

The effect of the growth spurt on strength, power, speed and agility training in boys during mid-adolescence

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This dissertation is done in article format. The study was planned and performed by three researchers. The contribution and role of each author in the study will be explained. Co-authors hereby give permission that the articles in this dissertation may be submitted for degree purposes.

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Mrs Joanita Badenhorst (JB) (Hons) Biokinetics	JB is the first author of the two articles. JB was head of data collection for both years (2015 & 2016) of the study. JB also processed the raw data to the results discussed in the articles.
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Solemn statement by supervisors

I hereby declare that the above-mentioned articles have been approved and that my role in the study as set out above is correct and reflects my share in the study. I consent to the articles being published as part of Mrs Joanita Badenhorst's dissertation.

Prof Anita E. Pienaar

Mr Barry P. Gerber

PREFACE

“Twenty years from now you will be more disappointed by the things that you didn’t do than by the ones you did do. So throw off the bowlines. Sail away from the safe harbour. Catch the trade winds in your sails. Explore. Dream. Discover.” – H.J. Brown Jr.

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ABSTRACT

The effect of the growth spurt on strength, power, speed and agility training in boys during mid-adolescence

Four physical and motor fitness components are essential to excel in sport, namely muscle strength, speed, agility and explosive power. Size and performance differences which are associated with variation in biological maturation can contribute to performance differences during the adolescence period in boys. This period of rapid growth is also associated with a higher injury risk and temporary awkwardness. The aim of this study was twofold, firstly to determine to what extent speed and agility, and secondly strength and power are influenced by the growth spurt during mid-adolescence and whether negative influences of the growth spurt such as injuries and late development can be overcome by training during this period.

The study formed part of two-year longitudinal research design based on a sample of convenience (N=68) consisting of boys in their grade 8 year with a mean age of 13.68 years $\pm$ SD at baseline measurements. A two-group pre-test post-test design was followed, where the experimental group (EG) of sport participants (n=47) was subjected to a strength, speed, power and agility sports training programme for the first six-months of every year and compared to a control group (CG) (n=39) of non-sport participants who was not exposed to any training programme. The experimental group and control group were also subdivided into three growth development groups, late developers (LD), early developers (ED) and typical developers (TD).

Both the EG and CG underwent a fitness evaluation twice annually, representing a baseline and three additional time point measurements over the two-year period. This protocol consisted of thirteen tests including four anthropometric tests (stature, mass, sitting height and sitting height ratio, and fat percentage) and nine physical and motor fitness tests (10- and 40-meter speed, agility t-test, shuttle runs, vertical jump, horizontal jump, squats, sit-ups and seven-stage abdominal strength).

The data was analysed by “Statistica for Windows” (StatSoft, 2015) and SAS 9.3 Level TS L1MO (2000–2010). Data was analysed descriptively while Spearman rank order correlations were done to determine relationships between changes in anthropometric and physical and motor fitness measurements. A hierarchical linear model was used to analyse the differences in growth and fitness among the three measuring points. Practical significance of differences was determined according to Cohen’s d-value 0.25 (small), 0.55 (medium), and 0.85 (large) (Cohen, 1992).

The results revealed significant increases in height and weight in all the groups during every six-month period ($p<0.05$).

Speed and agility increased nonlinearly ($p<0.05$) in both groups. Moderate correlations were found between changes in speed and agility and anthropometric measurements confirming an interrelationship during mid-adolescence between these variables. Both the EG and CG showed negative effects of growth on the development of speed and agility. Results indicated that the training programme had a positive effect on strength and power of TD and ED, with little or no effect on LD who had not reached their peak height velocity (PHV) yet.

It is concluded from this study that the growth spurt influences the development of motor fitness capabilities such as speed, agility, strength and power in mid-adolescent boys at different stages of growth differently but that participation in a training programme can counter the negative effects of the growth spurt while also providing additional fitness benefits.

Keywords: Strength, power, speed, agility, motor fitness, growth spurt, mid-adolescence, boys

OPSOMMING

Die effek van die groeiversnellingsfase op krag, eksplosiewe krag, spoed en ratsheid by seuns gedurende mid-adolesensie

Vier sleutelkomponente, naamlik spierkrag, eksplosiewe krag, spoed en ratsheid is belangrik as atlete in sport wil presteer. Liggaamsgrootte en prestasieverskille wat met variasie in biologiese volwassenheid geassosieer word, kan bydra tot prestasieverskille gedurende die adolessensietydperk by seuns. Hierdie tydperk van vinnige groei word ook geassosieer met 'n hoër beseringsrisiko en tydelike lompheid. Die doelwitte van hierdie studie was tweeledig van aard: om eerstens te bepaal tot watter mate spoed en ratsheid en tweedens krag en eksplosiewe krag beïnvloed word deur groei gedurende die middel-adolessensie-periode en of negatiewe invloede as gevolg van die groeiversnelling soos beserings en laat ontwikkeling oorkom kan word deur inoefening van hierdie vermoëns gedurende hierdie tydperk.

Die longitudinale navorsingsontwerp van twee jaar is gebaseer op 'n gerieflikheidssteekproef (N=86) van seuns in hulle graad 8 skooljaar met 'n gemiddelde ouderdom van 13.68 ± 0.26 SA jaar tydens die basislyntoetsings. 'n Twee-groep voor-toets-na-toetsontwerp is gebruik, waar die Eksperimentele Groep (EG) wat aan sport deelneem (n=47), aan 'n krag-, eksplosiewe krag-, spoed- en ratsheids-sportoefenprogram onderwerp is vir ses maande van elke jaar, terwyl die Kontrolegroep (KG) (n=3), wat nie aan sport deelneem nie, nie aan enige oefenprogram in die tydperk blootgestel was nie. Beide die EG en KG is verder verdeel in drie groei-ontwikkelings-groepe, naamlik: laatontwikkelaars (LO), vroeë ontwikkelaars (VO) en tipiese ontwikkelaars (TO).

Beide die EG en die KG het tweejaarlik 'n fiksheidsevaluering ondergaan, wat 'n basislyn en drie addisionele opvolgtydpuntmetings oor die twee jaar tydperk verteenwoordig. Die toetsprotokol het uit 13 toetse bestaan wat vier vir antropometriese toetse (lengte, massa, sithoogte, sithoogte verhouding en vetpersentasie) en nege fisieke en motoriese fiksheidstetse (10 en 40 meter spoed, T-toets, ratsheidswisselloop, vertikale sprong, horisontale sprong, hurk oefeninge, opsitte en sewevlak-maagspierkrag).

Die data is geanaliseer deur "Statistica for Windows" (StatSoft, 2015) en SAS 9.3 Level TS L1MO (2000-2010). Data is beskrywend ontleed, terwyl Spearman se korrelasie-Koëffisiënte uitgevoer is om verbande tussen veranderinge in antropometriese en fisieke en motoriese fiksheidsmetings te bepaal. 'n Hiërgiesse lineêre model is gebruik om die verskille in groei en fiksheid tussen die drie meetpunte te analiseer. Praktiese betekenisvolheid van verskille is bepaal volgens Cohen se d-waarde 0.25 (klein), 0.55 (medium) en 0.85 (groot) (Cohen, 1992).

Die resultate het gedurende elke ses maande periode ($p < 0.05$) beduidende toenames in lengte en gewig in alle groepe getoon.

Spoed en ratsheid het in beide groepe nie-lineêr toegeneem ($p < 0.05$). Matige korrelasies is gevind tussen veranderinge in spoed en ratsheid en antropometriele metings wat 'n interverwantskap gedurende die middel-adolessensie tydperk tussen hierdie veranderlikes bevestig. Beide die EG en KG het 'n

negatiewe uitwerking van groei op die ontwikkeling van spoed en ratsheid getoon. Die resultate het wel aangedui dat die oefenprogram 'n positiewe effek gehad het op eksplosiewe krag en krag van TO en VO, met min of geen effek op LO wat nog nie hul piek groei versnelling bereik het nie.

Uit hierdie studie se bevindinge word afgelei dat die groeiversnellingsfase die ontwikkeling van motoriese fiksheid soos spoed, ratsheid, krag en eksplosiewe krag in mid-adolessente seuns in verskillende stadiums van groei verskillend beïnvloed, maar dat deelname aan 'n oefenprogram die negatiewe gevolge van hoë toenames van groei kan teenwerk, terwyl dit ook addisionele fiksheidsvoordele bied.

Slutelwoorde: Krag, eksplosiewe krag, spoed, ratsheid, motoriese fiksheid, groei versnelling, mid-adolessensie, seuns

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LIST OF ABBREVIATIONS

EG	Experimental Group
CG	Control Group
LD	Late Developers
ED	Early Developers
TD	Typical Developers
PHV	Peak Height Velocity
LTAD	Long-Term Athlete Development
T1	Test one
T2	Test two
T3	Test three
T4	Test four

CHAPTER 1**INTRODUCTION**

- 1.1 INTRODUCTION
- 1.2 PROBLEM STATEMENT
- 1.3 OBJECTIVES
- 1.4 HYPOTHESES
- 1.5 STRUCTURE OF DISSERTATION
- 1.6 REFERENCES

1.1 INTRODUCTION

Various researchers worldwide have studied the development of physical and motor fitness capabilities among adolescent boys (Armstrong *et al.*, 2011:25; Malina *et al.*, 2004a,b:555; Milojevic & Stankovic, 2010:110; Pantisotou, 2007:149; Viru *et al.*, 1999:93), the interrelationships among these variables (Behringer *et al.*, 2011:196; Malina *et al.*, 2007:292; Melanese *et al.*, 2010:270) and the trainability of motor capabilities like speed, agility, strength and power (Santos & Janeira, 2008:903; Takai *et al.*, 2013:60; Wong *et al.*, 2010:644). Similar studies have also been conducted in South Africa from as early as 1945 (Botha *et al.*, 1945:382; Sloan, 1966:691), although results from these studies are mostly outdated because these studies took place a long time ago (Henneberg & Louw, 1998:75; Richter *et al.*, 2007:506). According to a more recent South African study by Gerber *et al.* (2014:624) motor and physical fitness improves significantly from 13- to 15-years in boys, showing definite interrelationships with anthropometric growth during the mid-adolescent period.

The mid-adolescent period is associated with major growth changes known as the growth spurt, which also include peak height velocity (PHV) and the development of mature gender characteristics (puberty) over a short period of time. This period is known as the transitional phase from childhood to adulthood due to various physical and physiological changes occurring during this phase (Dahl, 2004:12). In this regard, literature indicates that the major changes in size, physical body composition and motor skills occur among boys between the ages of 9 and 16 years old (Malina *et al.*, 2004a:710) due to increases in hormonal secretion.

Pienaar (2010:401) states that all growth (structural and physiological changes during the process of development to adulthood) and maturing processes (changes occurring in form and complexity of body organs and determined by genetics) that adolescents undergo during puberty has an influence on their body composition and physical fitness. These changes could have an impact on the execution of motor skills (Armstrong *et al.*, 2011:25; Cameron, 2014:5;

Pienaar, 2010:420; Viru *et al.*, 1999:95). Researchers report in this regard that motor and physical fitness development, including aerobic and anaerobic endurance, speed and coordination, strength and explosive power, are influenced in various ways during the adolescent period by the growth spurt (Bompa 2000:1; Gerber *et al.*, 2014:623; Milojevic & Stankovic, 2010:109; Viru *et al.*, 1999:90). Sports participation is positively associated with the development of these motor and physical fitness changes during the adolescent period (Bergeron 2007:30; Gerber *et al.*, 2014:61). Due to anthropometric changes and the reaching of PHV, muscle mass increase and maturation of the nervous system (Faigenbaum, 2000:172; Jenkins, 2005:336), the mid-adolescent phase poses the opportunity to develop these motor and physical fitness capabilities (Balyi *et al.*, 2013:81).

Consequences of rapid growth during the mid-adolescent period include muscle imbalances, problems with postural control and poor core and muscle control due to odd body proportions and height to weight ratios which will influence balance and coordination (Anthanasios & Hackfort, 2014:6; Bompa 2000:71; Pienaar, 2010:420). Clark and Metcalfe (2002:185) describe an unstable growth period during early childhood, referred to as the *compensation period* which represents that period in the motor development journey when the child must compensate for rapid biological changes. The growth spurt during the early adolescent years in boys, aged between 12- and 14-years, is another period of such rapid growth (Anthanasios & Hackfort, 2014:6).

Bodily changes during this period will result in adolescents being less skilful than they were before, perhaps returning to a lower period of skill for the period of time (Anthanasios & Hackfort, 2014:6; Clark & Metcalfe, 2002:185). Jenkins (2005:336) refer to this phenomenon as adolescent awkwardness, and described it as a period of time during the growth spurt that is associated with PHV that is accompanied by a temporary disruption in motor performance found primarily in boys aged 13- to 14-years. Muscular imbalances, poor core muscle control and temporary loss of coordination due to differential rates of growth in different body segments that contribute to variation in body proportions are indicated as possible reasons (Balyi *et al.*, 2013:71; Cameron, 2014:9; Faigenbaum *et al.*, 2009:66; Freitas *et al.*, 2016:3; Malina, 2014:160). In this regard Gerber *et al.* (2014:621) studied 73 boys aged 13- to 16-years and reported an increase of 13.87cm in height over a two-year period, with an exponential increase of 8.07cm between 13.58- and 14.58-years of age. The same pattern was noted in mass and sitting height, where mass increased by 8.73kg and sitting height by 8.38cm between 13 and 14 years of age. Beunen *et al.* (1981:321) report that stature and body mass accounted for a maximum of 17% of variance in motor fitness in boys aged 13- to 16-years, in addition to Freitas *et al.*'s (2016:3) report that boys aged 12- to 14-years can experience a small but noticeable

variance of 8.1% in motor coordination as skeletal maturity status changes during the adolescent years. When the physical features of the body change in such drastic leaps, the Central Nervous System (CNS) has to make big adaptations to accommodate such changes and adapt to the new segmental forces which in return will impact on the execution of motor skills (Clark & Metcalfe, 2002:178). Changes in body proportions during this period could furthermore contribute to awkwardness in motor skill execution (Pienaar, 2010:420). Micheli and Konstantinos (2013:513) add that the consequences of muscle imbalances are threefold and that all these can lead to overuse injuries. Examples are stresses to underlying tissues such as the iliotibial band (ITB) and misalignment of anatomical parts that can cause patellofemoral pain, or which can interfere with proper foot strike (Micheli & Konstantinos 2013:514). Knowledge of these risk factors can contribute to better management of risk factors in young athletes during the early training years (Micheli & Konstantinos 2013:505).

In 2005 Balyi and Way developed a seven-stage model called the long-term athlete development (LTAD) model that was developed to be a practical pathway incorporating empirical coaching observations and experiences, coaching science, human growth, development and maturation principles (Balyi *et al.*, 2013:7). This model has been developed to the demands of growth on the development of athletic abilities such as strength, speed and agility in growing children (Balyi & Way, 2005:8). Males aged 12- to 16-years are categorised as being in the early- to mid-adolescent phase which falls within the "Train to Train" stage of the LTAD (Spano, 2004:2; Stang & Story, 2005:5). The outcome set to be achieved during the Train to Train stage of this development model is to make adolescents in this age group practice-ready with respect to the demands that will be exerted upon them in a competitive sport (Balyi & Way, 2005:8). This stage holds the window for accelerated adaptation to strength training which starts 12- to 18-months after PHV in boys (Balyi & Way, 2005:8; Beunen & Thomis, 2000:190). While anaerobic training should be prioritized after the onset of PHV, it is also clear from this model that the emphasis should fall on training (60%) and to a lesser degree on competition (40%). To accommodate the changes and awkwardness of body proportions and muscle imbalances and make most of the window of development that is available during this period, it would be best to subject boys 13- to 15-years to conditioning programmes that will improve abilities such as strength, power, speed and agility in order to improve the sporting abilities that they will need in later stages like the "Training to Win stage" (Balyi & Way, 2005:8).

1.2 PROBLEM STATEMENT

A number of motor and fitness performance tasks show well-defined adolescent spurts in boys that should be noted when training or conditioning programmes are planned during the mid-adolescent period (Beunen & Malina, 1988:523). Static strength (grip strength, arm pull), power

(vertical jump), and functional strength (flexed arm hang) show peak gains, on average, after PHV (Philippaerts *et al.*, 2006:224), while measures of speed and agility (shuttle run), speed of arm movement (plate tapping), and lower back flexibility (sit and reach) show peak gains before PHV (Beunen & Malina, 1988:523; Malina *et al.*, 2004b:555; Philippaerts *et al.*, 2006:224). The trends for measures of strength and power are similar in timing to those for body mass and muscle mass, both of which experience maximum growth after PHV. The earlier adolescent spurts for running speed and lower back flexibility may be related to growth of the lower extremities that happens before PHV (Malina 2000:437; Philippaerts *et al.*, 2006:227). Height is composed of the legs, trunk, neck and head, while the legs experience maximum growth first. Boys, thus have relatively longer legs for their heights early in the adolescent spurt, which may influence running speed and lower trunk flexibility (Sheppard & Young, 2006:922). In this regard Gerber *et al.* (2014:622) reported that speed over 40m improved significantly between the ages of 13.58 - 14.58 years ($d > 0.8$) and similar to speed, agility also showed a statistical ($p < 0.05$) and large practical significant ($d > 0.8$) improvement of 1.01 sec in the same period (Gr 8–9, age 13- to 14-years). Explosive leg power (as measured by the vertical jump) also showed a significant mean improvement of 3.17cm ($p < 0.05$, $d > 0.5$) between 13- and 14-years of age. Findings from Spencer *et al.* (2011:494) confirms the results of Gerber *et al.* (2014:622) regarding the development of speed while Philippaerts *et al.*'s (2006:227) findings on explosive leg power are also in agreement with the findings of Gerber *et al.* (2014:622).

It has been shown that strength training is effective in children and adolescents as indicated by a number of review papers and position statements (Behm *et al.*, 2008:552; Blimkie, 1992:268; Faigenbaum, 2000:601; Malina, 2006:484; Wong *et al.*, 2010:644). A recent position statement paper from the National Strength and Conditioning Association (Faigenbaum *et al.*, 2009:66) documented that children and adolescents can gain real benefits from participating in well-designed and carefully supervised programmes, using strength training modalities such as resistance training, plyometric and complex training. Strength training in children and adolescents however does hold a certain risk for injuries, due to reasons such as muscle imbalances, strong tendons inserted into growing bones with a low bone density, rapid growth that causes the bone to be too long for the more strongly trained muscle that might lead to avulsion fractures, open growth plates and poor core muscle control due to odd body proportions (Bompa 2000:71; Faigenbaum *et al.*, 2009:66). Despite the potential injury risk present in any supervised youth strength training, one broad review study has clearly specified that experimental training protocols with weights and resistance machines are safe and do not negatively impact on the growth and maturation of youngsters (Malina, 2006:485). Strength training broadly refers to a component of physical fitness conditioning by overloading the skeletal muscles through different training modalities, encompassing different types of

resistances and muscle actions, which in turn can be used in isolation or in combination (Fleck & Kraemer, 2004:1). Several researchers have reported significant increases in the vertical jump (Channell & Barfield, 2008:1525; Faigenbaum *et al.*, 2007:521; Wong *et al.*, 2010:649) and long jump distances (Faigenbaum *et al.*, 2007:521) when adolescent boys, aged 12- to 15-years followed resistance training programmes for six weeks or longer. Literature further demonstrated that resistance training programmes significantly increased running speed and agility in adolescent boys (Christou *et al.*, 2006:788; Faigenbaum *et al.*, 2007:522; Wong *et al.*, 2010:650). Vertical jump improvements were also reported from all types of strength training programmes (Takai *et al.*, 2013:60; Santos & Janeira, 2008:904; Wong *et al.*, 2010:649). Christou *et al.* (2006:786) explained that the increases in the maximal muscle force, as a result of strength training, also improves muscular power, despite the absence of specific jumping exercises.

