina, 1988; Butterfield *et al*, 2004; Davies & Rose, 2000; Lloyd & Oliver, 2012; Philippaerts *et al*, 2006; Quatman-Yates *et al.*, 2012; Tanner, 1978). The stage of growth and maturation, once all major factors were accounted for, did not have a statistically significant effect on the performance of FMS. The lack of effect from BA grouping could be due to CA being more important than biological category. As an individual increases in CA they not only become more biologically mature but they also are able to accumulate more practice time in a sport or on a skill. FMS and other sport specific skills require practice to improve, refine, and maintain performance (Cliff *et al,* 2012). The ability for more practice time may have washed out the benefits of biological maturity in this cohort but due to the limitations of the recall questionnaire it is difficult to know how much practice across the lifespan that each participant has had.

PA had no statistical effect on the performance of FMS and this could be attributed to the fact that most of these participants participated in similar amount of PA regardless of age or maturity. Only Post-PHV females had lower amounts of daily PA than their pre-PHV counterparts, this is not a surprise as it has already been documented that PA declines as maturity increase (Sherar *et al.*, 2010). Despite the lack of significance the four out of the six maturity groups are considered "moderately active" and the other two (Peri-PHV females and Pre-PHV males) are "highly active" (Chen, 2008). Whilst it is known that FMS and PA are positively correlated with one another (Barnett *et al,* 2009; Cohen *et al.,* 2015; Okely *et al,* 2001). The TGMD-2 normative data places the Pre-PHV participants in the 99th percentile for their FMS scores (Ulrich, 2000). Unfortunately normative data is not available for the CA that the Peri-PHV and Post-PHV groups but due to the ceiling of the TGMD-2 they would also rank in the 99th percentile (Ulrich, 2000). This study did not have enough participants across the PA spectrum to conclusively say that PA and FMS are positively correlated in this cohort. With more participants from varied PA backgrounds past research would likely be confirmed.

FMS play an important role in setting the foundation for more specialized movement patterns required for SP (CS4L, 2016; Lubans *et al,* 2010). As previously discussed a certain amount of maturity is required in order learn and perform varying skills and FMS should be mastered prior to sport-specific skills (Balyi, 2001; CS4L, 2016; Ford *et al,* 2011). As with all skills, FMS require practice to improve, refine, and maintain performance (Balyi, 2004; Cliff *et al,* 2012). Individuals who consistently practice sports, and by extension can be participating in more PA, have better motor coordination levels than those who do not (Barnett *et al,* 2009; Cohen *et al.,* 2015; Okely *et al,* 2001; Vandorpe *et al,* 2012). This study showed no difference between non-multisport and multisport participants in FMS performance. A large number of the participants who came from a non-multisport background were from the Post-PHV group and this could have skewed the results. The older, Post-PHV individuals were part of more directed sports programs. Their decision to participate in sport would be more focused as they have could have chosen to pursue a position in the elite levels of their sport. The questionnaire used to determine SP was a one-year recall of SP and does not account for the SP across the lifetime of the participants, therefore it is unknown as to the variety of sports these participants had exposure to prior to deciding to be singular sport focused.

The adolescent period is characterized by rapid increases in physical and mental characteristics and this variance in the onset of the adolescent growth spurt can result in an athletic advantage for those maturing early (Malina *et al,* 2004b; Malina *et al,* 2015). This is problematic for sports based on CA categories (Baxter-Jones, 1995). Even though athletes are selected based on skill it has been suggested that apparent skill may be based on physical characteristics, which in turn are reliant on maturation and pubertal changes (Baxter-Jones, 1995). Selection bias due to physical characteristics typically favours early maturing individuals as they are more physically developed at all CA (Baxter-Jones, 1995).