Behringer *et al.* (2011:196) reported in their meta-analysis study of which 1019 subjects were boys with a mean age of 13.2 years, that both, functional (e.g. changes in motor unit coordination) and structural adaptations (e.g. muscular hypertrophy) might explain the observed changes in motor performance. However, these researchers found higher gains in children compared with adolescent subjects. Since there is little evidence of hypertrophy in children, improvements are considered to be more related to neural adaptations than to hypertrophic factors (Cameron, 2014:5; Malina *et al.*, 2004a:320; Delecluse *et al.*, 1995:1205). These neural adaptations include changes in motor unit coordination, firing and recruitment factors that are known to be essential for movement optimization (i.e. eliminating unnecessary and counterproductive muscle movements). Based on the fact that children perform better at strength tasks because of neural adaptation, and the fact that there is a bigger impact on the CNS of adolescents because of the growth spurt causing bodily imbalance, one could argue that the growth spurt might put a hold on the development of certain motor skills at times during mid-adolescence. This opinion is confirmed by studies of Gerber *et al.* (2014:623), Spencer *et al.* (2011:491) and Phillippaerts *et al.* (2006:229) in which they found that strength showed gains after PHV and measures of speed and agility showed gains before PHV.

The literature study revealed a lack of research on the impact of the growth spurt on fitness improvement during the mid-adolescent period within a training programme for speed, strength, explosive power and agility conditioning. Several researchers have completed studies on the interrelationships between anthropometric and fitness changes during mid-adolescence (Behringer *et al.*, 2011:186; Gerber *et al.*, 2014:617; Malina *et al.*, 2007:291; Melanese *et al.*, 2010:267; Pienaar, 2010:72). These studies however, did not subject the participants to sports conditioning programmes, or report on any effect in this regard. Spencer *et al.* (2011:497)

studied 119 boys across the age range of 11- to 18-years and the correlation of different sporting capabilities with one another. The shortcomings of the study were in the absence of a control group and the boys were not subjected to a special training programme, but only focused on evaluating the changes that took place in motor and fitness performance. The boys who were studied by Gerber *et al.* (2014:619) were in the mid-adolescent period and from one school in the North West Province in South Africa which limits the generalizability of the results and the study. There is also no specific age linked to the performance measurements in the meta-analysis study by Behringer *et al.* (2011:189) who studied children between the ages of 8- and 18-years. They also did not take maturational age into consideration in the interpretation of their results.

Studies on the effect of strength training for children and adolescents were also reported by researchers worldwide (Christou *et al.*, 2006:790; Faigehbaum, 2000:617; Ingle, 2006:992; Philippaerts *et al.*, 2006:229), but also have shortcomings. Although the study of Ingle (2006:992) included a control group, the boys were still in their pre-adolescent phase, aged 11- to 12-years, and the effect of growth on motor skill development of the boys was not determined. The study done by Christou (2006:786) also had some shortcomings, where the number of boys in the experimental group (nine participants) was small, and the boys were selected from only one soccer club. The duration and frequency of the strength conditioning programme were furthermore too low and the researchers did not study the effect of growth on the outcome of the programme. Wong *et al.*, (2010:645) studied the outcome of a 12 week strength training programme on u/14 soccer players of one club, but the maturational stage of the players was not taken into consideration in the findings.

With these limitations in the literature, a short coming was found regarding the role that the growth spurt plays in the effect of physical and motor fitness training on the improvement of speed, agility, strength and power during this developmental period in boys. The research questions that therefore need to be answered are firstly, whether the growth spurt will have a significant effect on the training of speed and agility in mid-adolescent boys aged 13- to 15-years in Nelspruit, and secondly whether the growth spurt will have a significant effect on strength and explosive power training during the mid-adolescent phase of boys aged 13- to 15-years in Nelspruit. Answering these questions will help Sports Scientists, Biokineticists and sports coaches to understand how changes in body composition and stature due to the growth spurt will affect speed, agility, strength and power training of the mid-adolescent boy.

It will also help experts to plan and compose proper programmes for the preparation of adolescent boys for sports participation at higher levels. Adolescents will also benefit from this

knowledge as well-structured conditioning programmes can be compiled by experts to improve their speed, agility, strength, and power in preparation for sports performance later in their lives.

1.3 OBJECTIVES

The objectives of this study are:

- (1) to determine the role of the growth spurt in speed and agility training of 13- to 15-year old mid-adolescent boys in Nelspruit and
- (2) to determine the effect of the growth spurt on strength and power development during mid-adolescence in boys from Nelspruit.

1.4 HYPOTHESES

This study is based on the following hypotheses:

- (1) Participating in a speed and agility training programme can significantly counter the possible negative effects of growth during mid-adolescence of boys aged 13- to 15-years.
- (2) A strength and power training programme will counter the possible negative effects of the growth spurt on fitness capabilities of mid-adolescent boys, aged 13-15 years.

1.5 STRUCTURE OF DISSERTATION

The dissertation is submitted in article format and is structured as follows:

- Chapter 1: Introduction. A bibliography is provided at the end of the chapter in an adapted NWU Harvard Style in accordance with the guidelines as set for dissertations and theses at the North-West University.
- Chapter 2: Literature review: The effect of growth on the development and trainability of motor and fitness performance components in mid-adolescent boys. A bibliography is provided at the end of the chapter in an adapted NWU Harvard Style in accordance with the guidelines as set for dissertations and theses at the North-West University.
- Chapter 3: Article 1 - The role of the growth spurt on speed and agility training of 13- to 15-year old mid-adolescent boys. The technical references and presentation of the article are prepared according to the guidelines of the *American Journal of Human Biology* (see Appendix A). Some small changes have been made in the

dissertation for technical purposes. For example, the tables and figures are placed in the text of the dissertation for better readability and to conform to the other technical aspects of the dissertation. Line spacing was changed to 1.5.

Chapter 4: Article 2 – The effect of the growth spurt on strength and power training during mid-adolescence in boys. The technical references and presentation of the article are prepared according to the guidelines of the *Journal of Strength and Conditioning research* (see Appendix B). Some changes have been made in the dissertation for technical purposes. For example, the tables and figures are placed in the text of the dissertation for better readability and to conform to the other technical aspects of the dissertation. Line spacing was changed to 1.5.

Chapter 5: Summary, conclusions, shortcomings and recommendations.

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CHAPTER 2**LITERATURE REVIEW: THE EFFECT OF GROWTH ON THE DEVELOPMENT AND TRAINABILITY OF MOTOR AND PHYSICAL FITNESS CAPABILITIES OF MID-ADOLESCENT BOYS**

- 2.1 INTRODUCTION
- 2.2 READINESS FOR SPORT PERFORMANCE IN BOYS AT TWELVE TO FIFTEEN YEARS
- 2.3 CHARACTERISTICS OF THE DEVELOPING BOY AGED TWELVE TO FIFTEEN YEARS
- 2.4 DEVELOPMENTAL TRENDS OF ANTHROPOMETRIC CHARACTERISTICS AND THEIR INTERRELATIONSHIP WITH MOTOR FITNESS
- 2.5 DEVELOPMENTAL TRENDS OF MOTOR AND PHYSICAL FITNESS CAPABILITIES IN THE ADOLESCENT BOY
- 2.6 TRAINABILITY OF MOTOR FITNESS CAPABILITIES IN MID-ADOLESCENT BOYS
- 2.7 TRAINING AND ITS POTENTIAL EFFECTS ON GROWTH DURING MID-ADOLESCENCE
- 2.8 INJURIES AND RISKS DURING ADOLESCENCE FOR BOYS COMPETING IN SPORTS AND IN TRAINING PROGRAMMES
- 2.9 SUMMARY
- 2.10 REFERENCES

The purpose of this study is to analyse the growth changes in physical (muscle strength) and motor fitness (speed, agility and explosive power) of boys during mid-adolescence and to determine the effect of the growth spurt on training of these physical and motor fitness components during this period. With this literature review the current knowledge and results on growth, physical and motor fitness and training of these capabilities in boys during mid-adolescence will therefore be the main focus of the chapter.

2.1 INTRODUCTION

With increasing age, progress through puberty and the growth spurt in males, samples of athletes in several sport codes include proportionally more players who are advanced (early) in biological maturation and proportionally fewer players who are delayed (late) in maturation (Malina *et al.*, 2004:351). Variations in size and performance associated with inter individual differences in biological maturation are especially important for sports performance during the transition into and during male adolescence (Malina *et al.*, 2004:351; Malina & Geithner, 2011:267). However, this period of rapid growth is also associated with a higher risk of injuries and temporary awkwardness which should also be taken into consideration (Bompa, 2000:71). Therefore the importance of this study is to discover to what degree physical and motor fitness

is influenced by the growth spurt and whether negative influences of the growth spurt such as injuries and delayed development can be overcome by sound training of these capabilities during this period.

The developing characteristics of boys aged 12- to 15-years and their readiness for sport performance will firstly be discussed, with the focus on developmental trends of anthropometric characteristics and motor and physical fitness performance capabilities in the adolescent boy. The trainability of motor and physical fitness performance capabilities, the effects of training on growth during mid-adolescence and the risk of injury for adolescent boys participating in training programmes will also be discussed.

In order for sport participants to excel in any sport, four essential components including muscle strength, speed, agility and power need to be developed optimally, whether it is naturally developed due to maturation (Amstrong *et al.*, 2011:25) or through special training programmes (Bompa, 2000:1). This literature review will additionally focus on the interrelationship between changes in anthropometrical components with the changes in these motor and physical fitness capabilities of boys during mid-adolescence.

2.2 READINESS FOR SPORTS PERFORMANCE IN BOYS AT TWELVE TO FIFTEEN YEARS

Sport (and exercise) is a vast enterprise involving major social institutions and large numbers of participants, workers and consumers (Vilhjalmsson & Kristjansdottir, 2003:363). According to a report by the Department of Sport and Recreation South Africa, the most popular sports codes among boys age 13- to 18-years in South Africa are soccer, cricket, athletics, rugby, basketball, swimming and tennis (Department of Sport and Recreation, South Africa, 2009:44). In 2007 there were nearly 5.9 million (12% of the total population) children between the ages of 13 and 18 years in South Africa. An estimated 63% of juniors (13- to 18-years) participate in sport. Soccer, athletics, rugby, tennis, volleyball and hockey, in that order have the highest number of participants within a school context (Department of Sport and Recreation, South Africa, 2009:39). The wide ranging implications of participation in sport have resulted in numerous studies suggesting that active involvement in sport and exercise has beneficial effects relating to psychological well-being (Biddle, 1993:215; Vilhjalmsson & Thorlindsson, 1992:673), self-esteem and sense of control (Gilroy, 1989:166; Gill, 1988:145), physical fitness (Dotson & Ross, 1985:88; Tell & Vellar, 1988:14) and lowered risk of negative health behaviour, such as smoking and alcohol use (Escobedo *et al.*, 1993:1394). Bompa (2000:1) is of the opinion that all successful sport participants are trained individuals who excel in a particular physical activity and usually have followed a well-designed, long-term training programme over several years. In

the field of sport, training is the process of repetitive, progressive exercise or work that improves the potential to achieve optimum performance. For sport participants, this means adhering to long-term training programmes that condition the body and mind to the specifics of competition that can lead to excellence in performance (Bompa, 2000:1).

The development of motor and physical fitness capabilities during childhood and adolescence will be strongly influenced by growth in size, increasing complexity of the nervous system and also by rates of maturational change and sexual dimorphism (Cameron, 2014:5). Participation in sports is customary in South Africa and there is a well-developed school sports system in place. The South African school sports system for secondary school learners includes team sports codes like rugby and field hockey (winter sports) and sports like cricket and athletics (summer sports) for boys to train and compete in (Department of Sport and Recreation, South Africa, 2009:44). The competition season, which is based on chronological age, stretches from January through to August, starting with athletics and cricket, followed by rugby and field hockey. The last four months of the year are used as preparation for general conditioning of motor and fitness skills for the next competition season (www.nelliesh.co.za/sport.html). Motor and physical fitness needed for a variety of school sports are strength, power, speed and agility (Docherty *et al.*, 1988:269; Gabbett *et al.*, 2008:175; Keogh *et al.*, 2003:397).

In 1989 Sanderson introduced an athlete development model called Long-term structure of training (Balyi *et al.*, 2013:7). This training model took into consideration among others, the growth and maturation processes of young developing sports participants (Balyi *et al.*, 2013:7). Sanderson's work was important because it considered developmental age as a crucial factor in sports participants' development (Sanderson, 1989:5). In 1995 Balyi and Way developed a four-stage model called the long-term athlete development (LTAD) model that, by 2005, had evolved into seven stages (Balyi *et al.*, 2013:7). LTAD was developed to be a practical pathway incorporating empirical coaching observations and experiences, coaching science and human growth, development and maturation principles (Balyi *et al.*, 2013:7). Stages 4 (Train to Train), 5 (Train to Compete) and 6 (Train to Win) of the LTAD model provide guidelines for elite training and preparation of those who want to specialize in sport and compete at the highest level, maximizing the physical, mental and emotional development of each athlete. The ages that fall within the scope of this study, that define the Train-to-Train stage (stage 4) are based on the approximate onset and end of the adolescent growth spurt, which is generally defined as ages 12- to 16-years for males (Balyi *et al.*, 2013:229). At this stage, sport participants are ready to consolidate their basic sport-specific skills and tactics that were developed in previous stages (stages 1-3) and this is also a major fitness development stage (Balyi *et al.*, 2013:231). Although sports participants may exhibit special talent during stage 4, they still need to allocate

more time to training skills and improve physical capacities such as strength, power, speed and agility rather than competing in formal settings during this period (Balyi *et al.*, 2013:232; Beunen & Malina, 1988:523).

This phase of anthropometrical change during adolescence that co-exists with the train-to-train phase in boys also provides a window of opportunity to use the effect of growth during mid-adolescence to further improve the needed motor and fitness capabilities of boys aged 12- to 15-years. Studies report a spurt for speed development from age 13- to 16-years and a spurt of strength training after Peak Height Velocity (PHV) (ages 14- to 15-years) (Balyi *et al.*, 2013:86). However, this period of rapid growth is also associated with a higher risk of injuries and temporary awkwardness which should also be taken into consideration in training programmes (Bompa, 2000:71).

2.3 CHARACTERISTICS OF THE DEVELOPING BOY AGED TWELVE- TO FIFTEEN YEARS

The age period between 12- to 15-years is a time of change in all aspects of life including physical, emotional and cognitive development for children, especially boys (Cameron, 2014:9; Blakemore & Choudhury, 2006:296). Malina (2014:156) states that growth, maturation, and development dominate the daily lives of children and adolescents for approximately the first two decades of their lives. Growth and maturation are biological processes, while development is largely a behavioural process (Malina, 2014:156). The term growth refers to an increase in body size or a particular body part, while development describes the natural progression from pre-natal life to adulthood and maturation to the process of becoming mature and fully functional (Baechle & Earle, 2008:142). These three processes occur simultaneously and are in constant interaction with each other (Malina *et al.*, 2004:4). All these processes can be influenced by physical activity and also can influence physical activity, performance, and fitness (Cameron, 2014:10; Malina, 2014:157). These entire processes take place during the adolescent period, and this period is seen as the changeover from boyhood to manhood. Characteristics of adolescence and aspects such as puberty, chronological and maturational age and growth that influence the motor- and physical fitness capabilities of boys, will be described in more detail in the next section.

2.3.1 Adolescence

According to Bitar *et al.* (2000:158), mid-adolescence starts between the ages of 10- to 14-years and continues up to 17-years, when boys enter the late adolescent (17–20 years) period. During adolescence patterns and systems are established that lead to mature functioning of the

body as a unit (Spano, 2004:1). Several models (biological, psychological, psychosocial and cognitive) have been established in the past to outline and describe the period of adolescence (Spano, 2004:2). In this regard, Sigmund Freud focused on psycho-sexual development, and describes adolescence as a developmental period of sexual awareness (Deborah & Russel, 2005:301; Spano, 2004:2). Piaget described adolescence as a cognitive development phase during which abstract thinking is used to make the transition from childhood to adulthood possible and Erikson defines adolescence as a period during which personal identity develops (Deborah & Russel, 2005:301).

During adolescence boys develop larger hearts, larger skeletal muscles and lungs, higher systolic blood pressure, lower resting heart-rate, a greater capacity for carrying oxygen in the blood, and a greater power of neutralizing the chemical products of muscular exercise (Tanner, 1981:48). The number of red blood cells and the amount of haemoglobin also increase during adolescence in boys (Tanner 1981:49). Tanner (1981:49) further stated that it is, as a direct result of these changes that athletic ability increases so much in boys at adolescence. Although the brain experiences no growth spurt during adolescence, the neural networks continue to increase in complexity throughout childhood and adolescence (Cameron, 2014:5).

2.3.2 Puberty

The onset of puberty is generally termed pubescence. Pubescence is the earliest period of adolescence, generally about two-years in advance of sexual maturity (Gallahue & Ozmun, 2006:304). During pubescence secondary sex characteristics (body hair, deepening of voice) begin to appear, sex organs mature, changes in the endocrine system begin to occur and the adolescent growth spurt begins (Gallahue & Ozmun, 2006:304). Boys begin their pubertal development prior to the initiation of the adolescent growth spurt and appear to experience most secondary sexual changes relatively early in adolescence, thus being sexually mature prior to the end of the adolescent growth spurt (Cameron, 2014:10). The onset of puberty marks the transition from childhood to sexual adulthood. Time of onset is highly variable and may begin as early as age 9 years or as late as age 15 years in boys (Gallahue & Ozmun, 2006:304). According to Cameron (2014:5) the development of athletic performance during childhood and adolescence will be strongly influenced, not only by growth in size and increasing complexity of the nervous system, but also by rates of maturational change and sexual dimorphism.

2.3.2.1 Chronological and maturational age

Growth, maturation and development operate in a time framework, and are measured or observed over time (Davids & Baker, 2007:7). The point of reference is the child's chronological

age, and most sporting codes use chronological age to group teams and manage participation (Davids & Baker, 2007:7). However, biological processes have their own timetables. Children of the same chronological age can therefore differ by several years, up to six years according to Woodman (1985:51), in their levels of biological maturity (Malina *et al.*, 2004:7; Cameron, 2014:10). A group of 14-year old boys can have a height difference as great as 23cm and a weight difference of up to 18kg (Beachle & Earle, 2008:143), which leads to the fact that late maturing boys are typically outperformed by early maturing boys (Till *et al.*, 2014:572). This may result in the over-representation of early maturing and relative older sports participants in the youth sports context. Due to anthropometrical and motor performance developmental trends that cause early and late maturers, there will consequently always be a difference in the skills development of children with the same chronological age (Davis *et al.*, 1997:253). Growth measurements are thus needed for monitoring and identifying the maturity level of athletes, so that training, competition and recovery programmes can be based on maturational age rather than chronological age (Balyi *et al.*, 2013:69).

2.3.2.2 Early vs late maturers

Due to anthropometrical and motor performance developmental trends caused by the onset of puberty, the phenomenon of early and late maturers exists (Davis *et al.*, 1997:253). This phenomenon will always be the cause of differences in the skills and fitness development of children with the same chronological age (Davis *et al.*, 1997:253). Identifying early and late maturers and educating them about the advantages and disadvantages of their developmental status therefore is a key priority (Balyi *et al.*, 2013:69). Maturation indicators such as PHV (indicator of somatic maturity) are used to classify children as average maturers (within +/- 1 year of the average value), early maturers (advanced with more than one year) and late maturers (delayed by more than one year) (Malina *et al.*, 2004:340). Researchers noted the following: Early maturing boys tend to be heavier and taller (at all ages) when compared to late maturers (Baxter-Jones, 2008:167; Bompá & Carrera, 2015:136). Early maturers tend to have broader hips and relatively narrow shoulders when compared to late maturers, and late maturers tend to have relatively greater leg length and shorter trunks compared to early maturers (Malina *et al.*, 2004:341). In terms of body shape (somatotype), late maturers tend to be more ectomorphic, and early maturers more endomorphic and mesomorphic (Malina *et al.*, 2004:342). As would be expected, early maturing boys tend to have greater muscle mass, but also more fat tissue at all ages (Malina, 2004:342). Lefevre *et al.* (1990:424) did a longitudinal study on Belgian boys from age 12- to 17-years, and classified the boys as early (13.1 years), average (14.1 years) and late (15.4 years) maturing. The motor performances (static strength, power and running speed) of early-maturing boys were, on average, better than those of

average-maturing and late-maturing boys (Lefevre *et al.*, 1990:432). Correlating results were also found in an earlier study by Beunen *et al.*, (1981) as quoted by Malina (2004:356) where skeletal age was used as the maturity indicator and after height and weight had been statistically controlled for, early-maturing boys performed better in most tasks after the age of 13 years, than late-maturing boys.

Advanced biological maturity status, with its concomitant size and strength advantages, constitutes an asset positively associated with success in several sports codes in early adolescence (Malina, 2004:445). Young male sports participants in baseball, football, swimming and track tend to be, on the average, advanced in skeletal and sexual maturation (Malina *et al.*, 2004:446). Performance in these sports relies to a large extent on strength and power, and a larger body size and muscle mass associated with advanced maturity status would therefore be an advantage. In contrast, boys who are average or delayed in skeletal maturity are often successful in distance running in pre- and early adolescence. Young figure skaters and gymnasts tend to be delayed in maturity status (Malina, 2004:446). According to Balyi *et al.* (2013:43) late developing males have an advantage over early developers in the sense that late developers spend more time in stage three (Learn to Train) of the LTAD model. All fundamental movement skills and overall sports skills must be developed and refined before the onset of the adolescent growth spurt (Balyi *et al.*, 2013:43). Thus, the longer a child remains in this stage, the more time he has to develop speed and skill (Balyi *et al.*, 2013:43). Early maturers, who have always relied on their advanced developmental age, lose this advantage as average and late maturers catch up. Because of their reliance on their early physical development, some do not develop the necessary skills or fitness (Balyi *et al.*, 2013:68).

2.3.3 Growth

Growth is an increase in the size of the body as a whole or the size attained by specific parts of the body (Malina *et al.*, 2004:4). For the first two decades of human life, growth is the dominant biological activity (Cole, 2003:162; Malina *et al.*, 2004:4). Pienaar (2010:137) defines growth as structural (anatomical) and physiological changes (changes that occur as a result of the proliferation of cells and intracellular compounds) that take place during maturation. Growth occurs mainly in three areas, namely neural growth, structural growth and genital growth (Balyi & Way, 2010:4). Neural growth entails the growth of the brain and the nervous system, and reaches 95% of maturity by age seven (Malina *et al.*, 2004:13). Structural growth refers to increases in height and weight, while genital growth refers to the development of primary and secondary sexual characteristics (Balyi & Way, 2010:4). All these different areas of growth influence motor fitness and performance development in boys (Balyi & Way, 2010:4).

Post-natal growth is divided into three periods namely infancy (first year of life), childhood (first birthday to the start of adolescence) that can be divided into, early childhood (preschool years) and middle childhood (primary school years). Adolescence, the third period is difficult to define in terms of chronological age because of variation in the time of its onset or the start of puberty (Cameron, 2014:5; Malina *et al.*, 2004:7). The World Health Organization defines the age of adolescence as between 10- and 18-years (World Health Organization, 2014). Growth is rather rapid in infancy and early childhood, slows down somewhat to a steadier pace during middle childhood, increases sharply during the adolescent spurt, and slows down and eventually terminates as adult dimensions are attained (Malina *et al.*, 2004:67). Specific body dimensions differ in the magnitude and timing of their respective adolescent growth spurts (Malina *et al.*, 2004:68). It should be noted, however, that late maturing children of both sexes tend to grow over a longer period of time and eventually catch up with and often surpass early maturing youth in height during late adolescence (Malina *et al.*, 2004:67).

The second dynamic purposive and directional process that goes hand in hand with growth is maturation. Maturation refers to the progress toward the biologically mature state or biological maturity (Malina *et al.*, 2004:277). Maturation is a process, while maturity is a state. Maturation occurs in all bodily organs and systems, but maturity varies with the biological system considered (Malina, 2014:158). Sexual maturity is fully functional reproductive capability (Malina *et al.*, 2004:284). Skeletal maturity is a fully ossified adult skeleton (Malina *et al.*, 2004:4). Maturation of the nervous and endocrine systems is a major factor underlying sexual, skeletal, somatic growth and maturation (Malina, 2014:158). Maturation refers to the timing and tempo of progress toward the mature biological state (sexual, skeletal and neuroendocrine) (Malina *et al.*, 2004:4). Timing and tempo of growth vary considerably among individuals, and are the cause of big differences in body size and composition of children of the same chronological age (Cameron, 2014:7; Malina *et al.*, 2004:7).

2.3.3.1 Growth spurt

The pattern of linear growth experienced by all children is characterized by rapid growth during infancy, relatively constant growth during childhood, and then accelerated growth during the adolescent growth spurt prior to reaching adult maturity and the cessation of growth in length (Cameron, 2014:5). The adolescent growth spurt is a dynamic growth period (Bitar *et al.*, 2000:158; Rogol *et al.*, 2002:196) during which boys experience physical and physiological changes in a relatively short time span. This period stretches over two to three years and usually falls within adolescence (Tanner, 1981:43). The adolescent growth period and more specifically the mid-adolescent period, age 13- to 15-years is associated with major growth changes known as the growth spurt, which also include PHV and the development of mature

gender characteristics (puberty) over a short period (Cameron, 2014:7). This period is known as the transitional phase from childhood to adulthood due to various physical and physiological changes occurring during this phase (Bitar *et al.*, 2000:157; Dahl, 2004:3). In this regard, literature indicates that the major changes in size, physical body composition and motor skills occur among boys between the ages of 9 and 16 years old (Bloomfield *et al.*, 1994:59; Malina *et al.*, 2004:12), due to increases in hormonal secretion. The commencement of this rapid growth period is, however, not rigid (Adair, 2001:e59; Towne *et al.*, 2005:213). Gradients in the growth of different body segments contribute to variations in body proportions (Cameron, 2014:9) which are especially apparent during adolescence. During the adolescent growth spurt the peak velocity of growth in height averages about 10cm a year (Tanner, 1981:43). PHV that represent maximal growth in one year, that takes place around age 14 in boys (Malina *et al.*, 2004:293), is especially important as it is also a reference for comparison of changes in body dimensions, proportions, and composition and physical performance during the adolescent growth spurt (Cameron, 2014:6; Malina *et al.*, 2004:307). Differential timing of the growth spurts in segment lengths and skeletal breadths relative to PHV is also apparent (Cameron, 2014:9). Peak velocity for estimated leg length occurs earlier than that for height, whereas peak velocity for sitting height or trunk length occurs after that for height. Rapid growth of the lower extremities is characteristic of the early part of the adolescent growth spurt (Malina *et al.*, 2004:320). Boys will experience a change in the centre of gravity as a result of these growth gradients of different body segments that will cause temporary loss of coordination and speed during this phase of rapid growth, according to Balyi *et al.* (2013:71).

2.4 DEVELOPMENTAL TRENDS OF ANTHROPOMETRIC CHARACTERISTICS AND THEIR INTERRELATIONSHIP WITH MOTOR FITNESS

This section will discuss developmental trends of growth and changes in anthropometric characteristics of boys during mid-adolescence and the interrelationship between anthropometrics like height and body mass and physical capacities like speed, agility, strength and power. Anthropometry involves measurement techniques to determine and evaluate size, proportions and aging of the human body or segments thereof (Balyi & Way, 2010:3; Jenkins, 2005:55). Jenkins (2005:55) sub divides these measurements into skinfolds and weight (body weight), girths (circumferences) lengths (including stature) and diameters. This information can provide an objective view of an individual sports participant when compared to other sports participants (Balyi & Way, 2010:3). These techniques contribute to proper evaluation of the structural status of an athlete at any given time or more importantly it allows for quantification of differential growth (Balyi & Way, 2010:3). According to the LTAD model, boys between the ages of 12- to 16-years fall in the Train-to-Train stage during which they become practice-ready in

respect of the demands that will be made upon them in a competitive sport (Balyi & Way, 2005:8). Knowledge in regard to the nature and extend of growth during this phase can contribute to the optimal utilization of this development period. A discussion of the following anthropometrical measurements and their developmental trends during the adolescent years of boys will follow.

2.4.1 Height

Human height, also known as stature is the distance from the bottom of the feet to the top of the head in a human body, and is measured using a stadiometer (Malina *et al.*, 2004:49). Growth in height occurs as a result of the proliferation of cells in bones and muscles from birth, and growth ends when growth plates in the spine close (Malina *et al.*, 2004:62; Pienaar, 2010:137). Human height starts with a period of accelerated growth during infancy (0-3years) (Malina *et al.*, 2004:49), with a second, but smaller growth spurt that is experienced from 7 or 8 years (Gasser *et al.*, 1985:129). From 8 years until puberty / adolescence growth is constant and linear (Malina *et al.*, 2004:7). During adolescence a third period of accelerated growth is experienced, lasting up to three years between the ages of 13- to 15-years. After the accelerated growth period, the growth curve gradually slows down and eventually terminates as adult dimensions are attained (Malina *et al.*, 2004:49). Growth in height is a continuous process with short velocity spurts. During infancy, children grow about 10cm during the first year and 12-13cm in the second year, after which growth slows down and reaches a plateau at age four (Rogol *et al.*, 2000:523). From age four children grow about 5-6cm per year until the onset of puberty, after which a final phase of accelerated growth occurs (Rogol *et al.*, 2000:523). Boys have accelerated growth as a result of an increased hormonal secretion that includes testosterone and human growth hormone (Baechle & Earle, 2008:56). Testosterone performs a variety of functions and is important for the development of a child (Baechle & Earle, 2008:56). Tanner and Whitehouse (1976:172) developed growth standards for boys that can be used in various populations and are still in use today. Tanner and Whitehouse (1976:172) stated that there is acceleration in growth at about age 13-15 years with peak acceleration at 14 years, after which a plateau is reached at age 17. In this regard the results of Armstrong and McManus (2000:20) show that the height of boys increased with 7-9-7cm per year during the accelerated growth phase (13- to 15-years). In a study of adolescent boys residing in the North West Province of South Africa by Gerber *et al.* (2015:24), mean height increments of 8.07cm, 3.35cm, and 2.15cm over the three years were found, with the first measurement at age 13.58 years, in the grade eight year of the boys. According to Wheeler (1991:10) boys can grow as much as 12cm within the year of PHV that on average occurs at age 14. A review study by Kim *et al.* (2008:232), that focused on anthropometrical changes in Korean children and adolescents over the past 40 years, showed

that boys grew 6.8cm (11-12 years), 7.7cm (12-13 years), 5.2cm (13-14 years), 3.4cm (14-15 years) and 1.6cm (15-16 years) respectively. In a study of 1008 Czech Republic and Polish boys between the ages of 7- and 15-years, Kopecký *et al.* (2013:56) measured the largest additional growth in their adolescent phase with a peak height velocity reaching more than 8cm per year during ages 12 and 13 years. Results by Gerber *et al.* (2015:24) suggested that PHV occurred between ages 13.58 – 14.58 years in boys of the North West Province, with height increases of 8.07cm and only 3.35cm in the following year.

2.4.1.1 Sitting height

Sitting height is defined as the distance between the transverse area (surface) of the vertex and the lower part of the thigh area (ischium) when in a seated position (Marfell-Jones *et al.*, 2006:60). Sitting height shows a linear increase from birth to about ten years, with a slight decline in growth around 13.5 years of age, after which acceleration is observed again (Malina *et al.*, 2004:68). The final increase in sitting height occurs after the final increase in standing height or stature (Malina *et al.*, 2004:68). Lee *et al.* (2005:17) found in their study of 570 boys in Taipei that the acceleration phase of sitting height takes place between the ages of 12 and 14 years. These increases were respectively 4.6cm (12-13 years) and 3.7cm (13-14 years) during this period. Lee *et al.* (2005:17) also found that the growth curve of boys increases in a linear pattern with a mean value of 1.4cm/year until late adolescence (17-18 years). In a South African study by Gerber (2013:83) it was found that sitting height increased by 3.83cm in boys from age 13.58- to 14.58-years and 3.02cm from age 14.58- to 15.57-years.

2.4.1.2 Sitting Height Ratio

Sitting Height Ratio is defined as a percentage of total body stature (Malina *et al.*, 2004:48). This ratio is calculated in order to determine the length of the torso and lower limbs separately (Malina *et al.*, 2004:48). In the study by Gerber *et al.* (2014:617) height showed a statistically significant increase of 8.07cm, while sitting height ratio showed a volatile development curve over the three years of the study. During the first year a decrease in sitting height ratio of 0.15% was observed, which showed the magnitude of the contribution that increasing leg length during this period has on total body length. During this period total body length increased by 8.07cm and sitting height increased by 3.83cm (42%), which leaves 58% of growth to the lower extremities (Gerber *et al.*, 2014:617). The results from Pienaar and Viljoen's (2010:88) cross-sectional study on 10-15 year old boys confirm the trend that sitting height is about 51% of total body height at age 10 years, and 50% at age 12 after which a plateau is reached.

2.4.2 Weight

Weight can be defined as the total mass of the body (Marfell-Jones *et al.*, 2006:57). Body weight is a composite of bodily tissues, but it is often viewed in terms of its lean (fat-free) and fat components (Malina, 2014:159). Thus, body weight equals fat-free mass (FFM) plus fat mass (FM). Major components of FFM are skeletal muscle and bone mineral. FFM has a growth pattern similar to that of height with a clear adolescent spurt (Malina, 2014:159). FM increases more gradually during childhood and adolescence (Malina, 2014:159). Weight follows the same development curve as height but keeps on increasing till the mid-twenties while height reaches a plateau at age 18 years (Armstrong & McManus, 1996:22). The growth spurt in body weight begins slightly later than that of height (Malina, 2014:159). According to Santrock (2010:293) boys experience an accelerated increase in weight and reach up to 50% of their adult weight during adolescence. Rogol *et al.* (2002:195) stated that a peak in weight increase coincides with PHV in boys at age 14 years and shows a systematic slow down during late adolescence. Rogol *et al.* (2002:195) also noted that boys on average gain 9.5 kg/year during the accelerated growth phase. A study by Lee *et al.* (2005:17) in Taipei, a study on boys (N=570) which focused on longitudinal growth patterns, expressed weight as kg/cm, and indicate that from age 8-11 years, weight of boys increased in a linear pattern with 0.1- 0.2 kg/cm/year, with a sudden increase of 0.4 kg/cm that was noted at the age of 12-13 years. During the two-years that followed (13-15 years) an increase of 0.3 kg/cm was noted. After this weight velocity phase a levelling off and plateau were reached where mass/cm showed a mean increase of 0.1 kg/cm up till age 18 years. In a cross-sectional study by Pienaar and Viljoen (2010:75) they found that the weights of boys show a statistically significant annual increase that stayed unchanged throughout their adolescent years (12-15 years). Their results correlate with the standard secular peak weight acceleration as reported by Tanner and Whitehouse (1976:173). Kopecky *et al.* (2013:56) reported increases in body weight of up to 6 kg in the Czech boys during ages 13- to 14-years. In Polish boys, a Peak Weight Velocity (PWV) of 7.76kg was observed between 12- to 13-years of age (Kopecky *et al.*, 2013:56). Gerber (2013:83) reported an increase of 8.55kg in South African boys of the North West Province during the first year of the study (13.58–14.58 years) and only a 4.47 kg increase during the second year (14.58 – 15.57 years).

2.5 DEVELOPMENTAL TRENDS OF MOTOR AND PHYSICAL FITNESS CAPABILITIES IN THE ADOLESCENT BOY

Motor performance can generally be described as factors or components that influence a person's current performance levels and allow a person to execute a certain level of movement skill (Gallahue & Ozman, 1995:73; Gallahue & Ozman, 2006:16). Capabilities such as speed, agility, balance, coordination and power will, therefore, fall under the category of motor

performance capabilities (Gallahue & Ozman, 1995:73) while strength can be classified as a physical fitness component. Motor and physical fitness capabilities change as a function of growth, maturation, development and interactions among the three processes (Malina, 2014:165). As a child grows up his capacity for physical exertion increases. Some of this is due to the simple fact that the child becomes bigger, i.e. grows longer legs and arms, larger heart and muscle mass (Asmussen & Heeboll-Nielsen, 1955:603). Performances on standardized tests of motor performance, including several fitness items improve with age during childhood and with the onset of adolescence, performances of boys show acceleration in improvement (Malina, 2014:60). Clark and Metcalfe (2002:185) describe an unstable growth period during early childhood, referred to as the compensation period which represents that time in the motor development journey when the child must compensate for rapid biological changes. The growth spurt during the early adolescent years in boys aged between 12- and 14-years is another period of such rapid growth (Anthanasios & Hackfort, 2014:6). When the physical features of the body change in such drastic leaps, the CNS must make big adaptations to accommodate such changes and adapt to the new segmental forces which in return will impact on the execution of motor skills (Clark & Metcalfe, 2002:178). Changes in body proportions during this period could furthermore contribute to awkwardness in motor skill execution (Pienaar, 2010:420). A discussion of the literature on developmental trends of motor performance capabilities like speed, agility, strength and power in the adolescent boy will follow.

2.5.1 Speed

Running speed is defined as the skill and ability to achieve rapid movement (Baechle & Earle, 2008:458). Speed implies acceleration from a starting position whereas acceleration implies power, while maintenance of speed requires muscular endurance (Sharkey & Gaskill, 2006:110). Athletes thus require power to accelerate to the speeds necessary for success, whether the speed is that of a ball being released, vertical velocity during the high jump or running speed during a sprint (Sharkey & Gaskill, 2006:110). Sprinting and running are key fundamental movement skills that are considered to be the building blocks for many sporting activities (Rimmer & Sleivert, 2000:298; Taylor, 2003:670) and are common forms of locomotion performed by children during playground games and activities (Faigenbaum *et al.*, 2009:75). Furthermore, sprinting performance appears to be an important determinant of success in many adult and youth sports (Young *et al.*, 2002:283; Gabbett *et al.*, 2008:175; Mendez-Villanueva *et al.*, 2010:480), and assessments of maximal speed are commonly included in batteries of talent identification tests (Reilly *et al.*, 2000:676).

Speed can be divided into the following components, namely maximal speed, stride length (SL), stride frequency (SF), flight time (FT) and contact time (CT) (Meyers *et al.*, 2015:85). While it is

accepted that running speed is the product of stride length and stride frequency (Hunter *et al.*, 2004:270), it is also known that other mechanical stride characteristics may influence stride length and stride frequency (Hay, 1994:400). In adults it has been reported that faster runners achieve longer strides through greater application of ground reaction forces during a reduced ground contact period (Weyand *et al.*, 2000:1993; Weyand *et al.*, 2010:953). In adults, improvements in strength and power have been associated with improved stride length and speed (Weyand *et al.*, 2000:1993; Wisloff *et al.*, 2004:286). It has been suggested that a similar relationship may be evident in children, especially around the period of PHV when physiological characteristics linked to improved neuromuscular function (Malina *et al.*, 2004:26) and greater limb length (Ecker, 2015:60) have been reported.

Phillippaerts *et al.* (2006:225) found that speed has a phase of negative development (speed reduction) during the 12 month period before the start of the PHV. Malina (2014:160) stated that the earlier adolescent spurts for running speed and lower back flexibility may be related to growth of the lower extremities which experience maximum growth before the upper extremities. Thus, boys have relatively longer legs for their heights early in the adolescent spurt, and this may influence running speed and lower trunk flexibility. Gerber *et al.* (2014:623) confirmed that improvements in speed, correlated with changes in stature and sitting height, before and after adjustment for anthropometric growth, and these relationships had medium level practical significance. They also reported a relationship with body mass although these relationships had small significance (Gerber *et al.*, 2014:623). Meyers *et al.* (2015:92) stated that SF has been shown to decrease during the pre-PHV period. Furthermore, while reduced CT is often reported as desirable for sprint performance, it appears that as a result of natural development, CT actually increases during childhood. SL increases with maturation, and this is likely due to increased limb length and improved relative force production (Meyers *et al.*, 2015:92). According to Phillippaerts *et al.* (2006:228) speed develops systematically during the 12 months before PHV and reaches a peak that coincides with the peak of PHV, after which speed reaches a plateau about 12-18 months after PHV. In a study by Spencer *et al.* (2011:503) speed of boys between the ages of 11-13 years increased with 0.1m/s. Followed by two-years (13-14 years) of acceleration in speed development of 0.5m/s and between ages 14-15 years an increase of only 0.3m/s is noted after which speed development reached a plateau of 0.1m/s until the age of 18 years (Spencer *et al.*, 2011:503). In this regard Pienaar and Viljoen (2010:85) found in a cross-sectional study of boys in the North West Province, that speed remains stable over 40m for boys age 10-12 years (7.7s; 7.8s; 7.7s) after which a steady improvement occurs for boys age 13-15 years (7.4s; 7.2s; 7.0s) respectively. In a longitudinal study by Gerber *et al.* (2014:621) a small but significant increment of 0.47s and 0.24s between 13.58-14.58 years and 14.58-15.57 years respectively were reported over a distance of 40m.