However, in this present research it was found that biological maturity did not have a statistical effect on FMS performance. When comparing individuals, a 16-year-old should outperform an eight-year-old as the 16-year-old has had twice as long to practice and develop. This difference would be less apparent if you were comparing a 12.0 year old to a 12.9 year old. If; however the chronological difference, representing a discrepancy of almost a year in practice time, was accompanied by a biological maturity discrepancy, if the 12.9 year old was more mature, and there would be great difference in FMS performance. It is possible that the 12.0 year old could be more biologically mature than a 12.9-year-old, but the 12.9-year-old has still had more time to practice and the benefits or maturation could be negated by the relative age effect when observing FMS performance (Jeronimus *et al*, 2015*)*. Although the performance has shown to be unaffected, this does not mean that earlier maturing individuals do not produce greater outcome measures coveted by sport. Force production, accuracy, and physicality within sport were not the focus of this study and when execution or performance of skills is measured within a sporting environment earlier maturing individuals may have an advantage.

The present research demonstrates a plateau in FMS during the peri-PHV time period. If AA were present we would hope to see a detriment to FMS during the time of peri-PHV meaning individuals experiencing the adolescent growth spurt would score less than those in the pre-PHV and post-PHV categories. Peri-PHV FMS scores were significantly different from the post-PHV period but not significantly less than the pre-PHV period and therefore showing that FMS are not negatively impacted by growth. This could suggest that during periods of rapid growth the improvement of FMS could be impaired while performance appears to be maintained. The finding from this study refutes the concept of a period of "adolescent awkwardness" that has been addressed as a reason for performance decline in previous studies. "Adolescent Awkwardness" (AA) is a term used to describe the phase of development characterized by clumsiness occurring during the period of greatest statural growth (peak height velocity [PHV]) (Van der Kamp, 2015). To date the results of studies regarding the existence of this AA have been inconclusive (Beunen & Malina, 1988; Butterfield *et al*, 2004; Davies & Rose, 2000; Isaacs *et al*, 2003; Lloyd & Oliver, 2012; Philippaerts *et al*, 2006; Quatman-Yates *et al.*, 2012; Tanner, 1978; Visser *et al.*, 1998). Previous studies evaluated motor performance based outcome measures but failed to look at the quality of performance in the movement skills. This studies objective analysis of the quality of performance demonstrated no detriment during PHV.

5.1 Limitations

Limitations of the study include a small sample size measured cross-sectionally, lifelong sport participation of participants was unknown, limitations of the fundamental movement skills scoring criteria, filming of participants, and the researchers went to find a normal population but the majority of small sample of participants came from select sports programs.

A small sample size of individuals who actively participate in at least on sport is not truly representative of the whole population. In order to better understand what effects growth and maturation, physical activity, and sport participation have on the performance of fundamental movement skills a larger cohort is necessary. Having a larger group of participants from varying backgrounds including those that participate in multiple sports, only play a single sport, are highly active but do not participate in formal organized sport, are inactive, and other demographics identified would provide a better sample. With this larger cohort of individuals with varied experiences would allow the effects of growth to be better understood.

In order to accurately measure any detriments to an individual's fundamental movement skills (FMS) they would need to be measured across the adolescent growth spurt. This would require measuring FMS and anthropometric measures at regular intervals across a two-year period. Regular measures would allow peak height velocity and any periods of detriment to FMS to be accurately identified.

Knowing the variety of sports that an individuals has experienced would allow the researchers to have a better understanding to exposure to varying movements. Current sports participation would have positive implications on the execution of FMS skills needed by the sports the individual is involved in. Experience in a variety of sports prior to having FMS tested could still have positive benefits regardless of current sports participation. Even if an individual has chosen to be single sport focused if they were exposed to different skills from previous sports exposure that ability to perform skills patterns may not be significantly affected. For example an individual who has chosen to focus their athletic pursuits in soccer would have fairly proficient running and kicking skills, if they played baseball years previously their striking skills may be proficient enough to receive a top score when their FMS are tested.

The previous example of the soccer player and their striking skills also applies to the limitations of the FMS scoring tool. The TGMD-2 scores individuals based on their ability to execute identified criteria for each skill. However, the quality of the criteria is not scored. The individual who has previously played baseball, but has not competitively played for years, may be able to meet the criteria for required for the skill of striking but an individual who has chosen baseball as their singular athletic pursuit would not be able to score better than this individual despite a possible higher quality in the striking ability. This would require a FMS scoring tool that not only grades a skill based on criteria being met but also by the quality of each criteria. However, a tool such as this would be a more subjective measure and could have other issues as well.