2.5.1 Agility

At present, there is no consensus among the sports science community for a clear definition of agility. Traditional definitions of agility have simply identified speed in directional changes as the defining component (Young *et al.*, 2001:318). Some authors have defined agility as including whole-body change of direction as well as rapid movement and directional change of the limbs (Draper & Lancaster, 1985:16). Young *et al.* (2002:282) identified agility as comprising two key sub-components; speed in changing direction, and cognitive factors. More recently, agility has been identified as “a rapid whole body movement with change of velocity or direction in response to a stimulus” (Sheppard & Young, 2006:915), which can also be described as an athlete’s collective coordinative abilities (Tittel, 1991:209). These are the basic elements of technical skills used to perform motor tasks spanning the power spectrum from dynamic gross motor activities to fine motor control tasks and include adaptive ability, balance, combinatory ability, differentiation, orientation, reactivity, and rhythm (Plisk, 2008:458). Thus agility refers to the use of abilities such as muscle strength, rapid muscle contractions, speed and coordination to achieve sudden change of direction and maintain speed during a movement (Baechle & Earle, 2008:458).

Phillippaerts *et al.* (2006:228) state that agility starts to develop 12 months before peak height growth and reaches its peak at the start of peak height growth, after which a plateau is reached. According to Pearson *et al.* (2006:282) agility can increase by up to 20% during puberty. Pienaar and Viljoen (2010:87) found a plateau in agility of boys 10-11 years with a systematic increase up to 14 years of age. A possible explanation could be that agility is influenced by dynamic strength, power / explosive strength and the speed of muscle contractions, which all only develops at a later stage than agility (Badenhorst & Pienaar, 2000:6). Sheppard and Young (2006:920) also report that agility is affected by body composition (lower body fat vs. higher muscle mass) as well as by stature, relative limb length and height of the centre of gravity. Gerber *et al.* (2014:263) used the shuttle run test to measure agility of boys aged 13.58 to 15.57 years. The results from Gerber’s study on agility indicate a similar developmental curve as speed over the first year (boys aged 13.58 to 14.58 years) during which significant improvement was seen ($p < 0.05$). Changes in agility also showed moderately significant relationships with changes in stature, mass and sitting height, over the two-year period of the study of Gerber *et al.* (2014:264).

2.5.2 Strength

Strength is an expression of muscular force, or the individual's capacity to develop tension against an external resistance (Kent, 2006:366; Malina *et al.*, 2004:216). Strength is defined as

the maximum power output during a single muscle contraction (Faigenbaum & Westcott, 2009:6; Pienaar, 2010:167). Male strength increases with advancing chronological age with peak strength gains that occur approximately 14 months after the occurrence of PHV and approximately nine months after peak weight gains (Beunen & Malina, 1988:523; Carron & Bailey, 1974:19; Malina *et al.*, 2004:555). Folland and Williams (2007:146) are of the opinion that gains in strength are undoubtedly due to a wide combination of neurological and morphological factors.

Strength increases in a linear pattern in boys from early childhood until the onset of puberty (13-14 years) (Malina *et al.*, 2004:218). A strength acceleration phase is reported during puberty, for about two-years, after which strength continues to increase linearly into late adolescence (De Ste Croix, 2007:296). Research by De Ste Croix (2007:300) showed a strength increase of 314% in knee extension and 285% in knee flexion in boys between the ages of nine and 21 years. In a cross-sectional study of boys 10-15 years by Pienaar and Viljoen (2010:80) a significant increase was found in the grip strength of boys from the age of 12 and upper-body strength in boys 14- and 15-years, which was tested through the pullup test. These researchers also noted that the increase of upper-body strength coincided with the period of increase in weight.

Although physical stature, age, weight and gender play a role in the potential strength of a person, it has been proven that only 40-70% of strength development is influenced by these factors (Rowe *et al.*, 2004:549). One of the main factors responsible for the increase in strength with the onset of puberty is testosterone levels. Testosterone secretion increases fourfold during early puberty with a further twentyfold increase during mid-puberty (Rowe *et al.*, 2004:549). Several researchers also indicate that neurological factors play an important role in strength development (De Ste Croix, 2007:297; Paus *et al.*, 1999:1908).

Strength of the upper and lower extremities does not show the same developmental trends. In a study by Carron and Bailey (1974:30), a clear difference in terms of strength development between the two body segments was noted. According to the results of the study by Carron and Bailey (1974) the lower extremities show acceleration in development about one year before the upper-body. Furthermore these researchers stated that upper-body strength increases 3.9 times between the ages of 10-16 years, while leg strength increases only 2.5 times in boys (Carron & Bailey, 1974:33). The strength development acceleration of the legs happens about two-years before PHV and the acceleration of the upper-body strength development only one year before PHV (Malina *et al.*, 2004:328). In this regard Gerber *et al.* (2014:263) found that upper body strength (measured by cricket ball throw) showed a larger increase during the second year (14.58-15.57 years) of their study, which was after PHV of the group. This higher increase

during the second year is ascribed by Gerber *et al.* (2014) in part to increased muscle strength, which develops later in the upper limbs than in the lower limbs (De Ste Croix, 2007:297). Round *et al.* (1999:54) found two periods of strength development acceleration in the legs (measured by quadriceps strength), the first about three years before PHV and the second only one year before PHV. They also confirmed that upper-body strength accelerated only one year before PHV.

Malina *et al.* (2004:710) report that it is during the later stages of puberty that muscular strength and power showed major gains in adolescent boys. Another possible explanation might be improved upper arm and body coordination during this period as a result of a rapid increase in stature, arm span and sitting height during the previous year, which is then tied in with increased strength during this period (Gerber *et al.*, 2014:623). Gerber *et al.* (2014:617) also confirm small to moderate interrelationships between changes in anthropometrical growth and physical and motor fitness development in boys during mid-adolescence. Increases in cricket ball throwing distance showed small relationships with anthropometric growth changes after adjustment for maturational age.

2.5.3 Power

Explosive strength/power refers to the ability to exert a maximal amount of force in the shortest possible time interval (Syatt, 2012). Therefore power is the product of force times velocity ($\text{Power} = \text{Force} \times \text{Velocity}$), where force represents strength and velocity speed (Syatt, 2012). Kent (2006:197) defined explosive power as “the ability to expend energy in one explosive act or in a series of strong sudden movements as in jumping, or projecting some object (e.g. a javelin) as far as possible”. Baechle and Earl (2008:250) define explosive power as the ability of muscles to maintain high power output whilst contracting at high speed. Almost all sports require increases in power to increase performance (Sharkey & Gaskill, 2006:100).

The jumping capability of boys improved with age up to 19 years (Branta *et al.*, 1984:498). Data for the general population of adolescent boys suggest that strength and power attain maximal growth after PHV (Beunen & Malina, 1988:523; Malina *et al.*, 2004:555). In an overview study based on research evidence by Viru *et al.* (1999:91) it was found that the vertical jump height of adolescents increased between the ages of 12-14 years. In two separate studies that they reviewed increases of 7-9-7% and 5-12-5% were shown over the three year period. Gerber *et al.* (2014:622) also noted that explosive leg power (as measured by the vertical jump) showed a significant mean improvement of 3.17cm ($p < 0.05$, $d > 0.5$) between the ages of 13.58- and 14.58-years and a larger mean improvement of 5.65cm during year two of their study (age 14.58 -15.57 years). Gerber *et al.* (2014:264) however, found no significant interrelationships

between explosive leg power and any of the changes in anthropometric growth during the same period. Philippaerts *et al.* (2006:224) found in their study that explosive strength as measured with the vertical jump test showed a similar estimated velocity curve to that of height with a velocity of 1.5cm/year, 12 months before peak height velocity and reaching a peak coincident with PHV (Philippaerts *et al.*, 2006:224).

A constant but insignificant improvement of explosive upper-body strength in boys 10-12 years was also reported by Pienaar and Viljoen (2010:83). The basketball throw test done with boys 13- and 15-years of age showed a significant improvement of explosive upper-body strength which correlates with maximal stature increase and body mass acceleration in the study (Pienaar & Viljoen, 2010:83). Kopecky *et al.* (2013:58) also found that the values for upper-body power measured by medicine ball throw increased gradually between the ages of seven and 15 years, with the biggest increase in boys 15 years old. Gerber *et al.* (2014:263) found that explosive upper body power (measured by basketball throw) showed a more significant improvement between 13.58- to 14.58-years (1.08 m) compared to boys aged 14.58- to 15.57-years (0.29 m; $p < 0.05$). They also stated that changes in basketball throwing distance, showed interrelationships with all anthropometric growth changes that were measured in their study except sitting height ratio, which indicate that increases in stature, mass, sitting height and arm span are related to increases in performance of this ability (Gerber *et al.*, 2014:264).

The following section of this literature chapter will focus on literature that report on the training of motor fitness capabilities of mid-adolescent boys.

2.6 TRAINABILITY OF MOTOR FITNESS CAPABILITIES IN MID-ADOLESCENT BOYS

Boys aged 12- to 15-years (mid-adolescence) have a sensitive period of accelerated adaptation to training of motor fitness capabilities - speed, agility, strength and power (Balyi *et al.*, 2013:90).

Trainability refers to the responsiveness of developing individuals to the training stimulus, at various stages of growth and maturation (Balyi *et al.*, 2013:80). Monitoring growth helps to identify the sensitive periods of accelerated adaptation to training (Balyi *et al.*, 2013:69). Boys aged 12- to 15-years (mid-adolescence) are in the train-to-train stage of the LTAD model as described by Balyi *et al.* (2013:81). This phase poses the opportunity to develop certain motor performance capabilities. Windows of optimal trainability for strength and speed are reported by Balyi *et al.* (2013:81) and shown in fig 2.1. These windows are fully open during the sensitive periods of accelerated adaptation to training and partially open outside these periods (Balyi *et*

al., 2013:83). Following is a discussion of the different motor fitness components (strength, power, speed, agility) and the likelihood of improvement, this being subject to training.

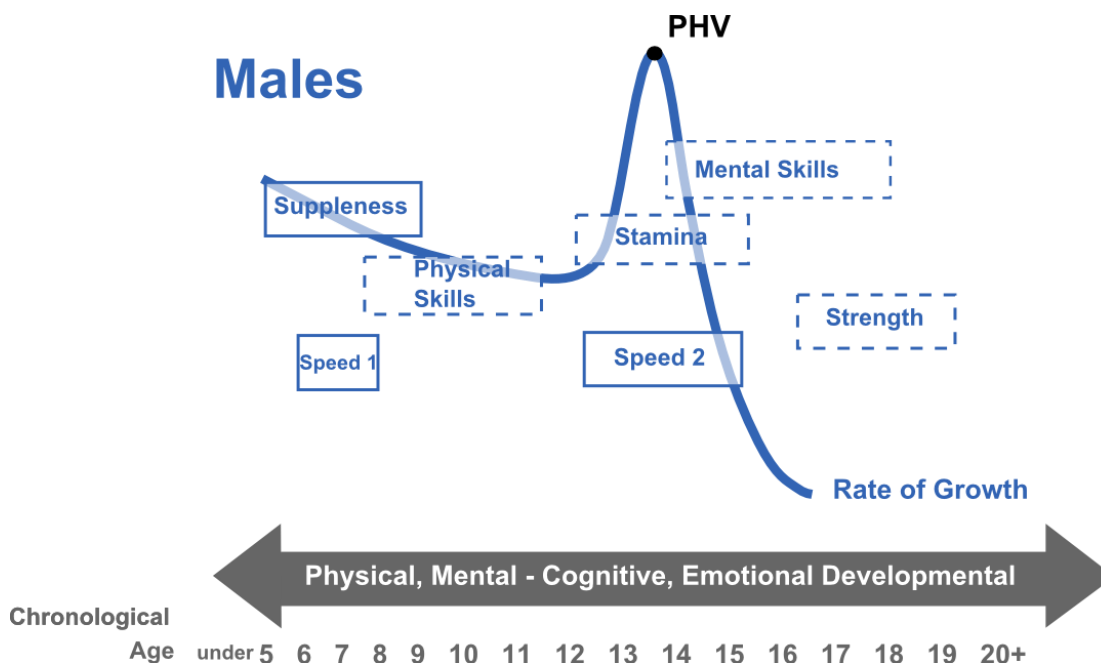


Figure 2.1: Windows of accelerated adaptation to training

(www.orienteing.co.za)

2.6.1 Strength training

Taking into consideration that boys during mid-adolescence have increased testosterone levels, increased body weight and muscle mass as well as increasing limb length, the period after PHV is seen as an opportune time to train and improve strength in boys (Malina, 2006:485). Resistance training in the pre-pubescent child may also effectively increase strength, without a concomitant increase in muscle mass (Naughton *et al.*, 2000:316). Without the anabolic effects of testosterone in boys, strength gains at this age (12-13 years) are mainly attributed to more efficient recruitment of motor units (Reilly & Stratton, 1995:210).

The term “resistance training” is defined as a type of exercise that requires the musculature to contract against an opposing force generated by some type of resistance (e.g. body weight, barbells, dumbbells and weight machines) (Behringer *et al.*, 2010:e1200). If free weights or specific machines were applied to generate resistance, the term “weight training” is used synonymously. By contrast, the term “strength training” is used in a broader sense (e.g. to describe any type of conditioning that is used to increase physical strength) (Behringer *et al.*, 2010:e1200). Numerous studies have shown resistance training to be an effective and safe way

for enhancing muscle strength in children and adolescents, if appropriately prescribed and supervised (Behringer *et al.*, 2010:e1200; Falk & Tennebaum, 1996:182; Payne *et al.*, 1997:83). Furthermore, resistance training has been shown to be associated with several health-related benefits such as increased bone mineral density, improved body composition and enhanced mental health and well-being (Faigenbaum, 2007:196). Accurate knowledge of an individual's present level of muscular strength is, however, important for both occupational functional capacity evaluation and appropriate athletic and rehabilitation exercise prescription (Brown & Weir, 2001:2). Absolute strength is probably less trainable in pre-pubertal than in pubertal and/or post-pubertal youth (Blimkie & Sale, 1998:193). Responses to resistance training stimuli in pre- and early-pubertal youth are largely neural and may include a learning component (Blimkie & Sale, 1998:193). Enhanced motor unit recruitment and/or frequency of motor unit firing, alterations in pattern of motor unit recruitment, and changes in muscle activation and contractile characteristics with strength training are possible contributing factors (Ozmun *et al.*, 1994:510; Ramsay *et al.*, 1990:605). Whatever the sport, strength training lays the foundation for power, a necessity in all sports codes (Sharkey & Gaskill, 2006:100).

2.6.2 Power training

Higher power could be attributed to the fact that a larger lean body mass and muscle mass produce greater anaerobic power as found among male adolescents (Mikulic, 2011:147). Research has shown that power training, using light to moderate loads at high velocities, most effectively increases sport specific power and the maximal rate of power development (Sharkey & Gaskill, 2006:101). It is important to understand that power is the result of applying force (strength) quickly. It is also necessary to have adequate strength before one can develop power (Sharkey & Gaskill, 2006:101)

If anthropometric composition and the development of acceleration of speed and strength are taken into consideration, one would be advised to start training and developing power before PHV. Researchers also claim that greater height-to-weight ratios, as displayed by leaner and taller adolescents, would benefit these subjects during the execution of tests such as the vertical jump (Nevill *et al.*, 2009:230). Takai *et al.* (2013:60) found in their study of 94 Japanese boys aged 13.7 years that the experimental group (36 boys) showed improvement of 3.4% in the vertical jump test after eight weeks of body mass-based squats of 100 reps/day, compared to the 1.8% improvement of the control group (58 boys) who were not subjected to extra training except their normal daily sports training (Takai *et al.*, 2013:62). In a study by Santos and Janeira (2008:903) of 25 boys aged 14- to 15-years where the experimental group was subjected to a ten week weight and plyometric training programme, the experimental group showed an improvement of 13% in explosive leg power (measured by the standing long jump

test) compared to a loss of 8.6% in the control group who only adhered to their normal sports practice (Santos & Janeira, 2008:904). In a South African study by Duvenhage (2012:59) on 153 Grade 10 boys of the North West Province competing in sport and 48 boys who did not compete in sport, a difference of 11.6cm in vertical jump height was found between the two-groups. According to Duvenhage (2012:65) these differences are attributable to participation in sport, and Duvenhage (2012:65) argues that participation in sports codes such as athletics, rugby and hockey requires participants to be able to deliver sudden bursts of power when rapidly changing direction or when a high velocity must be generated (Duvenhage, 2012:65).

2.6.3 Speed training

The time around PHV is a key point in the improvement of speed in boys (Meyers *et al.*, 2015:92). In a study by Mendez-Villanueva *et al.* (2010:502), 61 male soccer players were divided into three groups, pre-age at peak height velocity (APHV) players (12.3 ± 0.7 years), circum-APHV players (14.3 ± 0.9 year) and post-APHV players (16.9 ± 0.7 years). Mendez-Villanueva *et al.* (2010:502) found that maximal sprinting speeds were higher in the post-APHV players than the other two-groups. This difference can be due to the disproportion of body segments during the mid-adolescent period (Malina *et al.*, 2004:320) and the increase in complexity of neural networks during adolescence (Cameron 2014:5). Meyers *et al.* (2015:85) found in another study of 336 boys aged 11 to 15 years that speed stayed the same during the years pre-PHV because of decreases in SF and increase of SL, while speed improved when PHV is reached (Meyers *et al.*, 2015:88). A potential explanation for their results was that boys who are pre-PHV may lack the necessary motor coordination and strength to effectively orientate, stabilize and apply force through their lower limbs. SL increases with maturation and this is likely due to increased limb length and improved relative force production (Meyers *et al.*, 2015:92). Therefore boys at- or post-PHV seem to be able to use the additional leg and stride length more effectively as both CT and SF stabilize around this time (Meyers *et al.*, 2015:91). Philippaerts *et al.* (2006:228) reported on a similar phenomenon whereby decrements in speed in boys approaching PHV were speculated upon to be caused by temporary disruption in motor coordination, termed adolescent awkwardness. Findings from the study of Meyers *et al.* (2015:85) would suggest that pre-PHV boys should focus on the development of neural parameters to facilitate improved SF and CT. Improved neural factors may result in increased technical competency and assist in coping with the growth-related anthropometric changes observed at this time. While neural training should continue for boys around and post-PHV, the focus of training should shift toward improved SL with the development of strength and rate-of-force development to make optimal use of the maturity-related changes in circulating androgens and increased muscle mass (Meyers *et al.*, 2015:92).

Duvenhage (2012:59) found in her study of 153 sporting boys in the North West Province in South Africa versus 48 non-sporting boys a difference of 0.28s over 10m and 0.89s over 40m. Duvenhage (2012:67) attributes the differences in speed over 10m and 40m to anthropometric differences such as greater muscle mass and a lower fat percentage in sports participants compared to non-sporting participants. Wong *et al.* (2010:650) did a study on 62 u/14 soccer players, and subjected 28 boys to a 12 week combined strength and power training programme. The speed over 10m of the experimental group improved from 2.05s pre-test to 1.95s post-test compared to 2.07 pre-test to 2.04 post-test of the control group who did no extra training except their daily soccer training. Takai *et al.* (2013:62) found in their study a 5% improvement of speed of 36 boys aged 13.7 years compared to a 2.9% improvement in the speed of the control group. Participants in the experimental group did an extra 100 body weight squats per day, 4-6 days per week, for eight weeks.