Filming of participants was a limitation in that is made participant recruitment difficult at times. The purpose of filming was to reduce the time commitments of participants and the resources needed by the researchers. Parents were hesitant to have their children participate or reluctant to have their children participate due to the requirement of filming. Once further explained some parents were receptive to the idea but the majority was not.

Ideally, participants would have come from a wide variety of sports exposures and some without any formal sports participation. Having participants with backgrounds in a singular sport, multiple sports, and no formal sports participation would give a better idea of how much effect growth and maturation has on FMS development.

5.2 Future Directions

The current study should be expanded to include a more diverse cohort in terms of sports participation (both current and lifelong), PA levels, and stages of maturity. A longitudinal study measuring objective quality of performance and outcome measures across the growth period would provide better insight into detriments to FMS during the time surrounding PHV. Measures would have to be taken on a regular basis within short intervals around the time of PHV so that if a period of awkwardness exists it can be found. A period of awkwardness could vary depending upon the individual and the magnitude of growth experienced. Studies, which explore the relationship between neuromuscular development and somatic changes accompanying PHV, would also provide further insight into FMS changes during the pubertal period.

6. Conclusion

The stage of maturation was not found to have a measurable effect on the quality of the performance of fundamental movement skills. The largest effect on fundamental movement skills performance came from sports participation and increasing chronological age. This suggests that exposure to, and accumulated time spent in, practice may be the biggest contributor to refining fundamental movement skills.

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Appendix A: Parent/Guardian information and consent form

Project Title: Are Fundamental Movement Skills impaired during periods of rapid growth?

Researcher(s):
Tyler Tait, MSc Student, College of Kinesiology, University of Saskatchewan, (306)-966-1078, tyler.tait@usask.ca

Supervisor:
Adam Baxter-Jones, College of Kinesiology, (306)-966-1078, baxter.jones@usask.ca

Purpose(s) and Objective(s) of the Research:
Your child is invited to participate in this study because he/she is between the ages of 8-16 and is participating in Children's Activity Camp/Huskies Sport Camp. Their participation in this study is entirely voluntary and they may withdraw at any time without penalty. Before you decide to allow them to participate it is important that you understand what the research involves. This consent form will tell you about the study, why the research is being done, and your child's role as a volunteer along with the possible benefits, risks and discomforts involved. If you decide to allow your child to participate, you will be required to sign this consent form. Please take time to read the following information carefully.

The purpose of this study is to investigate whether growth & maturation has an effect on the quality of motor performance. It has been found that physical activity levels decrease as a child's maturity increases. Research has shown that mastery as well as perceived proficiency of fundamental movement skills is associated with higher levels of activity as well as lifelong participation in physical activity. There have only been a few studies on maturation and quality in performance. This study aims to help with understanding whether adolescents becoming less active because they don't have a strong foundation with fundamental movement skills before adolescence begins or if their physical abilities are impaired during growth and maturation causing them lose interest during these dynamic changes. With a better understanding of why physical activity decreases, more educated means of increasing physical activity throughout the life span can be created.

Who can participate in this study:

- Your child is eligible to participate in this study if he/she is aged 8-16 years and of good health.
- Your child is not eligible if he/she has any health conditions that affect his/her ability to perform physical activity.

Procedures:

- After you've provided consent and you and your child have had the opportunity to ask any questions you may have, your Child will be asked to fill out a PAQ-C (8-13) or PAQ-A (14-20) survey. These are surveys that are designed to be age appropriate to assess physical activity levels.
- Anthropometric measures will be taken of your child. The anthropometric measures that will be taken are Height, Weight and Age. These measures will be used only to determine whether your child has achieved peak height velocity, which is the greatest gain in height increases.

- The Fundamental Movement Skills of your child will be filmed for assessment. The Fundamental Movement Skills will be assessed using The Gross Motor Development 2 criteria. Skills assessed will include: running, galloping, hopping, leaping, performing a horizontal jump, sliding, striking a stationary ball, a stationary dribble, kicking, catching, throwing overhand and underhand rolling.
- These measures will all be taken during your child's regularly scheduled camp activities and should not require any extra time commitments from yourself or your child. Assessments will occur during lunch time, near the end of the day, and during the aftercare program as to not interfere with scheduled activities.
- Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Funded by: *University of Saskatchewan College of Kinesiology*

Potential Risks:
As with any participation in any physical activity there is a rare risk of injury while performing the activities. However, every precaution is taken by the researchers to ensure your child understands the movement we are asking them to perform and the appropriate mats, etc. are provided when needed to ensure a safe environment.

Potential Benefits:
The benefit of participating in this study is that your child would be helping increase the knowledge of how maturational status may play a role in youth's ability to perform essential and fundamental movement skills.

Compensation:
There is no direct compensation for participating in the study.

Confidentiality:
While absolute confidentiality cannot be guaranteed, every effort will be made to ensure that your child's information provided for this study is kept entirely confidential. Your child will be identified in this study only by their initials and an assigned participant number. Their name will not be attached to any information, nor mentioned in any study report, nor be made available to anyone except the research team. If the results of this study are used in a published paper your child's identity will not be disclosed.

Storage of Data:
Information with your name and your child's name will be stored in a locked file cabinet in the locked office of Dr. Adam Baxter-Jones at the University of Saskatchewan. All data, such as measurements will be identified by an anonymous number. At the completion of your participation, all identifying information about you and your child will be destroyed.

Right to Withdraw:
- Your participation is voluntary and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on your child's participation in camp activities.

- If your child chooses to enter the study and then decides to withdraw later, all data collected about them during their enrolment will be retained for analysis.
- Your right to withdraw data from the study will apply until data has been pooled. After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data.

Follow up:

- If you wish to obtain the results from the study, please provide a contact email below.

Questions or Concerns:

- You can ask the researcher to explain any words or information that you do not clearly understand. You may ask as many questions as you need.
- Contact the researcher(s) using the information at the top of page 1;
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent:

Your child's participation is voluntary. It is up to him/her and you decide whether or not they wish to take part. If your child wishes to participate, you will be asked to sign this form. If your child does decide to take part in this study, they are still free to withdraw at any time and without giving any reasons for the decision.

Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________	______________________	______________
Name of Participant	*Signature*	*Date*
______________________	______________________	______________
Name of Parent/Guardian	*Signature*	*Date*

______________________ ______________

Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Name of Participant	*Signature*	*Date*
Name of Parent/Guardian	*Signature*	*Date*

Visually Recorded Images/Data: Participant or parent/guardian to provide initials:

- Photos may be taken of me [my child] for: Analysis _______ Dissemination* ________
- Videos may be taken of me [my child] for: Analysis _______ Dissemination* _________

*Even if no names are used, you [or your child] may be recognizable if visual images are shown as part of the results.
If you would like the results of the study please provide an email that can be contacted below:
Email: ____

Appendix B: Participant information and assent form

University of Saskatchewan College of Kinesiology ***Participant Assent Form***

Project Title: Are Fundamental Movement Skills impaired during periods of rapid growth?

Researcher(s):
Tyler Tait, MSc Student, College of Kinesiology, University of Saskatchewan, (306)-966-1078, tyler.tait@usask.ca

Supervisor:
Adam Baxter-Jones, College of Kinesiology, (306)-966-1078, baxter.jones@usask.ca

Introduction:
We are inviting you to be a part of our study that looks at the your growth and it's affect on movement. This study will help us learn about whether or not movement is affected by your growth. We will compare your growth rate with your movement scores.

What happens in this study?
During lunch time, near the end of the day, and during the aftercare program we will get you to do the following:

1. You will fill out a questionnaire asking questions about your activity.
2. We are then going to take height and weight measurements.
3. We will film you performing the following movements: Run a square, run there and back, run, jump then land on two feet, crossovers, skip, gallop, hop, jump, overhand throw, strike with stick, one-handed catch, hand dribble stationary & moving forward, kick ball, foot dribble moving forward, balance walk (heel-to-toe) forward, balance walk (toe-to-heel) backward, drop to ground & back up, Lift and lower.

Please feel free to ask any questions regarding the procedures and goals of the study or your role.