2.6.4 Agility training

Recognizing the close relationship between strength, speed, and endurance as well as coordination and agility allows both instructor and sports participants to understand the multilateral process. The higher the levels of strength and speed the easier the development of coordination and agility (Bompa, 2000:44). Agility requires strength, power and endurance, therefore as sports participants develop speed and power they will become more agile (Sharkey & Gaskill, 2006:117). Pearson *et al.* (2006:282) argue that agility can improve up to 20% during adolescence. In a study by Pittoli *et al.* (2010:284) on 42 Brazilian soccer players compared to 45 non-players a small but linear improvement of agility was seen from ages 11- to 15-years in the non-players. The improvement of agility was substantial bigger in the players between the ages of 11- to 12-years and 13- to 14-years, with only a small negative improvement between ages 14- to 15-years (Pittoli *et al.*, 2010:284). The 42 soccer players only did speed and agility specific exercises. This can be explained by the fact that boys at age pre-PHV (11- to 12-years) who do specific training show better improvement because of neural adaptation to specific training (Meyers *et al.*, 2015:92). Duvenhage (2012:60) found that agility (as tested with the 505 Agility test) of 153 boys who competed in sport were 0.3s better than that of 48 boys who did not compete in sports.

2.7 TRAINING AND ITS POTENTIAL EFFECTS ON GROWTH DURING MID-ADOLESCENCE

Scientific reports of training that affected pubertal growth negatively are scarce (Naughton *et al.*, 2000:320). A recent position statement paper from the National Strength and Conditioning Association (Faigenbaum *et al.*, 2009:66) documented that children and adolescents can gain

real benefits from participating in well-designed and carefully supervised strength programmes. A wide variety of resistance training programmes from single set sessions on weight machines to progressive, multi-set training protocols on different types of equipment have proven to be efficacious (Santos & Janeira, 2008:904; Takai *et al.*, 2013:61; Wong *et al.*, 2010:647). Training modalities have included weight machines and child size free weights hydraulic machines, medicine balls elastic bands, isometric contractions and body weight exercises (Faigenbaum *et al.*, 2009:4).

Naughton *et al.* (2000:320) describe the results of a study by Baxter-Jones and Helms (1996:320) on elite junior athletes with the aim to determine the effect of strength training on growth from different sporting codes profiled over three years, where the ages of the participants ranged from eight- to 16-years. The young participants remained on the same growth percentile for height and weight over the three year period. The absence of a downward shift in percentile rankings suggested that sports specific intensive training was not delaying growth during the years of measurement (Naughton *et al.*, 2000:320). The preceding comparisons of the growth status of sports participants to reference data for non-sports participants clearly indicate that young sports participants grow in a manner similar to non-sports participants and that much of the variation in body size is associated with variation in rate of biological maturation (Malina *et al.*, 2004:461). On the other hand, training is a significant factor affecting body composition, performance, and physiological parameters, implying that some of the variation between sports participants and non-sports participants represents an interaction between innate and acquired individual differences and various selective considerations for sport participation (Malina *et al.*, 2004:461).

Parizkova and Carter (1976:338) did a longitudinal study of eight years on 39 boys from age 11 until 18 years to examine the stability of somatotypes of boys with different activity levels. Parizkova and Carter (1976:338) divided the boys into three groups according to their level of activity during the week. Group one participated for more than four hours of moderate to vigorous physical activity or exercises, group two participates in exercised two to four hours per week and group three did less than two hours of physical exercises per week. Although somatotypes of boys changed during the eight years of growth, no significant differences could be found among the three groups with different activity levels (Parizkova & Carter, 1976:338). In a review study of the effect of resistance training programmes for boys during early-puberty and the potential influence on growth (Malina, 2006:484), nine studies (each had an experimental and control group) found that resistance training of eight to 20 weeks did not influence growth in height, weight and estimates of body compositions of the experimental groups (Malina, 2006:484). In another review study by Malina *et al.* (2013:789) on the role of training on the

growth and maturation of artistic gymnasts, the available evidence does not support the suggestion that adult height of male gymnasts is compromised by intensive gymnastic training at young ages (Malina *et al.*, 2013:484).

A phenomenon of a temporary decline in performance or a disruption of motor coordination called the “adolescent awkwardness” is, however, documented in the literature. Because of its temporary character, the awkwardness tends to depend more on individual patterns and changes in growth and performance (Beunen & Malina, 1988:511; Butterfield *et al.*, 2004:227). There is a brief period during which trunk length increases relative to the legs, and this contributes to new problems of balance, while the muscles have yet to reach their full size and strength (Tanner, 1981:49). This period seldom lasts more than six-months, but may bring about temporary problems in young male athletes (Tanner, 1981:49). During mid-adolescence, a period of rapid growth, boys experience a temporary loss of coordination and speed caused by the change in their centre of gravity and a variation in body proportions caused by growth gradients of different body segments (Balyi *et al.*, 2013:71; Cameron, 2014:9; Malina *et al.*, 2004:322). Although research shows that training during adolescence does not have a significant effect on growth, but rather temporary disruptions, another concern is the risk of injuries during this sensitive growth period of participants subjected to training. Literature findings in this regard will now be explored.

2.8 INJURIES AND RISKS DURING ADOLESCENCE FOR BOYS COMPETING IN SPORT AND IN TRAINING PROGRAMMES

Maffulli and Pintore (1990:239) report that the greatest incidence of injury in any sporting group occurred in 11-16 year old sports participants. A drop-off in sit-and-reach scores for males around age 12 are reported by researchers (Gallahue & Ozmun, 2006:340). This may be associated with the growth spurt during which the long bones are growing faster than the muscles and tendons (Gallahue & Ozmun, 2006:340). Boys are also very prone to overuse injuries during mid-adolescence because of muscle imbalances and improper alignment (Micheli & Natsis, 2013:511). The relative weakening of the bone during this stage of growth, muscle imbalances between the flexor and extensor groups around a joint, and the relative tightening of the muscle-tendon units spanning rapidly growing bones are risk factors for overuse injuries (Beachle & Earle, 2008:143). The zones of ossification are sensitive and liable to injury and damage (Reilly & Stratton, 1995:210). Heavy loads, unilateral burdens or faulty techniques should therefore be avoided in order to take care of the cartilage of the epiphysis (Reilly & Stratton, 1995:210). Attention has to also be paid to arthromuscular dysbalances and to a possible onset of osteochondritis (Israel, 1991:321). The undisturbed rapid growth during

puberty does not call for physical restrictions but certain precautions in carrying out strength exercises are warranted (Israel, 1991:321).

Muscle imbalances between adjoining muscle groups are also common in sports participants (Micheli & Natsis, 2013:511). It may be caused by asymmetric muscle use that reflects the special demands of the sport for example excessive strength and tightness of the hip abductors in relation to weak and overstretched adductors in dancers (Micheli & Natsis, 2013:511). Muscle imbalances can also be induced by the growth process during adolescence, for example the iliotibialband (ITB) has a tendency to become stronger and tighter than the vastusmedialis (VMO) (Micheli & Natsis, 2013:511). Other muscle imbalances are seen in the lower back and the legs. Micheli and Natsis (2013:511) further report that the consequences of muscle imbalances are threefold. First, imbalances can cause stresses to the underlying tissues. For example, excessive tightness of ITB cause trochanteric bursitis and ITB friction syndrome. Tightness of gastrocnemeus, soleus and Achilles tendon can cause Achilles tendinopathy and plantar fasciitis; second, they can pull certain parts of the anatomy out of alignment; patellofemoral pain is caused due to the imbalance between vastus medialis and vastus lateralis which results in lateral tracking of the patella (Micheli & Natsis, 2013:511). Weak spinal postural stabilizing muscles can cause lordosis (Micheli & Natsis, 2013:511). This posture problem in turn predisposes the sports participants to overuse injuries of the lower back, such as herniated disk and spondylolysis, and thirdly, they may interfere with proper foot strike, for example, a loss of flexibility as a result of growth causes tightness in muscles like the psoas, hamstrings and gastroc-soleus-Achilles tendon unit. This, in turn, affects the biomechanics of running in athletes, where they may develop a much briefer than normal foot strike which interferes with an optimally relaxed heel-to-toe foot strike. This causes increased stress absorption and leads to stress fractures (Micheli & Natsis, 2013:511).

In contact sports like rugby the risk of injury may increase when boys of the same chronological age but different maturational ages compete against each other, because of the difference in size or stature and strength (Reilly & Stratton, 1995:208).

Knowledge of these risk factors that are the result of rapid growth can contribute to better management of these risk factors in young athletes during the early training years, as acute and overuse injuries can be reduced by 15-50% according to Micheli and Natsis (2013:505).

The application of well-designed, age-appropriate training programmes conducted by knowledgeable coaches who understand the effect of rapid growth during the mid-adolescence period is also clear from this background.

2.9 SUMMARY

This literature overview aimed to provide an overview of the changes in physical (muscle strength) and motor fitness (speed, agility, and explosive power) capabilities of boys during mid-adolescence and the interrelationships of these changes with rapid growth. The literature review also investigated literature findings regarding the role of the growth spurt on training of these physical and motor fitness capabilities during this period. It also focused on possible negative effects of the growth spurt, such as on performance and the risk of increased injuries during mid-adolescence. The LTAD model of Balyi and Way has long been used as a guide for coaches and scientists to incorporate age-appropriate training of specific motor fitness capabilities taken into consideration human growth, development and maturation of boys. This model is described in the review.

This review established that much research has been done on the describing characteristics of the developing boy aged 12- to 15-years to define adolescence and the influence of puberty and the growth spurt during these years. Individual variability in anthropometrical and motor performance developmental trends contributes to early and late maturers which will always be a cause of differences in the skill and fitness development of children with the same chronological age. This review also studied literature regarding the developmental trends of motor fitness capabilities and their interrelationship with anthropometric characteristics. This review found that there is a significant relationship between anthropometric and physical capabilities during mid-adolescence. Although this review highlights that intense training during mid-adolescence poses a threat in terms of overuse injuries because of muscle imbalances, improper alignment and temporary loss of coordination due to a change in center of gravity and variation in body proportions, it also reports research that indicated that knowledge about these risk factors can contribute to better management and programming of training programmes for young sports participants.

Although scientific reports were found that stated the effect of training on growth and a good description of the windows of accelerated adaptation to training is done by Balyi *et al.* (2013:69), very little scientific evidence could be found on the effect of growth during mid-adolescence on training of strength, power, speed and agility with this findings as a background, chapters three and four will report the findings of this study.

The following chapters three and four will discuss the results of the study.

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CHAPTER 3

**ROLE OF THE GROWTH SPURT IN SPEED AND AGILITY TRAINING
OF 13 TO 15 YEAR OLD MID-ADOLESCENT BOYS**

RESEARCH ARTICLE

ROLE OF THE GROWTH SPURT IN SPEED AND AGILITY TRAINING OF 13 TO 15 YEAR OLD MID-ADOLESCENT BOYS

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ROLE OF THE GROWTH SPURT IN SPEED AND AGILITY TRAINING OF 13- TO 15-YEAR OLD MID-ADOLESCENT BOYS

3.1 ABSTRACT

Objectives: To determine whether a speed and agility training programme can counter the possible negative effects of growth on boys aged 13- to 15-years.

Methods: A two-group pre-test post-test design was used. A convenience sample (N=86) of boys, aged $13.6 \pm 0.26SD$ years at baseline was divided into a group of sports participating boys (n=47), EG who were subjected to a strength, speed, power and agility training programme for the first six months of every year, two times per week for 45 minutes, and compared to a control group (CG) (n=39) of non-sports participating boys who were not exposed to any training programme. Both the experimental group (EG) and CG were subdivided further into growth groups, late developers (LD), early developers (ED) and typical developers (TD). Speed, agility and anthropometric measurements (stature, body mass, fat percentage, sitting height) were taken every six months. Correlations were determined between anthropometric, physical and motor fitness changes while hierarchical linear modelling was used to analyse differences among the three measuring points over the two year period. Practical significance of differences was determined by using the cut-off values of Cohen.

Results: Speed and agility increased nonlinearly in both groups. The biggest increase in the first six months was in speed while agility increased most in the following six months. Moderate correlations were found between changes in speed and agility and anthropometric measurements confirming an interrelationship during mid-adolescence between these variables. Both the EG and CG showed negative effects of growth on the development of speed and agility. ED benefited most from the speed and agility training programme

Conclusion: Although segmental growth could have influenced the development of speed and agility, participation in sport and a generalised strength, power, speed and agility training programme can counter this negative effect on the further development of speed and agility in boys during mid-adolescence.

Keywords: Speed; agility; boys; mid-adolescence

3.2 INTRODUCTION

Motor fitness capabilities like running, sprinting and agility are key fundamental abilities (Rimmer & Sleivert, 2000; Sheppard & Young, 2006) to excel in most sports such as athletics, rugby, soccer, field hockey and cricket (Chiwaridzo, Ferguson & Smits, 2016). These abilities are known to develop in a nonlinear fashion throughout childhood and adolescence (Malina, Bouchard & Bar-Or, 2004) with accelerated development of speed during both pre-adolescence (age seven to nine years) and adolescence (age 12 to 15 years) (Balyi & Way, 2005).

Adolescence is characterised by immense hormonal and physical changes (Blakemore & Choudhury, 2006). This transition from childhood to adulthood is also characterised by noteworthy changes in identity, self-consciousness and cognitive flexibility, while the most dominant and influential change is biological growth (Blakemore & Choudhury, 2006; Malina *et al.*, 2004). The adolescent growth spurt, which is a result of biological growth, is a period of accelerated growth of the body that lasts about four years. During this period of accelerated growth, sports participation in boys is positively associated with development and changes in various physical and motor performance and anthropometric components (Bergeron, 2007; Gerber, Pienaar, Kruger & Ellis, 2014). Due to body composition and hormonal changes which result in increasing muscle mass and the maturation of the nervous system (Faigenbaum, 2000; Jenkins, 2005), the mid-adolescent phase poses the opportunity to develop, additionally to natural growth and development, certain motor capabilities and fitness components like speed and agility (Balyi, Way & Higgs, 2013).

Research confirms maturity-related development of speed and agility capabilities during the mid-adolescent years (Gerber *et al.*, 2014; Malina, 2014). These changes associated with the transition into puberty, influence motor coordination during adolescence in boys with the largest variances at ages 13- to 14-years, the same age as the occurrence of Peak Height Velocity (PHV) (Freitas, Thomis, Lausen & Leferve, 2016). Upon the time of reaching PHV speed improvement is likely due to increased limb length and improved relative force production that contribute to increased stride length (SL) (Meyers, Oliver, Hughes, Cronin & Lloyd, 2015). The time around PHV (11- to 14-years) (Jenkins, 2005; Malina *et al.*, 2004) is important in the improvement of speed in boys (Meyers *et al.*, 2015) as speed is likely to be influenced by peak gains in strength and power, once again as a result of increases in muscle mass and testosterone concentrations (Lloyds, Oliver, Hughes & Williams, 2011). Studies (Beunen, Ostyn, Simons, Renson & Gerven, 1981; Beunen *et al.*, 1997) showed that individual differences in maturity status which are most marked during adolescence in boys influence motor performance which contributes to the phenomenon of earlier and later maturity (Beunen *et al.*, 1981; 1997). They furthermore report that stature and body mass accounted for a 17% of variance in the

motor fitness in boys (Beunen *et al.*, 1981; 1997). Freitas *et al.* (2016) also report that skeletal maturity status explained a small but noticeable variance of 8.1% in motor coordination of boys aged 12- to 14-years.

Peak gains in shuttle run performance which is a test for agility are reported before the age of PHV (Beunen & Malina, 1988; Malina *et al.*, 2004). Phillippaerts *et al.* (2006) report a negative influence of the growth spurt on the development of speed and agility of sports participants during the 12 months period before age at PHV. In this matter Jenkins (2005) describes this occurrence as adolescent awkwardness, a period of time during the growth spurt that is accompanied by a temporary disruption in motor performance that is primarily found in boys aged 13 to 14 years. Muscle imbalances, poor core muscle control and temporary loss of coordination due to differential rates of growth in different body segments that contribute to variation in body proportions are indicated as possible reasons for this period of adolescent awkwardness (Balyi *et al.*, 2013; Cameron, 2014; Faigenbaum *et al.*, 2009; Freitas *et al.*, 2016; Malina, 2014). Clark and Metcalfe (2002) additionally report that when the physical features of the body change in such drastic measures, the Central Nervous System (CNS) has to make big adaptations to accommodate such changes and adapt to the new segmental forces which in turn will impact on the execution of motor skills. Positive and negative gains in speed and agility can therefore be a result of rapid growth, while these abilities can also be developed through training (Roozen & Suprak, 2012).

As children grow and develop there are times that are described as sensitive periods when practice and training will have the greatest effect on physical capabilities like strength, speed and endurance (Balyi *et al.*, 2013). These “sensitive periods” provide a special opportunity to train and develop important skills and physical capabilities that will impact sport performance through the life span (Balyi *et al.*, 2013). Balyi *et al.* (2013) highlight two windows of accelerated adaptation to speed training, including the age period between ages seven to nine, where increases in speed can be attributed to neural adaptation or neuromuscular maturation (Balyi *et al.*, 2013). The second window falls within the adolescent years of boys (age 13- to 16-years) and provides the opportunity to improve the anaerobic lactic power and capacity within an individual through training (Balyi *et al.*, 2013). Speed development incorporates linear and lateral speed, change of direction, agility and deceleration (Balyi *et al.* 2013; Lockie, Schultz, Callaghan & Jeffries, 2014) and consists of the following components: stride length (SL), stride frequency (SF), flight time (FT) and contact time (CT) (Meyers *et al.*, 2015).

To accommodate the changes and awkwardness of body proportions and muscle imbalances caused by the adolescent growth spurt and make most of the window of opportunity of trainability that becomes available during this period, it would be best to subject boys 13- to 15-

years to conditioning programmes (Balyi and Way, 2005). These researchers argue that the conditioning programme will improve capabilities such as speed and agility in order to improve sporting abilities that will be needed in the later stages of the Long-term athlete development (LTAD) model, of the Training to Win stage (Balyi & Way, 2005). Researchers report improved speeds in boys aged 13 to 14 years after they had been subjected to training programmes that focused on the development of strength and the rate-of-force development to make optimal use of the maturity-related changes in circulating androgens and increased muscle mass (Duvenhage, 2012; Meyers *et al.*, 2015; Takai *et al.*, 2013; Wong, Chamari & Wisloff, 2010). However, this period of rapid growth is also associated with a higher risk of injuries which highlight the importance of sound training programmes during a development programme (Bompa, 2000; Adirim & Cheng, 2003; LaBella, 2007).

The development of speed and agility during adolescence (Baechle & Earle, 2008; Gerber *et al.* 2014; Meyers *et al.*, 2015; Pearson, Naughton & Torode, 2006; Pienaar & Viljoen, 2010; Phillippaerts *et al.*, 2006; Spencer, Pyne, Santisteban & Mujika, 2011), and also trainability of speed and agility (Duvenhage, 2012; Takai *et al.*, 2013; Wong *et al.*, 2010) during the sensitive periods of accelerated adaptation as identified by Balyi *et al.* (2013), is well researched. Researchers have also studied the interaction and correlation between anthropometric changes and the development of speed and agility (Baechle & Earle, 2008; Gerber *et al.*, 2014; Phillippaerts *et al.*, 2006; Sheppard & Young, 2006). None of these studies had as a primary aim the effect of the growth spurt on the training of speed and agility. This study therefore aims to address the short commings in the literature regarding how the growth spurt will affect training and improvement of speed and agility during the mid-adolescent period in boys. The findings of this study will provide scientists with a better understanding of how the growth spurt will affect the training of motor and physical capabilities such as speed and agility in mid-adolescent boys.