Will you have to answer all questions and do everything you are asked to do?
It is your choice whether you choose to answer our questions. It is also your choice to choose if you want to fill in the questionnaire or participate in the 20 activities and you won't have to do it if you don't want to. If you do not want to do be a part of the study you can tell the researcher that you do not want to. You will not get in trouble if you choose not to do something in this study.

Who will know that you are in the study?
Your name will not be on any information that you give us or that we collect from you. No one will know that the information from our study came from you.

We will not let anyone see your answers or any of your other information. Your teachers, friends and teammates will not see your results.

Do you have to be in this study?
You can be in this study if you want, but you don't have to. This study in not a part of your school or camp work and it is your choice to participate. Even if you decide to be a part of the

study now, you can change your mind later. You just have to say that you do not want to be a part of the study anymore. If you decide not to be a part of the study no one will get angry or upset with you. If you choose not to be in this study it will not affect your ability to participate in school activities or other activities at the University of Saskatchewan.

Do you have any questions?
You can ask any questions at any time. You can ask now or you can ask later. You can talk to me or you can talk to someone else at any time during the study.

Consent to have my picture/video taken:
It is okay for my picture and video to be taken when I am being tested so that the researchers can use them to show others what kinds of tests I did. No one will be able to see my face in these pictures or videos, so they won't know who I am.

Yes No

Consent to participate:
I have talked with my parents/guardians about this study and I understand what I will be asked to do. I know I can stop being in the study at any time and I will not get in trouble. I have had the chance to ask questions and all my questions were answered in a way that I understood.

_______________ _______________ _______________
Name of Participant *Signature* *Date*

_______________ _______________
Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

_______________ _______________ _______________
Name of Participant *Researcher's Signature* *Date*

Appendix C: Data collection form

Participant Information

Name: ______________________ Subject Number: ______________________

Date: ______________________

Date of Birth: ______________________

Height 1	Height 2	Height 3

Sitting Height	Sitting Height 2	Sitting Height 3

Weight 1	Weight 2	Weight 3

TGMD Scores	
Run	Dribble
Gallop	Catch
Hop	Kick
Leap	Strike
Horizontal Jump	OH throw
Slide	UH roll

Appendix D: Questionnaires

The Adolescent Physical Activity and Recall Questionnaire (APARQ)

Thank you for helping us today. Many students are helping us by completing this questionnaire. By answering these questions you will help us understand more about the health of young people like yourself.

Your answers are confidential and will be looked at by the survey team and no-one else. No-one at your school will see your answers.
Take your time to read each question in turn and answer it as best you can.

Thanks again for being part of this important survey!

HOW TO COMPLETE THIS FORM

Most questions can be answered by placing a tick in a box or writing your answer in a box.

- Read each question carefully
- Place a tick or write your answer in the box.
- Use only the 2B pencil provided
- Fully erase any mistakes
- Do not make any stray marks on this form
- Do not fold this form
- Ask one of the staff if you need help

Name ____

Year ____

School ____

[1] School of Public Health, University of Sydney, NSW 2006

[2] Faculty of Education, Child Obesity Research Centre, University of Wollongong NSW 2522
tokely@uow.edu.au

First, a few questions about you…

1 **What is your date of birth?**

☐☐ ☐☐ ☐☐☐☐

Day Month Year

2 **Are you a boy or a girl?**

Boy ☐
Girl ☐

3 **What language do you speak most at home?**

English ☐
Another language ☐
(please write it here) ________________

4 **Are you an Aboriginal or Torres Strait Islander?**

Yes ☐
No ☐

5 **What suburb do you live in?**___________________________

6 **What is the postcode where you live?**___________________

2

These are some questions about the organised sports and games that you do at school, before and after school and on weekends...

7 The following questions are about the **ORGANISED** sports and games that you do at school, before and after school and on weekends during the **SUMMER** school terms (terms 1 and 4). **DO NOT INCLUDE SCHOOL HOLIDAYS**. Please think about a normal week and write in the table below:

- ❖ the sports or games you usually do (including training),
- ❖ how many times per week you usually do them, and
- ❖ the usual amount of time you spend doing them.

If you do not do any organised activities, please write "zero" in the first row of the table.