3.3 METHODS

3.3.1 Research group

The Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University approved the study (NWU-00330-15-A1). The parents of all grade eight boys (N=145) received a parental permission consent form containing all the information explaining the purpose and objectives of the study as well as the procedure of all the tests. Parents had the opportunity to ask questions at an information meeting held at the school or to contact the researcher via e-mail or telephone. All parents or legal guardians and participants themselves voluntarily signed consent and child assent. The participants were all healthy boys from one

school in their grade eight year who were able to participate in physical activities (N=145), which was determined by a self-compiled pre-test health screening questionnaire. The boys represented all levels of physical capability, from boys who did not participate in any sports to boys who competed in sport up to national level. The boys were all recruited from one state governed high school in the Mpumalanga Province within the Mbombela Local Municipality area of South Africa, namely Nelspruit. Nelspruit is classified as a city with a high socio-economic status, which is surrounded by small towns such as Komatipoort, Sabie and Malelane that are classified as rural areas with farming communities. KaNyamazane a Township area near Nelspruit is considered a low socio-economic area. Children attending Nelspruit high school are enrolled from all over these Lowveld areas and can attend this school because of boarding facilities. The learners enrolling into the school therefore came from different primary schools and areas and represent different socio-economic backgrounds. However, the group of learners cannot be considered to be representative of the adolescents' population, either of the Mbombela Local Municipality area or of South African adolescents in general. All 145 grade eight boys who enrolled in the school were recruited and invited to participate in the study. Forty-seven of these boys were categorised into the experimental group (EG) because they took part in school sports, namely rugby, field hockey, cricket and athletics. They were also, apart from training in their different sporting codes, subjected to a sports training programme two times per week for 45 minutes. A control group (CG) of thirty-nine boys was also selected from the initial sample who did not compete or train in any sports and who can be described as non-sports participants. They were used as a reference group for biological growth that took place during this period, without a training effect. The remaining 59 boys were excluded from the study because they participated in other sports that are not part of the school's sporting codes, like swimming, mountain biking, gymnastics and tennis. Both main groups (EG & CG) were divided further but only for statistical purposes, in three sub-growth groups based on the age at PHV. The age at PHV was also used as an indication to separate the late and early developers. This division in each of the EG and CG was done to determine the co-founding influences of early, late and average or typical development during this period on the effect of the training programme.

3.3.2 Research procedure

The research design is based on a convenience sample consisting of a two-group pre-test post-test design, where one group was subjected to a strength, speed, power and agility sport training programme for the first six months of every year twice a week in the afternoon after school for 45 minutes. The control group of non-participating boys was not exposed to any training programme. The study spanned a period of two-years, with the baseline measurements

in the beginning of the Grade eight year of the boys (February 2015), when they had a mean age of 13.68 ± 0.26 SD years. The final measurements were done during their Grade nine year in August 2016 when they had a mean age of 15.2 ± 0.31 SD years. Both the EG and CG underwent a complete fitness evaluation twice per year during February and August (Feb 2015, Aug 2015, Feb 2016, Aug 2016), representing a baseline and three additional time point measurements over the two-year period.

3.4 MEASUREMENTS

Anthropometric, motor and fitness measurements were taken at each measuring point. The anthropometric variables were measured firstly in an enclosed area after which the physical and motor fitness measurements were completed in the gymnasium and on the sports field. The participants had to rotate in small groups between the stations. Sufficient rest periods were allowed between the tests to prevent exhaustion from having an influence on optimal performance of the participants. The testing protocol for anthropometric growth and physical and motor capabilities consisted of eight tests, which included four anthropometric tests (stature, body mass, sitting height and fat percentage) and four motor fitness tests (10m and 40m speed, agility T-test and shuttle runs). A combination of protocols from The Australian Sport Search Program (Australian Sports Commission, 1996), the U.S Navy Physical Readiness test (Bartlett, Phillips & Galarneau, 2015) were used and combined with a few additional field tests such as the 5-m multiple shuttle test (Boddington *et al.* 2001), the seven-stage abdominal strength test (Kuro, 2008) and relative load test (Brown & Weir, 2001).

3.4.1 Anthropometric measurements

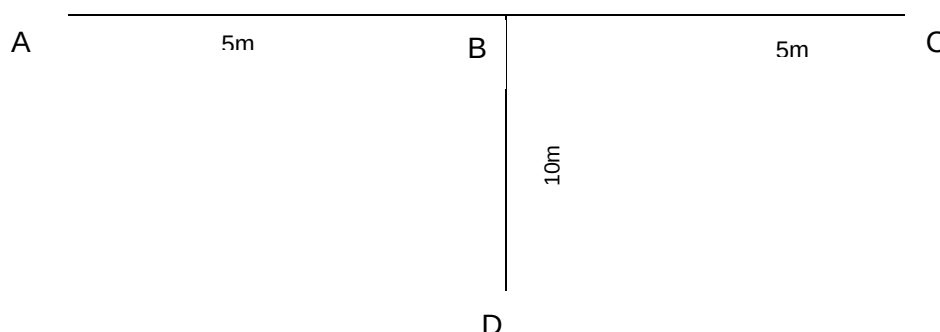
The anthropometric measurements were made by a qualified Exercise scientist, who was trained according to the international standards for anthropometric assessment (ISAK) protocol (Marfell-Jones, Olds, Stewards & Carter, 2006). Body stature and sitting height were determined with a Harpenden stadiometer. Stature was measured while standing with the back against the stadiometer (Seca 206, Germany) and the feet together. The heels, buttocks and upper back had to be in contact with the stadiometer and the head held in the Frankfort position. While the subject inhaled deeply in this position, the measurement was taken to the nearest 0.1 cm. Sitting height was measured while sitting flat on the stadiometer with the back against the stadiometer and the knees bent slightly. The head of the subject was held in the Frankfort position by the administrator and the measurement was taken to the nearest 0.1 cm after lowering the arm of the stadiometer onto the subject's head (Marfell-Jones *et al.*, 2006). Sitting height ratio was calculated by using a formula: sitting height/stature x 100. Mass was taken with a calibrated electronic scale (SOEHNLE, Germany) with the subject standing upright with his

weight evenly distributed on the scale and his arms next to his sides. The measurement was taken to the nearest 0.1 kg, while the subject had to look straight ahead. The six skin folds, triceps, subscapular, iliac, abdominal, front thigh and calf thicknesses were measured by one researcher using a Harpenden calliper (Gima, Modena, Italy) according to standard (ISAK) protocol procedures (Marfell-Jones *et al.*, 2006). Two measurements were taken at each site, and the average of the two readings was calculated as the score. Fat percentage was calculated by using a formula: $(\text{sum of six skinfolds} \times 0.1051) + 2.585$ (Topendsport).

3.4.2 Motor fitness measurements

Speed was measured over a distance of 40m with the Fusion Sport Smart Speed-System (Fusion Sport Pty Ltd, 2009). The test is executed from a stationary position from where the participant has to accelerate and run through a series of infrared photoelectric gates that record horizontal velocity through each gate. The procedure involves sprinting 40m in total, running through the first pair of gates (10m) and the last pair of gates (40m). The better of two attempts for both 10m and 40m is taken in seconds to the nearest 0.01sec, with two minutes rest between attempts. For agility the T-test requires of the participant to touch a series of cones set out in “T” shape whilst side stepping and running as fast as possible. Place three cones five metres apart on a straight line (A, B, C) and a fourth cone (D) is placed ten metres from the middle cone (B) so that the four cones form a 'T' (Fig 1). The participant stands at the cone (D) at the base of the “T” facing the “T”. The participant runs to and touches the middle cone (B), side-steps five metres to the left cone (A) and touches it, side-steps ten metres to the far cone (C) and touches it, side-steps five metres back to the middle cone (B) and touches it and then runs ten metres backwards to the base of the 'T' and touches that cone (D). Time from start to finish is recorded. The better of two attempts is taken in seconds (Pauole, 2000).

Figure 1: Agility T-Test



Start at D, run forward to B. Shuffle sideways to A, shuffle sideways from A to C and back to B, run backwards from B to D

The 5-m Multiple Shuttle test (5-m MST) required the subjects to sprint between a series of six beacons spaced five meters apart in a straight line to cover a total distance of 25m. Subjects were instructed to perform maximally throughout the whole test. Each subject started the test in line with the first beacon (A), and upon an auditory signal sprinted five meters to beacon B, touched the ground adjacent to the beacon with their hand, and returned to beacon A, touching down on the ground adjacent to the beacon with the hand again. The subject then sprinted ten meters to the third beacon C, and back to beacon A, etc., until an exercise period of 30 seconds had elapsed. The distance covered by each subject was recorded to the nearest 2.5m during each 30-second shuttle. Thereafter there was a 35-second recovery, during which the subjects walked back to beacon A, the participant did a total of six shuttle runs of 30s each. The totals of all six runs were recorded (Boddington, Lambert, Gibson & Noakes, 2001)

3.4.3 Sports participation frequency

Participants completed a health screening questionnaire during their first evaluation to report on their current health and fitness and family medical history. The sports participation frequency of each participant was determined by means of a self-compiled questionnaire where the participant had to indicate his sports participation and training frequency by ticking the different sports that he participated in and the number of days and hours per day (frequency and duration) he spent at training for a particular sport. Injuries during the two-years, time of the programme and treatment of injuries were monitored by the Exercise scientist.

3.4.4 Training protocol and implementation

The boys in the EG took part in one or more school sports that included athletics, rugby, field hockey and cricket. The boys practised sport specific skills three days per week with a school sports coach. These sessions consisted of 60min of drills and techniques that applied to the relevant sport of each participant. Additionally they took part in one session of speed and agility training and one session of strength and power training for two additional days per week in the afternoon for 45min per session. This programme was compiled by a registered Sports Scientist who was also responsible for the adjustment and progression of the programme throughout the six-months. One session was a combined session for resistance training (own body weight exercise, elastic resistance bands, gym apparatus and free weights) and plyometrics (skipping ropes, plyometric jumping box). Each session consisted of 12 exercises that were made up of five strength exercises (leg extensions, leg curls, squats, sit-ups and bench presses), four plyometric exercises (skipping, box jumps, front and sideways and depth jumps) and three combinations of strength and plyometric exercise (lunge jumps, squat jump with high pull, burpee to pull up). At the start of the six-months each exercise was done with light to medium

weights for 15 to 20 repetitions, and every exercise was repeated three times, with emphasis on technique. As the participants improved their conditioning and skill in the proper technique the weight increased and repetitions decreased to ten repetitions. The second session was made up of 45min of speed and agility training (speed ladders and hurdles, weighted sleds and parachutes) with the focus on improvement of foot speed, acceleration balance and proprioception. At the start of the six-months in February of each year, the session focused on proper sprinting mechanics, short distances of 10 to 20 metres were used and no more than four hurdles and speed ladders with four blocks were used. As participants mastered the skills, techniques and exercises during the six-months the distances were increased up to 80m and the numbers of hurdles and length of the speed ladders were also increased.

3.4.5 Statistical analysis

The data were analysed with “Statistica for Windows” (StatSoft, 2015) and with SAS 9.3 Level TS L1MO (2000–2010). Data were analysed for descriptive purposes using means (M), standard deviations (SD), minimum and maximum values and lower and upper quartiles (Statsoft, 2015). Spearman correlations analysis was done to determine relationships between changes in anthropometric and physical and motor fitness measurements. A hierarchical linear model was used to analyse differences between the three measuring points over a period of two-years within the group for all variables. Practical significance of differences between means was determined according to Cohen's d-value 0.25 (small), 0.55 (medium), and 0.85 (large) (Cohen, 1992).

3.5 RESULTS

Table 1 reports the baseline and follow-up descriptive characteristics of the research group divided into an experimental (EG, N=47) and a control group (CG, N=39) with a mean total group age of 13.68 ± 0.264 SD years at baseline. During the study's two year timeframe no loss of participants was recorded. Table 1 further reports the distribution of the participants as classified as early (ED), late (LD) and typical developers (TD) in both the EG and CG groups. The biggest sub-group in both the EG and CG groups was the TD's (n=32 and n=33), while early and LD were more evenly distributed in numbers with fewer participants in these subgroups in both the EG and the CG groups. The mean chronological age of each group and the sub-groups consisting of early, late and typical developers at the beginning of the study in their Grade eight year indicate that the LD group (n=8) was the youngest with a mean age of 13.5 years and the ED (n=7) the oldest, 13.85 years with the TD who fell in the middle 13.66 years.

Table 1: DESCRIPTIVE INFORMATION FOR THE GROUP OVER TWO-YEARS

			N	n	Sport participation	Mean Age	SD
Year 1 Feb 2015 (GR8)	EG	LD.	47	7	5=1 Sport	13.52	0.28
					2=2 Sports		
		ED		8	1=1 Sport	13.85	0.23
					7=2 Sports		
		TD		32	15=1 Sport	13.66	0.28
					13=2 Sports		
Year 2 Feb 2016 (GR9)	CG	LD	39	4	4=3 Sports	13.38	0.21
		ED		2		14.05	0.01
		TD		33		13.62	0.26
	EG	LD	47	7	5=1 Sport	14.56	0.28
					2=2 Sports		
		ED		8	1=1 Sport	14.89	0.23
					7=2 Sports		
		TD		32	15=1 Sport	14.70	0.28
					13=2 Sports		
	CG	LD	39	4	4=3 Sports	14.42	0.21
		ED		2		15.09	0.01
		TD		33		14.66	0.28

EG=Experimental Group, CG=Control Group; LD=Late developers, ED=Early developers, TD=Typical developers; N= amount of participants for EG & CG; n= amount of participants for each sub-group; Sport participation = number of participants per development group that participated in either one, two or three school sports; SD= standard deviation

The descriptive characteristics of the different developing groups in the EG also reveal that the sport participation frequency of boys is most probably influenced by their developmental stage. The sports participation frequency of the TD, who was also the biggest group, showed participation in at least two sports with a more even distribution, between participating in one sport (n=15) and two sports (n=13) while participation in three sports (n=4) was also recorded. LD tend to participate in mostly one sport where as the ED mostly participated in two school sports.

Tables 2 and 3 show the results of the correlation analysis between the changes in body composition characteristics, including height, weight, fat% and sitting height and 10m and 40m motor fitness measurements for the group over the study period of two-years (T1-T4), divided into six month periods and the total period (T1-T4). Only small significant correlations were found between 10m speed and height during T3–T4 and over the entire study (T1-T4). In mass and especially fat percentage changes were significantly associated with changes in 40m sprint performance, although mostly in the T2-T3 period (Table 2). Height increase and 40m sprint performance correlated over the total period T1–T4.

With regard to agility (Table 3), the T-test showed a small significant relationship between changing height and fat mass in the T2-T3 and overall (T1-T4) periods. The shuttle run was the only performance ability that showed a small significant relationship in T1-T2 with changes in fat mass and this relationship was still evident in T2-T3. These relationships confirmed an interrelationship between body composition and motor fitness changes in speed and agility which subsequently motivate further analysis of the results displayed in tables 4 and 5.

Table 2: CORRELATIONS BETWEEN CHANGES IN BODY COMPOSITION CHARACTERISTICS AND CHANGES IN SPEED

Variable	10m				40m			
	T1 - T2	T2-T3	T3-T4	T1-T4	T1 - T2	T2-T3	T3-T4	T1-T4
Height								
T1-T2	0.02	-0.02	-0.08	-0.03	-0.02	-0.09	-0.05	-0.05
T2-T3	-0.11	0.04	-0.10	-0.20	-0.16	-0.07	-0.14	-0.28*
T3-T4	0.09	0.18	-0.29*	-0.03	0.15	0.03	-0.11	0.10
T1-T4	-0.04	0.11	-0.23*	-0.18	-0.05	-0.02	-0.18	-0.16
Mass								
T1-T2	0.02	-0.13	0.11	0.02	-0.03	-0.19	0.14	-0.04
T2-T3	-0.02	0.15	-0.06	0.02	-0.02	0.21*	-0.13	-0.03
T3-T4	0.01	-0.01	-0.01	-0.04	0.06	-0.15	0.05	-0.02
T1-T4	-0.01	0.07	-0.02	-0.01	0.01	0.02	-0.03	-0.04
Fat %								
T1-T2	-0.17	0.05	0.06	-0.12	-0.26*	0.23*	0.02	-0.14
T2-T3	0.11	0.07	-0.07	0.15	0.18	0.07	-0.05	0.23*
T3-T4	0.07	-0.20	0.07	-0.01	0.01	-0.19	0.13	-0.05
T1-T4	0.04	-0.05	0.10	0.08	0.01	0.10	0.12	0.10
Sitting Height								
T3-T4			0.09				-0.05	

Marked correlations are significant at $p < 0.05$; $r = 0.1$ = small*; $r = 0.3$ = medium**; $r = 0.5$ = large***;

T1-T2=Difference between measurement one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurement three and four (six-months); T1-T4=Difference between first and last measurements (two-year period)

Table 3: CORRELATIONS BETWEEN CHANGES IN BODY COMPOSITION CHARACTERISTICS AND CHANGES IN AGILITY

Variable	T-Test				Shuttle run			
	T1 - T2	T2-T3	T3-T4	T1-T4	T1 - T2	T2-T3	T3-T4	T1-T4
Height								
T1-T2	0.12	-0.07	-0.17	-0.04	0.03	0.09	-0.08	0.06
T2-T3	-0.12	-0.25**	0.05	-0.14	0.05	0.01	-0.04	0.08
T3-T4	0.14	0.09	0.21	0.22**	-0.03	-0.03	0.05	-0.06
T1-T4	0.01	-0.15	0.06	-0.02	0.06	0.00	-0.02	0.07
Mass								
T1-T2	-0.08	-0.18	-0.09	-0.16	-0.04	0.11	0.03	0.10
T2-T3	-0.02	0.10	0.13	0.10	0.16	-0.27**	-0.03	-0.13
T3-T4	0.01	-0.16	0.04	-0.06	-0.10	0.09	-0.12	-0.04
T1-T4	-0.05	-0.08	0.06	-0.03	0.07	-0.09	-0.10	-0.07
Fat %								
T1-T2	-0.04	-0.07	-0.08	-0.07	0.23*	0.00	0.04	0.28*
T2-T3	-0.01	0.35**	0.16	0.23*	-0.23*	-0.03	0.05	-0.35*
T3-T4	0.11	-0.16	0.01	-0.04	0.05	-0.08	-0.09	-0.00
T1-T4	0.04	0.17	0.15	0.16	0.00	-0.10	-0.02	-0.13
Sitting Height								
T3-T4			0.06				-0.04	

Marked correlations are significant at $p < 0.05$; $r = 0.1$ = small*; $r = 0.3$ = medium**; $r = 0.5$ = large***;

T1-T2=Difference between measurements one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurements three and four (six-months); T1-T4=Difference between first and last measurement (two-year period)

A hierarchical linear model was used to analyse the differences between the three measuring points over a period of two-years within the group for all the variables. Table 4 contains the descriptive means for each assessment period, significant differences between assessment periods as well over the total period (T1-T4). The analyses include results of the anthropometric measurements (stature, mass, fat percentage, sitting height, sitting height ratio), of the EG and the CG divided into three sub-developing groups over the two-years of the study (ED, LD and TD). Results of sitting height and sitting height ratio are only reported in year 2 (T3 & T4). Statistical significant differences (p-values, $p < 0.05$) are reported in the table to indicate significant group differences, although it should be taken into consideration that the groups were not randomly selected which makes the p-value mostly irrelevant. More emphasis is therefore placed on the practical significance of differences found based on effect sizes of which the strength was interpreted according to the guidelines of Cohen (1988). An effect size of $d \geq 0.55$ is considered as practically significant.

Height of all three development groups of both the EG and CG increased significantly every six-months ($p < 0.5$), and these increases also had a small practical significance. Both TD groups showed the highest increases followed by the LD and the ED groups respectively. TD of both

groups showed significant increases of 3–5 cm every six-months with a total increase recorded of 10.57cm in the EG ($d > 0.85$) and 11.47cm in the CG ($d > 0.85$) ($p \leq 0.05$). Total height increase for LD was 5.11cm (EG) ($d > 0.55$) and 6.20cm (CG) ($d > 0.55$), while ED only showed height increases of 3.97cm (EG) ($d > 0.25$) and 3.05cm (CG) ($d > 0.25$) over the two-years of the study (Table 4).

Increases in weight differ from the pattern that was seen in height especially in the different developmental groups over the two-year period. All three the subgroups of both EG and CG showed a statistical significant increase in weight over the two-years. Weight increased by 8.72kg (TD of EG) and 7.47kg (TD of CG) in the first year, from a mean age of 13.66 to 14.66 years (EG) and 13.62 – 14.62 years (CG). Fat percentages changed minimally in all three subgroups of the EG over the two-years. The fat percentage of the ED in the CG showed a large ($d > 0.85$) practically significant increase over the two-years (3.93%) which differed significantly from what was seen in the ED group of the EG (0.18%). The ED of the EG also displayed the largest increase in body mass over the two-years (13.35 kg).