Sport or game	Number of times per week you usually do this sport or game, including training	The usual amount of time you spend doing this activity **each time you do it** (you can write fractions like 1/2 hour or 2 1/4 hours)
1		
2		
3		
4		
5		
6		
7		

8 The following questions are about the **ORGANISED** sports and games that you do at school, before and after school and on weekends during the **WINTER** school terms (terms 2 and 3). **DO NOT INCLUDE SCHOOL HOLIDAYS**. Please think about a normal week and write in the table below:

- the sports or games you usually do (including training),
- how many times per week you usually do them, and
- the usual amount of time you spend doing them.

If you do not do any organised activities, please write "zero" in the first row of the table.

Sport or game	Number of times per week you usually do this sport or game, including training	The usual amount of time you spend doing this activity **each time you do it** (you can write fractions like 1/2 hour or 2 1/4 hours)
1		
2		
3		
4		
5		
6		
7		

4

Now some questions about non-organised physical activity…

9 The following questions are about **NON-ORGANISED** physical activities at school, before and after school and on weekends during the **SUMMER** school term (such as walking or cycling to and from school). **DO NOT INCLUDE SCHOOL HOLIDAYS.**

Please think about a normal week and write in the table below:

- ❖ Activities that you usually do,
- ❖ How many times each week you usually do them, and
- ❖ The usual amount of time you spend doing them.

If you do not do any non-organised activities, please write “zero” next to Activity 1.

Sport or game	Number of times per week you usually do this sport or game, including training	The usual amount of time you spend doing this activity **each time you do it** (you can write fractions like 1/2 hour or 2 1/4 hours)
1		
2		
3		
4		
5		
6		
7		

10 The following questions are about **NON-ORGANISED** physical activities at school, before and after school and on weekends during the **WINTER** school term (such as walking or cycling to and from school). **DO NOT INCLUDE SCHOOL HOLIDAYS.**

Please think about a normal week and write in the table below:

- ❖ Activities that you usually do,
- ❖ How many times each week you usually do them, and
- ❖ The usual amount of time you spend doing them.

If you do not do any non-organised activities, please write "zero" next to Activity 1.

If you do not do any organised activities, please write "zero" in the first row of the table.

Sport or game	Number of times per week you usually do this sport or game, including training	The usual amount of time you spend doing this activity **each time you do it** (you can write fractions like 1/2 hour or 2 1/4 hours)
1		
2		
3		
4		
5		
6		
7		

Thank you for completing this questionnaire.

Physical Activity Questionnaire (High School)

Name:_________________________ Age:___________

Sex: M_______ F_______ Grade:__________

Teacher:_______________________

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

Remember:

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

---

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

	No	1-2	3-4	5-6	7 times or more
Skipping	❍	❍	❍	❍	❍
Rowing/canoeing	❍	❍	❍	❍	❍
In-line skating	❍	❍	❍	❍	❍
Tag	❍	❍	❍	❍	❍
Walking for exercise	❍	❍	❍	❍	❍
Bicycling	❍	❍	❍	❍	❍
Jogging or running	❍	❍	❍	❍	❍
Aerobics	❍	❍	❍	❍	❍
Swimming	❍	❍	❍	❍	❍
Baseball, softball	❍	❍	❍	❍	❍
Dance	❍	❍	❍	❍	❍
Football	❍	❍	❍	❍	❍
Badminton	❍	❍	❍	❍	❍
Skateboarding	❍	❍	❍	❍	❍
Soccer	❍	❍	❍	❍	❍
Street hockey	❍	❍	❍	❍	❍
Volleyball	❍	❍	❍	❍	❍
Floor hockey	❍	❍	❍	❍	❍
Basketball	❍	❍	❍	❍	❍
Ice skating	❍	❍	❍	❍	❍
Cross-country skiing	❍	❍	❍	❍	❍
Ice hockey/ringette	❍	❍	❍	❍	❍
Other:					
_________________________	❍	❍	❍	❍	❍
_________________________	❍	❍	❍	❍	❍

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

I don't do PE ....O
Hardly ever ....O
Sometimes ....O
Quite often ....O
Always ....O

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

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

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

None ....O
1 time last week ....O
2 or 3 times last week ....O
4 times last week ....O
5 times last week ....O

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

None ....O
1 time last week ....O
2 or 3 times last week ....O
4 or 5 last week ....O
6 or 7 times last week ....O

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

None ....O
1 time ....O
2 — 3 times ....O
4 — 5 times ....O
6 or more times ....O

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

F. All or most of my free time was spent doing things that involve little physical effort .... ❍

G. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) ....❍

H. I often (3 — 4 times last week) did physical things in my free time ....❍

I. I quite often (5 — 6 times last week) did physical things in my free time ....❍

J. I very often (7 or more times last week) did physical things in my free time .....❍

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

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

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

Yes ....❍
No ....❍

If Yes, what prevented you? ____________________________________

Reference:

The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A)

Kowalski, K., Crocker, P., & Donen, R. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. College of Kinesiology, University of Saskatchewan.

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Physical Activity Questionnaire (Elementary School)

Name:_________________________ Age:___________

Sex: M_______ F_______ Grade:__________

Teacher:_______________________

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

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

---

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

	No	1-2	3-4	5-6	7 times or more
Skipping	❍	❍	❍	❍	❍
Rowing/canoeing	❍	❍	❍	❍	❍
In-line skating	❍	❍	❍	❍	❍
Tag	❍	❍	❍	❍	❍
Walking for exercise	❍	❍	❍	❍	❍
Bicycling	❍	❍	❍	❍	❍
Jogging or running	❍	❍	❍	❍	❍
Aerobics	❍	❍	❍	❍	❍
Swimming	❍	❍	❍	❍	❍
Baseball, softball	❍	❍	❍	❍	❍
Dance	❍	❍	❍	❍	❍
Football	❍	❍	❍	❍	❍
Badminton	❍	❍	❍	❍	❍
Skateboarding	❍	❍	❍	❍	❍
Soccer	❍	❍	❍	❍	❍
Street hockey	❍	❍	❍	❍	❍
Volleyball	❍	❍	❍	❍	❍
Floor hockey	❍	❍	❍	❍	❍
Basketball	❍	❍	❍	❍	❍
Ice skating	❍	❍	❍	❍	❍
Cross-country skiing	❍	❍	❍	❍	❍
Ice hockey/ringette	❍	❍	❍	❍	❍
Other:					
_________________________	❍	❍	❍	❍	❍
_________________________	❍	❍	❍	❍	❍

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

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

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

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

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

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

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

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

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

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

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

None .... ❍
1 time .... ❍
2 — 3 times .... ❍
4 — 5 times .... ❍
6 or more times .... ❍

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

A. All or most of my free time was spent doing things that involve little physical effort .... ❍

B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) .... ❍

C. I often (3 — 4 times last week) did physical things in my free time .... ❍

D. I quite often (5 — 6 times last week) did physical things in my free time .... ❍

E. I very often (7 or more times last week) did physical things in my free time .... ❍

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

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

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

Yes .... ❍
No .... ❍

If Yes, what prevented you? ___________________________________

Reference:

The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A)

Kowalski, K., Crocker, P., & Donen, R. The Physical Activity Questionnaire for Older Children (PAQ-C) and Adolescents (PAQ-A) Manual. College of Kinesiology, University of Saskatchewan.

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Appendix E: TGMD-2 Score Rubric

Participant Number:						
	Locomotor Subtest		**Criteria**	**TRIAL 1**	**TRIAL 2**	**SUM OF SCORES**
1.1	**Run**	1.1.1	Brief period where both feet are off the ground			0
		1.1.2	Arms in opposition to legs, elbows bent			0
		1.1.3	Narrow foot placement landing on heel or toe (i.e. not flat footed)			0
		1.1.4	Non-support leg bent approximately 90 degrees (close to buttocks)			0
					Raw Skill Score Total:	0
1.2	**Gallop**	1.2.1	A step forward with the lead food followed by a step with the training foot to a position adjacent to or behind the lead			0

			foot			
		1.2.2	Brief period where both feet are off the ground			0
		1.2.3	Arms bent and lifted to waist level			0
		1.2.4	Maintains a rhythmic pattern for four consecutive gallops			0
					Raw Skill Score Total:	0
1.3	**Hop**	1.3.1	Foot of non-support leg remains behind body			0
		1.3.2	Non-support leg swings in pendula fashion to produce force			0
		1.3.3	Arms flexed and swing forward to produce force			0