Table 5 describes the results of the four motor fitness tests, measuring speed (10m; 40m) and agility (T-test; shuttle runs), of both main groups, as well as for each of the sub-groups. Practically significant speed and agility changes are evident from the table in both the EG and CG groups. The biggest increases in speed in both groups were found during the first year within the first six-month assessment period while the biggest increases in agility were found during the second six-month period (T2-T3). Over the two-year period (T1-T4) the smallest changes are seen in the ED of both the EG and the CG. Increases were also evident in the EG compared to decreases in the EG in both speed tests.

Table 4: DESCRIPTIVE CHARACTERISTICS AND SIGNIFICANCE OF CHANGES IN FOLLOW-UP ANTHROPOMETRIC MEASURES OF THE EXPERIMENTAL (EG) AND CONTROL GROUP (CG)

		Means for 4 measurements								Difference Between Measurements						Difference over 2 years	
		T1 M		T2 M		T3 M		T4 M		T1-T2		T2-T3		T3-T4		T1-T4	
		EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
	Height	(MSE = 1.24 ; Variance participants = 53.82) (Sub group2* Test p-value = 0.00 Sub group2* Test)															
LD	168.02	162.92	171.02	164.70	172.84	166.47	173.85	168.65	3.00#	1.78	0.44	1.77	1.67	2.65	5.11##	6.2##	
ED	175.91	175.11	177.38	176.26	178.58	177.02	179.80	177.92	1.47	1.15	0.87	0.30	1.62	1.60	3.97#	3.05#	
TD	162.93	161.51	166.19	164.79	169.98	168.94	173.69	173.12	3.26#	3.28#	4.40#	5.16##	2.91#	3.03###	10.57###	11.47###	
	Weight	(MSE = 6.57 ; Variance participants = 109.39) (EGCG* Sub-group2* Test p-value = 0.017)															
LD	60.78	56.89	64.97	59.54	66.53	64.74	68.78	67.44	4.18#	2.65	0.9	5.20#	2.57	2.92	7.65##	10.77###	
ED	71.08	71.25	73.78	72.80	77.11	79.67	78.78	84.48	2.70	1.55	3.17	6.65##	1.86	5.15#	7.73##	13.35###	
TD	52.15	55.99	55.38	59.63	60.58	62.98	64.28	66.80	3.22	3.63	5.49#	3.83	3.31	3.27##	12.04###	10.75###	
	Fat %	(MSE = 7.054 ; Variance participants = 10.87) (EGCG* Sub-group2* Test p-value = 0.217) (p-value = 0.128 EGCG)															
LD	11.48	12.38	10.74	13.11	10.46	13.09	11.06	12.80	-0.74	0.73	-0.13	-0.02	0.53	-0.34	-0.33	0.36	
ED	9.88	9.09	9.15	9.29	9.54	14.08	10.06	13.05	-0.73	0.20	0.43	4.83###	0.47	-1.10	0.18	3.93###	
TD	10.08	12.95	9.69	12.58	9.50	11.79	10.99	11.13	-0.39	-0.37	-0.25	-0.89	1.57#	-0.53	0.93	-1.81	
	Sitting Height	(MSE = 1.41 ; Variance participants = 14.10) (Sub-group 2 p-value = 0.002)															
LD					84.20	80.25	85.84	81.80					0.42#	0.39			
ED					89.75	87.35	91.08	90.00					0.34	0.67##			
TD					82.96	82.57	85.06	84.81					0.60##	0.57##			
	Sitting Height Ratio	(MSE = 4.58; Variance Participants = 0.00) (Sub group 2 p-value = 0.019)															
LD					0.49	0.48	0.49	0.48					0.26	0.07			
ED					0.50	0.49	0.50	0.50					0.20	0.72##			
TD					0.48	0.48	0.49	0.49					0.26	0.33			

T1=Measurement one; T2=Measurement two; T3=Measurement three; T4=Measurement four; M=Mean value of group at measurement date; T1-T2=Difference between measurements one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurements three and four (six-months); T1-T4=Difference between first and last measurement (two-year period); EG= experimental group, CG=Control group; MSE = Mean Square Error; LD = Late Developers; ED = Early Developers; TD = Typical Developers

Only statistical significant p-values are reported

Practically significant effect (#=Small; ##=Medium; ###=Large)

Table 5: DESCRIPTIVE CHARACTERISTICS AND SIGNIFICANCE OF CHANGES IN FOLLOW-UP MOTOR FITNESS MEASURES (SPEED AND AGILITY) OF THE EXPERIMENTAL GROUP (EG) AND CONTROL GROUP (CG)

		Means for four measurement						Difference between measurements						Difference over two-years			
		T1 M		T2 M		T3 M		T4 M		T1-T2		T2-T3		T3-T4		T1-T4	
		EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
	10m	(MSE = 0.0112 ; Variance participants = 0.0104) (p-value = 0.00 Test)															
LD	1.97	2.12	1.87	1.89	1.80	2.03	1.86	2.02	-0.10##	-0.23###	-0.07#	0.14###	0.06#	-0.01	-0.11##	-0.10##	
ED	1.95	1.87	1.79	1.85	1.81	1.91	1.89	1.99	-0.16###	-0.02	0.02	0.06#	0.08##	0.08#	-0.06#	0.11##	
TD	2.03	2.12	1.88	1.92	1.91	2.00	1.89	1.97	-0.15###	-0.2###	0.03	0.08#	-0.02	-0.02	-0.14###	-0.15###	
	40m	(MSE = 0.116 ; Variance participants = 0.162) (p-value = 0.00 Test)															
LD	6.07	6.81	6.07	6.28	5.61	6.44	5.67	6.44	0.00	-0.53###	-0.44###	0.16	0.06	-0.01	-0.40##	-0.37##	
ED	6.07	5.88	5.68	5.86	5.72	5.91	5.81	5.92	-0.39##	-0.02	0.04	0.05	0.09	-0.01	-0.26#	0.04	
TD	6.50	6.91	6.20	6.44	6.03	6.35	5.94	6.29	-0.30##	-0.47###	-0.17	-0.09	-0.09	-0.04	-0.56###	-0.62###	
	T-test	(MSE = 0.493 ; Variance Participants = 0.608) (p-value = 0.00 Test)															
LD	12.89	13.94	12.75	13.65	12.07	13.02	11.46	12.39	-0.14	-0.29	-0.64##	-0.63##	-0.63##	-0.63##	-1.40###	-1.55###	
ED	11.97	11.72	11.8	11.84	11.64	11.99	11.37	11.87	-0.17	0.12	-0.15	0.16	-0.27	-0.14	-0.6##	0.15	
TD	12.59	13.30	12.46	13.20	11.58	12.72	11.47	12.26	-0.13	-0.1	-0.89##	-0.51#	-0.08	-0.42###	-1.12###	-1.04###	
	Shuttle run	(MSE = 2025.48 ; Variance Participants = 1543.13) (p-value = 0.00 Test)															
LD	642.86	622.31	612.43	592.56	588.40	533.81	656.49	650.02	-30.43#	-29.75#	-24.14#	-58.75###	68.14###	116.21###	13.57	27.75#	
ED	662.69	643.08	612.82	445.08	644.1	503.12	659.44	522.56	-49.87##	-198###	31.25#	58.04###	15.37	19.44#	-3.25	-120.5###	
TD	644.93	619.32	595.80	569.35	641.03	618.69	658.97	635.91	-49.13##	-49.97##	45.28##	49.34##	17.87	17.12###	14.04	16.57	

T1=Measurement one; T2=Measurement two; T3=Measurement three; T4=Measurement four; M=Mean value of group at measurement date; T1-T2=Difference between measurements one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurements three and four (six-months); T1-T4=Difference between first and last measurement (two-year period); EG= experimental group, CG=Control group; MSE = Mean Square Error; LD = Late Developers; ED = Early Developers; TD = Typical Developers
Practically significant effect (#=Small; ##=Medium; ###=Large)

3.6 DISCUSSION

The aim of this study was to determine whether participation in sport, with additional training in speed and agility would counter the negative effect that might arise from changes in stature, body mass and body proportions during the growth spurt in mid-adolescent boys on speed and agility. This aim was studied by comparing boys who were participating in sports compared to those who were not, while also comparing the results of boys who were in different developmental stages of the growth spurt.

Small but significant interrelationships were found between body composition characteristics and speed and agility where height, mass and fat percentage related significantly during different periods of the two-years with these motor fitness characteristics. Increasing height during the second six-month period (T2-T3) (age 14.17–14.68 years) of the study and over the overall period (T1-T4) (age 13.68–15.3 years) had a significant relationship with speed and agility performance. The ED of the EG improved in both speed tests compared to a decline in CG.

Agility performance as measured by means of a T-test and a repeated shuttlerun test, and performance in both tests showed similar trends, where performance in both tests of the LD and TD of both EG and CG increased over the two-years. However, the results of the ED sub-group of EG showed an improvement (-0.6 s) while the agility of the ED of the CG showed a decline (0.15 s) over the period of the study. Similar trends were also found in the speed of ED groups. The TD of both groups showed significant increases over the two-years (EG = -1.12s; CG = -1.04s). This improvement in agility took place from T2 to T3 (age 14.17–14.68 years), which is the six-months that followed after the biggest improvement in speed was seen in the TD sub-group (table 4). The results of the shuttle run test showed the same developmental curve as what was found in the T-tests. The slight decrease in agility that was found during the first six-months of the study can possibly be ascribed to changes in body dimensions, proportions and composition and differential timing of the growth spurts in segment lengths which take place during this period.

Table 4 shows significant height increases during the T1-T4 period while body mass increased the most in the T2-T3 period (Cameron, 2014; Malina *et al.*, 2004). Literature findings indicate that peak velocity in leg length occurs earlier than that of height where peak velocity for sitting height or trunk length occurs after that of height. Rapid growth of the lower extremities is characteristic of the early part of the adolescent growth spurt (Malina *et al.*, 2004). Odd body proportions and height to weight ratio, muscle imbalances and problems with postural control can also influence balance and coordination (Anthanasios & Papaioannou, 2014; Pienaar, 2010). Boys will also experience a change in the center of gravity as a result of the growth

gradients of different body segments that can also cause temporary loss of coordination and speed during this phase of rapid growth according to Balyi *et al.* (2013). During T1-T2, the time during which the biggest increase in leg length and a subsequent loss of motor coordination and also assumed from the height increases in these groups is expected in the biggest number of participants (TD and LD), the agility of the experimental group showed a bigger increase than the control group. The CG only showed significant increases in performance in the T-test at T3-T4, the time during which all growth related imbalances (muscle imbalances, problems with postural control and poor core and muscle control due to odd body proportions and height to weight ratios which will influence balance and coordination) (Anthanasios & Papaioannou, 2014) are sorted out. The results of this study hereby confirm that the negative effects of growth on agility can be countered with a training programme that focuses on the development of strength, speed and agility.

Height increased significantly in all three developmental groups with the biggest increase in the TD group. This increase is in line with the findings of Wheeler (1991) that found that boys can grow as much as 12cm within the year of PHV that usually occurs at age 14 (Tanner & Whitehouse, 1976). The total increase in height for the TD in this study was 10.76cm (EG) and 11.61cm (CG) with the biggest increase in height during the first 12 months (7.05cm EG and 7.43cm CG) between age 13.68 – 14.72 years. These findings also correlate with Gerber, Pienaar & Kruger (2015) who reported PHV between the age of 13.58 – 14.58 years in boys of the North West Province, South Africa, with height increases of 8.07cm during that year. The mean age of the TD sub group at the start of the study was 13.66 years (EG) and 13.62 years (CG) respectively while the mean age of the ED groups was 13.85 years (EG) and 14.05 years (CG). In the light of the small increases in height over the two-years in the ED sub-group (3.05cm) it can be concluded that the ED sub-group had already passed through their PHV, while the TD sub-groups were still in the late stages of the peak height velocity (PHV) phase, with increases of 10.57cm and 11.47cm of height in the two-groups over the two-years of this study.

Increases in body mass followed the same developmental pattern as height. The biggest increases in body mass for both TD sub groups (EG = 5.49 kg; CG = 3.83 kg) were found at the same time as what the largest increase in height occurred (T2 – T3). These results correlates with the findings of Gerber *et al.* (2014) and are consistent with the findings of Rogol, Roemmich & Clark (2002) who stated that a peak in weight increase coincides with PHV in boys at age 14 years. Early maturing boys tend to have greater muscle mass, but also more fat tissue at all ages (Malina *et al.*, 2004) which agrees with the results of the ED in this study. The ED subgroup of the CG showed the largest increase in body mass over the two-years (13.35 kg) but also the largest increase in fat percentage (3.93%) over the two-years, compared to a total

increase of 0.18% for the ED of the EG over the two-years. These results might show that the training programme of the EG contributed to improved lean body mass (fat free mass) whereas the CG who did not participate in sport or training programmes put on fat mass of more than 5kg of their total weight gain over the two-years. Similar results were found in the LD of the control group who showed an increase compared to a decrease in fat mass in the EG. The bigger increase in body mass of the ED is due to the fact that they are further from their PHV and that an increase in weight continues throughout their adolescent years (12-15 years) (Pienaar & Viljoen 2010) as well as the fact that fat percentage starts to increase after 15 years of age in boys (Malina, 2011). Shang *et al.*, (2010) found in their study that children with more lean muscle mass perform better in speed and agility than children with excess fat mass.

The sitting height of boys in the study of Gerber *et al.* (2014) who studied similar aged boys in South Africa showed an increase of 3.83cm during year one (13.58-14.58 years of age) and another increase of 3.02cm during year two (14.58-15.57 years of age) while Lee, Chao, Tang, Hsieh, Chen and Ho (2005) reported a 4.6cm increase in boys aged 12–13 years and 3.7cm between ages 13–14 years. When we compared the increase of all the sub-groups of our study, especially the TD sub-group of both EG (2.1 cm) and CG (2.24 cm) the assumption can be made that the boys in this study had already passed through their maximum increase of sitting height and that the growth of the legs had caught up with the growth in the upper-body. This is supported by research findings of Malina *et al.* (2004) that showed that peak velocity in leg length occurs earlier than that of height and peak velocity for sitting height. Philippaerts *et al.* (2006) report a lack of motor coordination and strength to effectively orientate, stabilize and apply force through their lower limbs is what prevent boys to improve speed (Meyers *et al.*, 2015). This phenomenon is evident from the current study as the speed of LD of both groups showed an increase six months later (T2-T3) than that of ED and TD. One can argue in this regard that, once the growth of the upper body is in proportion with the trunk, speed will increase and a specialised programme will have an improved effect. Although the CG shows a better improvement in speed during the first (T1-T2) and last six-months (T3-T4), which is the months during which the intervention took place, the mean values of the EG at these test dates were still higher, which shows that sport participation and training have a positive effect on speed development.

Changes in 10m sprint speed showed a small correlation ($r=-0.29$) with changing height at T3-T4, while 40m speed showed no correlation with height changes but a small correlation ($r=0.21$) with changing body mass at T2-T3 and fat percentage ($r = 0.261$) at T1-T2 (Table 2). Ten meter sprint speed also referred to as acceleration speed, of all three sub-groups in this study showed the biggest improvement during the first six-months T1 to T2 (age 13.68 -14.17years) ($p<0.05$, $d>0.5$). Although the TD sub-groups of both the EG and CG showed the same overall

improvement over the course of the two-years, EG (-0.14s) and CG (-0.15s), the TD of the EG showed the biggest improvement between T1-T2 (EG = -0.15s; CG = -0.2s) ($d \geq 0.5$) which is also the time during which the EG group was subjected to the speed and agility training programme. The TD of EG also showed the smallest loss in acceleration speed from T2 to T3 (EG = 0.03 ; CG = 0.08) a time during which the EG did not follow a training programme (Table 5). This correlates with the findings of Duvenhage (2012) who found a difference (10m = 0.28s; 40m = 0.89s) in speed between boys who participated in sport vs non-sporting boys. The 40m sprint speed showed the same development curve as that of 10m Sprint Speed. Both TD sub-groups biggest improvement was seen between T1-T2 (EG = -0.30s; CG = -0.47s). Speed improvements of both 10m and 40m speed were found to be during the time before and after the most growth took place in this group. Although the 40m speed improvement of the CG was higher than that of the EG, the mean scores of the EG are better and the decrease in speed that is seen during T2-T3 (period of most growth) is also smaller in the EG than in the CG. One can therefore argue that this is due to the fact that the EG participated in sports and a strength, speed and agility focused programme that may have countered the effect of growth on speed.

The true training effect of the strength and agility programme can be seen in the significant differences in changes in speed and agility between the ED of EG and CG over the two-year period (T1-T4). The ED sub-groups are the only groups in this study who have already passed through their growth spurt where a clear intervention effect can subsequently be concluded from the results. The ED who were subjected to the intervention programme showed significantly bigger improvements in both speed and agility compared to their counterparts in the CG.

Based on these results it can be concluded that growth does have a negative influence on the development of speed and agility. Both TD sub-groups showed the biggest increase in height between T2 and T3. During this period the EG had a smaller loss over 10m and a significant bigger increase of 40m speed compared to the CG. The EG also had a significant ($d \geq 0.55$) bigger improvement than the CG in agility in the same time period. During the T1–T2 interval during which the TD sub-group of both EG and CG had the second biggest height increment, the EG had a larger increase in 10m acceleration speed as well as in the T-test for agility. During intervals of larger height increases the increases in speed, especially 10m (acceleration) and agility of the CG who were not subjected to a training programme were smaller than those of the EG who participated in a supervised strength, speed and agility training programme, although growth and motor performance development of both EG and CG showed a typical development curve as reported by other researchers. From the differences in the mean values at the different measurement intervals it can be deduced that growth does have an influence on the improvement of speed and agility (both positive and negative) but that the negative aspects can be countered by a training programme that focus on strength, power, speed and agility

specific training. The true value of the training programme can be seen once participants have passed through their growth spurt.

This study had shortcomings that need to be highlighted. The division of the group into subgroups based on participation in specific school sports and maturity levels, contributed to small groups of especially LD and ED participants, most probably because most boys in Grade eight are already in their growth spurt phase which made the ED and especially the LD groups small. Not all racial groups that represent South African children were represented in the study and results are hence mainly applicable to Caucasian boys. However, although the participants of the study were all from one high school in Mpumalanga Province in South Africa the participants enrol in the school from different primary schools in the Province which makes the results more generalizable. Environmental conditions (e.g. temperature, humidity, wind speed) could not be controlled for during the four measuring points and might have influenced the results. Data were only collected between the ages of 13- to 15-years and not over the full period of the growth spurt, which is more desirable. The age period between 11- to 16-years is the ideal time period for research of this nature to be conducted, although it is not practical in the context of the SA school system, where children move to different high schools after their Grade seven year which makes it impractical to follow them during this complete growth period. Shortcomings of the training programme should also be highlighted. The six-months' programme was interrupted by a ten-day school holiday during which there was no control over the adherence of the boys to the training programme. A six-months training programme might also be too long for boys aged 14 to 15 years to adhere to, as they can lose motivation and subsequent commitment to adhering to the intensity and duration of the programme which might also have influenced the effects of the programme. A training program of only one session per week of speed and agility might also not have the desired effect as three sessions per week might have had.

3.7 SUMMARY

This study showed definite changes in height, body mass and fat percentage (lean and fat mass) between 13- and 15-years which had significant influences on the development of speed and agility of adolescent boys. No differences were found in the developmental curves between the EG and CG in any of the anthropometric or motor fitness characteristics, differences were evident between the sub-groups (LD, ED, TD) and these results are in agreement with results found in the literature. The results also confirmed that boys in Grade 8 between the ages 13.68-14.72 years, experienced the biggest increase in height, while motor fitness capabilities also showed significant improvements during this period. According to other researchers the motor performances of early-maturing boys are, on average better than those of average-maturing

and late-maturing boys. This was true for the mean scores of the CG of this study, but the mean scores of the EG who participated in sport and a strength, speed and agility training programme were more closely distributed showing the influence of the training effect. Our findings confirm that changes in speed and agility can be attributed to the growth acceleration phase and maturation of the body. Increases in height showed a negative influence on speed of adolescent boys but our results showed that a specialized training programme and participation in sports can limit this negative influence as the EG suffered a smaller loss of speed at PHV than the CG. Few differences were seen in agility between TD of EG and CG over the two-years but clear differences were evident between the sub-groups that correlated with their maturity status. From this we can deduce that the influence of segmental growth during the growth spurt of boys has a negative influence on the agility of adolescent boys but it can be countered by a specialised training programme and participation in sport, which is confirmed by smaller decreases in agility scores which were evident during the first six-months, which was smaller in the EG.