		1.3.4	Takes off and lands three times on preferred foot			0
		1.3.5	Takes off and lands three consecutive times on non-preferred foot			0
					Raw Skill Score Total:	0
1.4	**Leap**	1.4.1	Take off on one foot and land on the opposite foot			0
		1.4.2	A period where both feet are off the ground (longer than running)			0
		1.4.3	Forward reach with the arm opposite to the lead foot			0
					Raw Skill Score Total:	0
1.5	**Horizontal Jump**	1.5.1	Preparatory movement includes flexion of both knees with			0

			arms extended behind the body			
		1.5 .2	Arms extend forcefully forward and upward, reaching full extensio n above head			0
		1.5 .3	Take off and land on both feet simultan eously			0
		1.5 .4	Arms are thrust downwar d during landing			0
					Raw Skill Score Total:	0
1.6	**Slide**	1.6 .1	Body turned sideways so shoulder s are aligned with the line on the floor			0
		1.6 .2	A step sideways with lead foot followed by a slide of the trailing foot to a point next to the lead			0

			foot			
		1.6 .3	A minimum of four continuous step-slide cycles to the right			0
		1.6 .4	A minimum of four continuous step-slide cycles to the left			0
					Raw Skill Score Total:	0
					Total Locomotor Subtest Raw Score:	0
					Locomotor Standard Subtest Score: **(found in Table B.1 of TGMD II manual)**	
	Object Control Subtest		**Criteria**	**TRIAL 1**	**TRIAL 2**	**SCORE**
2.3	**Catch**	2.3 .1	Preparation phase where elbows are flexed and hands are in front of body			0
		2.3 .2	Arms extend while reaching for the ball as it			0

			arrives			
		2.3.3	Ball is caught by hands only			0
					Raw Skill Score Total:	0
2.4	**Kick**	2.4.1	Rapid continuous approach to the ball			0
		2.4.2	An elongated stride or leap immediately prior to ball contact			0
		2.4.3	No kicking foot placed even with or slightly in back of the ball			0
		2.4.4	Kicks ball with the instep of preferred foot (shoe laces) or toe			0
					Raw Skill Score Total:	0
2.5	**Overhand Throw**	2.5.1	Windup is initiated with downward movement of hand/ar			0

			m			
		2.5.2	Rotates hip and shoulder to a point where the no throwing side faces the wall			0
		2.5.3	Weight is transferred by stepping with the foot opposite the throwing hand			0
		2.5.4	Follow-through beyond ball release diagonally across body toward side opposite throwing arm.			0
					Raw Skill Score Total:	0
2.6	**Underhand Roll**	2.6.1	Preferred hand swings down and back, reaching behind the trunk while chest faces cones			0

		2.6.2	Strides forward with foot opposite the preferred hand toward the cones			0
		2.6.3	Bends knees to lower body			0
		2.6.4	Releases ball close to the floor so ball does not bounce more than 4 inches high			0
					Raw Skill Score Total:	0
2.7	**Dribble**	2.7.1	Contacts ball with one hand at about belt level			0
		2.7.2	Pushes ball with fingertips (not a slap)			0
		2.7.3	Ball contacts surface in front of or to the outside of foot on the preferred side			0

		2.7.4	Maintains control of ball for four consecutive bounces without having to move the feet to retrieve it			0
					Raw Skill Score Total:	0
2.8	Strike	2.8.1	Dominant hand grips bat above non-dominant hand			0
		2.8.2	Non-preferred side of body faces the imaginary tosser with feet parallel			0
		2.8.3	Hip and shoulder rotation during swing			0
		2.8.4	Transfers body weight to front foot			0
		2.8.5	Bat contacts ball			0
					Raw Skill Score Total:	0
					Total Object Control Subtest Raw Score:	0
					Object Control Standard Subtest Score: **(found in Table B.2./B.3 of TGMD II manual)**	

					Total Standard Score:	0
					GMQ (found in Table C.1 of TGMD II manual) :	