Findings of this study will enable sports coaches to obtain a better understanding of motor- and physical fitness capabilities of male athletes at different developmental stages (ED, LD, TD) during the mid-adolescence period. It is recommended that coaches of young athletes should prioritize training that improves athleticism opposed to focusing on the immediate desire to win. The ultimate goal during this period should therefore be to optimally structure the training programmes of boys to improve their development of motor and physical fitness capabilities. Participating in programmes similar to what was developed for this study during the mid-adolescent period will also help to establish safer and more injuryfree training for boys during this period to improve their speed and agility.

More research that includes bigger groups and a wider geographical area is needed, however, to confirm these findings. Longterm studies that span the full period of puberty, which includes ages between 11- and 16-years is also recommended. Improved and more specialised training programmes are also needed to further our understanding of this complex research area. Research that focuses more on the effect of body proportions and growth velocities of the different segments and how specialised training of different muscle groups can counter this effect should also be done to improve our understanding of these influences.

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3.9 AUTHOR CONTRIBUTIONS

JB and AP planned and designed the study. JB collected all the measurements, designed and deliver the training programme and analysed the results in cooperation with AP and BG. AP and BG edited the manuscript for intellectual content and provided critical comments on the manuscript.

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CHAPTER 4

**THE EFFECT OF THE GROWTH SPURT ON STRENGTH AND POWER
DEVELOPMENT DURING MID-ADOLESCENCE IN BOYS**

RESEARCH ARTICLE

THE EFFECT OF THE GROWTH SPURT ON STRENGTH AND POWER DEVELOPMENT DURING MID-ADOLESCENCE IN BOYS

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Running Head: Effect of the growth spurt on strength and power development

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THE EFFECT OF THE GROWTH SPURT ON STRENGTH AND POWER DEVELOPMENT DURING MID-ADOLESCENCE IN BOYS

4.1 ABSTRACT

The aim of this study was to determine whether the growth spurt during mid-adolescence would have an influence on the development of strength and power in a group of boys ($N= 86$) with a mean age of 13.6 ± 0.26 at baseline. An experimental group (EG), who participated in different school sports were subjected to an additional strength and power training programme two times per week for 45min each for six-months in two consecutive years ($n=47$, mean age= 13.67 ± 0.26), and compared to thirty nine boys (mean age= 13.68 ± 0.16) serving as a reference group for normal growth during this period who did not compete in any sports nor had been subjected to a training programme. The subjects were assessed every six months for changes in height, weight and their performance in the squat, vertical jump, horizontal jump, sit-ups and seven-stage abdominal strength tests. Both EG and control group (CG) were sub-divided into three growth groups namely late developers (LD), early developers (ED) and typical developers (TD) by means of age at peak height velocity (PHV). A hierarchical linear and covariate structure was used to analyse all variables within the three groups. The p-level for significance was set at $p < 0.05$, followed by interpreting practical significance cut offs. Results indicated that the growth spurt had a positive effect on the training of strength and power of TD and ED, with little or no effect on LD who hasn't reached their PHV yet.

Keywords: Early developers, late developers, typical developers, boys, adolescents, strength, power.

4.2 INTRODUCTION

Athletic performance during childhood and adolescence is strongly influenced by growth in size and increasing complexity of the nervous system (8). Several researchers report a period of accelerated growth between the ages of 13- to 15-years with a peak acceleration at 14 years in boys (1; 15; 44). This accelerated growth is attributed to an increase in testosterone and human growth hormone secretion (5). Young male sports participants in cricket, rugby, swimming and athletics, on average, are more advanced in skeletal and sexual maturation (24). Performance in these sports relies to a large extent on strength and power, a larger body size and muscle mass that is associated with advanced maturity status which therefore can be an asset for better performance (25; 45). In this regard the results of a longitudinal study on Belgian boys aged 12- to 17-years showed that performances of early maturing boys in static strength, explosive strength/power and running speed were on average better compared to average-maturing and late-maturing boys (22).

Strength is essential for motor performance as a certain level of muscular strength is necessary to succeed in certain sport specific tasks (24). Strength is an expression of muscular force, or the individual's capacity to develop tension against an external resistance and is defined as the maximum power output during a single muscle contraction (12; 18; 24; 34). Several types of strength need to be enhanced e.g. static strength: the force exerted against an external resistance without change in muscle length (24), explosive strength or power: which is the ability of muscles to release maximal force in the shortest possible time (24), and dynamic strength which refers to the force generated by repetitive contractions of muscles (24). Muscular endurance describes the ability to repeat or maintain muscular contractions over time (24).

The growth curve of muscular strength is generally similar to that of body size and weight during childhood and adolescence (33). One of the main factors responsible for the increase in strength with the onset of puberty (age 9) is a fourfold increase in testosterone levels during early puberty with a further twentyfold increase during mid-puberty (age 15) (39). Balyi *et al.* (4) report in this regard that strength will increase by two thirds after Peak Height Velocity (PHV) as a result of growth. Strength of the upper and lower extremities does not show the same developmental trends where the lower extremities show accelerated strength development about one year before the upper body (10; 25; 38). Several researchers also indicate that neurological factors play an important role in strength development (10; 32).

Changes in fibre composition of muscles, hormonal changes in the body as well as adaptability (trainability) of muscles due to neurological factors occur in different life stages including the pubertal phase (17). Puberty is considered a sensitive period for the development of strength

especially for males as an increase in testosterone production in boys results in a marked increase in muscle mass during this phase (5). Resistance training in the prepubescent child may also effectively increase strength, without a concomitant increase in muscle mass (29), which is due to the lack of the anabolic effects of testosterone in boys. Strength gains at this age (12-13 years) are mainly attributed to more efficient recruitment of motor units (36). Responses to resistance training stimuli in pre- and early-pubertal youth are reported to be largely neural and may include a learning component (31; 35). Taking into consideration that boys during mid-adolescence have increased testosterone levels, increased body weight and muscle mass as well as increasing limb length, one can argue that the period after PHV will be the most optimal time to train and improve strength in boys (23).

The development of strength (5; 9; 10; 13; 14; 24; 38) and power (19; 24; 33) and also the trainability of strength (5; 7; 23; 24; 29; 31) and power (11; 27; 41; 43) is well researched. Researchers have also studied the relation between anthropometric changes and the development of strength and power and identified certain anthropometric and body composition parameters that will predict power in children (16; 24; 46). An obvious shortcoming in all of these studies is the direct investigation of the effect of the growth spurt on the training of strength and power in boys. This study therefore aims to address this gap by investigating how the growth spurts of boys at different stages of development during mid-adolescence will affect the training of strength and power during this period.

4.3 METHODS

4.3.1 Experimental approach to the problem

The research design is based on a two group pre-test post-test design within a two year follow-up period that included 4 time point measurements. A sample of convenience was used for the purpose of the study from which one group of boys who participated in 4 official school sports, were selected and subjected to an additional strength, speed, power and agility sports conditioning programme for the first six months of each of the two year follow up period, 2 days per week for 45 minutes. A control group who did not partake in any sports and who was not subjected to any training program, was also selected to serve as a reference group for growth that take place during this same period. The study spanned a period of two school years, with the first measurement at the beginning of the Grade eight year of the boys (in February), when they had a mean age of 13.68 years. This was followed, 6 months later, with a second testing in August of the same year. The last measurements were done during their Grade nine year in February and in August when they had a mean age of 15.3 years during the final testing date. Both the Experimental (CG) and control (CG) groups underwent a fitness evaluation that

includes measurements of body composition, three strength and two power tests, twice per year during February and August, representing four time-point measurements over the two-year period. Treatment effects could therefore be determined over three periods of six months by using 4 time point measurements. Both the EG and CG groups were divided further, but only for statistical analytical purposes, into sub-growth groups based on different levels of maturity that they represent. These three groups were labeled late developers (LD), early developers (ED) and typical developers (TD). The growth history of each subject over the 2 year period of the study were assessed individually by the researchers where after the subject were categorized. Based on scientific evidence (1) that indicates that more than 5 cm of growth in height per year is as sign of being in the growth spurt, was taken as a benchmark of being in the growth spurt phase and placed a subject in the typical development category (TD). The growth in height over the two years of all the boys who showed less than 6 cm growth per year, were once again studied and carefully considered to determine placement in the early or late development category. Those in this group who only showed small grow increments such as between 2-3 cm per year over the 2 year period were categorized as early maturerers (ED)(1), as this amount of growth is indicative of final growth that takes place after the growth spurt has been passed. The rest were categorized as late developers (LD). The co-founding influence of early and late development on the effect of the training program could be analysed in this manner.

4.3.2 Subjects

The Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University approved the study (NWU-00330-15-A1). All 145 Grade eight boys and their parents received a parental and participation permission form containing all the information explaining the purpose and objective of the study as well as the procedure of all the tests and had the opportunity to ask questions at an information meeting or by contacting the researcher. All parents or legal guardians and participants voluntarily signed consent. The boys were all recruited from one state governed high school in Nelspruit in Mpumalanga Province within the Mbombela Local Municipality area of South Africa. Nelspruit is classified as a city with a high socio-economic status, which is surrounded by small towns such as Komatipoort, Sabie and Malelane that are classified as rural areas with farming communities. KaNyamazane, a Township area near Nelspruit is considered a low socio-economic area. Children attending Nelspruit High school enrolled from all over these Lowveld areas and can attend this school because of boarding facilities. The leaners enrolling into the school subsequently came from different primary schools and areas and represent different socio-economic backgrounds. However, the group of learners cannot be considered to be representative of the adolescents' population, either of the Mbombela Local Municipality area or of South African adolescents in

general. All 145 Grade eight boys were recruited to participated in the study of which 47 boys who took part in school sports, namely rugby, field hockey, cricket and athletics was categorized into the experimental group (EG). This group was subjected to a sport conditioning programme. A control group (CG) of 39 boys was also selected from the initial sample who do not compete or train in any sports and who can be described as non-sport participants. The remaining 59 boys were excluded from the study because they participated in other sports that are not part of the school's sporting codes, like swimming, mountain biking, gymnastics and tennis. Since this was an all-inclusive sample of all children in the school satisfying the inclusion criteria, power calculations were not relevant. The 47 boys in the EG were subdivided into three groups, late developers (LD)(n=7), early developers (ED)(n=8) and typical developers (TD)(n=32). The CG was divided into the same three groups LD(n=4), ED(n=2) and TD(n=33).

4.3.3 Procedures

For the determination of the anthropometric growth, and physical and motor capabilities the test protocol consists of nine tests, which included four anthropometric tests (stature, mass, sitting height, and fat percentage) (26) and five physical and motor fitness tests (two minute sit-ups, seven-stage abdominal strength, squats, vertical and horizontal Jump) (2; 6; 21). A combination of protocols from the Australian Sport Search Program, the U.S Navy Physical Readiness test and a few additional field tests were used (2; 6; 21). First, the anthropometric variables were measured in an enclosed area where, after the physical and motor fitness measurements were completed in the gymnasium and on the sports field. Where the participants had to rotate between the stations. Sufficient rest periods were allowed between the tests to prevent exhaustion from having an influence on the test results.

4.3.3.1 Anthropometric measurements

The anthropometric measurements which include stature, mass, sitting height, and fat percentage were done by qualified exercises scientist, according to the international standards for anthropometric assessment (ISAK) protocol (26). Body stature and sitting height were determined with a Harpenden stadiometer. Stature was measured while standing barefoot with the back against the stadiometer (seca 206, Germany) and the feet together. The heels, buttocks and upper back had to be in contact with the stadiometer and the head held in the Frankfort position. While the subject inhaled deeply in this position, the measurement was taken to the nearest 0.1cm. The intra class correlation for height was $r=0.98$. Sitting height was measured while sitting flat on the stadiometer with the back against the stadiometer and the knees bent slightly. The head of the subject was held in the Frankfort position by the administrator and the measurement taken to the nearest 0.1 cm after lowering the arm of the

stadiometer onto the subject's head. Sitting height ratio was calculated by using a formula: sitting height/stature x 100. Mass was taken with a calibrated electronic scale (SOEHNLE, Germany) with the subject standing upright with his weight evenly distributed on the scale and his arms next to his sides, dressed in as little as possible clothing. The subject had to look straight ahead while the measurement was taken to the nearest 0.1kg. The intra-class correlation for body mass was $r=0.6$. The triceps, subscapular, iliac, abdominal, front thigh and calf skinfold thicknesses were measured by one operator using a Harpenden calliper (Gima, Modena, Italy) according to standard ISAK protocol procedures (26). Two measurements were taken at each site, and the average of the two readings will be taken as the score. Fat percentage was calculated by using a formula: (sum of six skinfolds x 0.1051) + 2.585.

4.3.3.2 Physical fitness measurements

Five physical fitness tests were used to test maximal strength (seven-stage abdominal strength and squat test), strength endurance (two-minute sit-ups test) and explosive strength or power (vertical and horizontal jump). These five tests are a combination of protocols from the Australian Sport Search Program (2), the U.S Navy Physical Readiness test (6) and a few additional field tests (shuttle runs, squat test, seven-stage abdominal strength) (2; 6; 21).

The seven-stage abdominal strength test begins with the participant lying on his back, with the knees at right angles and the feet flat on the floor. The participant then attempts to perform one complete sit-up for each level in the prescribed manner, starting with level 1. Each level is achieved if a single sit-up is performed in the prescribed manner, without the feet lifting off the floor. As many attempts as necessary can be made. The highest level correctly completed is recorded (21). A relative load test was done to determine leg strength (squat test): participants performed the most repetitions that they can at a load that is a percentage of their estimated 1-RM. The equation ($1\text{-RM} = 100 \times \text{rep mass} / (52.2 + 41.9 \times \text{exponential} [-0.055 \times \text{reps}])$) was used to determine the 1-RM of participants. One administrator with two helpers was assigned to minimize injury risk. For the two minute sit-up test the participant had to start on his back with bent knees and hands placed at the side of the head. An administrator was permitted to hold the feet or ankles of the participant to keep the feet on the floor. The upper body was then raised until the elbows touched the thighs while the hands remain at the sides of the head; after which the body is lowered back to the floor until the shoulder blades touches the ground. No bouncing or arching of the lower back is allowed, and the buttocks and feet must remain in constant contact with the floor throughout the test. The maximum number of correctly performed sit-ups in two minutes was recorded.

The participant's vertical jumping height was measured using the Vertec (Questek) (47). This apparatus included a sliding vertical pole attached to two weights at the base, which stabilized the apparatus. Movable horizontal levers are attached at the top of the pole and are marked in 1.27cm levers. The levers can be set to begin at 228.6, 243.84, 259.08, or 274.32 cm. The initial setting for the levers was dependent upon the participant's reaching height which was measured by having the participant standing with his dominant side next to a wall. The participant then had to extend the arm closest to the wall and reach as high as possible without allowing any part of the feet to lose contact with the ground, while keeping the hip as close to the wall as possible. This measurement was then recorded to the closest 1.27cm. The participants' vertical jump height was then measured after standing with the dominant side next to the apparatus, with feet shoulder-width apart and performing a vertical jump while touching the vanes on the Vertec (Questek). The participants were instructed to reach with their dominant hand while at the top of their jump and to move as many levers as possible. Two vertical jumps were allowed, and the average of the jumps was recorded. The height of the jump was the difference between the vertical reach and the vertical jump. For the Horizontal or Standing Long jump test, the participants were instructed to initially stand on a long jump mat and jump as far as possible taking off from two feet. The distance from the starting point to the landing point at heel contact was used as the jumping distance. The average of the three jumps was recorded (47).

4.3.3.3 Sports participation frequency

Participants completed a self-compiled health screening questionnaire during baseline measurements to report on their current health and fitness and family medical history. The sports participation frequency of each participant was also determined by means of a questionnaire where the participant had to indicate his sport participation and training frequency by ticking the different sports that he participates in and the number of days and hours per day he spends at training for a particular sport. Injuries during the two-years, time of the programme and treatment of injuries was monitored by the Exercise Scientist.

4.3.4 Training protocol

The participants who were included in the experimental group took part in one or more school sports that included athletics, rugby, field hockey and cricket. They practised sports specific skills in the afternoons, three days per week with their respective school sports coaches. These sessions consisted of 60min drills and techniques that applied to the relevant sport of each participant. Additionally they took part in a speed, agility, strength and power training programme for two additional days per week which was compiled and conducted by a

registered Exercise scientists who was also responsible for the adjustment and progression of each programme throughout the six-months. The content of the programme of two sessions per week was not sport specific, but rather generic as it had to accommodate the strength, power, speed and agility needs of all sports. These sessions consisted of one 45min combined session for resistance training (own body weight exercise, elastic resistance bands, gym apparatus and free weights) and plyometrics (skipping ropes, plyometric jumping box). Each of these sessions consisted of 12 exercises that included five strength exercises (leg extensions, leg curls, squats, sit-ups bench press), four plyometric exercises (skipping, box jumps, front and sideways and depth jumps) and a combination of three strength and plyometric exercises (lunge jumps, squat jump with high pull, burpee to pull up). At the start of the six-months each exercise was done with light to medium weights for 15 to 20 repetitions and repeated three times, with a great emphasis on technique. As the participants' conditioning increased and they became more skilled in the proper technique the weight was increased and repetitions decreased to ten repetitions. The second session was made up of 45min of speed and agility training (speed ladders and hurdles, weighted sleds and parachutes) with the focus on improvement of foot speed, acceleration balance and proprioception. At the start of the six-months the speed and agility sessions focused on proper sprinting mechanics, where short distances of 10 to 20 metres were used including no more than four hurdles and speed ladders with four blocks. As the participants mastered the skills, techniques and exercises during the six-months the distance was increased up to 80m and the number of hurdles and the length of the speed ladders increased.

4.3.5 Statistical analyses

The data were analysed by the "Statistica for Windows" (StatSoft, 2015) computer programme as well as with SAS 9.3 Level TS L1MO (2000–2010). Data were analysed for descriptive purposes using means (M), standard deviations (SD), minimum and maximum values and lower and upper quartiles (Statsoft, 2015). A hierarchical linear model was used to analyse differences between the three measuring points and over a period of two-years within the group for all variables. Practical significance of differences between means was determined according to Cohen's d-value (0.25 small, 0.55 medium, and 0.85 large; Cohen, 1992).

4.4 RESULTS

Table 1 shows the demographics of the participants with a mean age of 13.68 ± 0.26 years at baseline. No loss of participants was recorded during the two-years of the study. The 68 participants from both EG and CG were divided in to three sub-developing groups, late developers (LD), early developers (ED) and typical developers (TD). The table shows the mean

age of each group at the beginning of each year. From this it can be seen that the mean ages of boys in the different developing groups in both EG and CG differed notably which correlates with the relative age effect, which indicates that ED's are born during the first half of the year and LDs during the second half of the year. The TD in the EG which was the biggest group, participated in at least two sports and showed an even distribution between participating in one sport (n=15), two sports (n=13) while also participating in a third sport (n=4). LDs tend to participate in only one sport while the EDs participate in two school sports. This sports participation frequency suggests an influence of their development stage. Very few growth related injuries were reported in the EG. From the 47 boys of the EG who competed in sports like athletics, field hockey and rugby only one scheuremans, two with sprained ankles, one minor shoulder injury and a hamstring strain was reported during the two-year period of the study. None of these injuries kept the boys from participating in the programme or their sport for more than two weeks.

Table 1: DESCRIPTIVE INFORMATION FOR THE GROUP OVER TWO-YEARS

			N	n	Sport participation	Mean Age	SD
Year 1 Feb 2015 (GR8)	EG	LD.	47	7	5=1 Sport 2=2 Sports	13.52	0.28
		ED		8	1=1 Sport 7=2 Sports	13.85	0.23
		TD		32	15=1 Sport 13=2 Sports 4=3 Sports	13.66	0.28
	CG	LD	39	4		13.38	0.21
		ED		2		14.05	0.01
		TD		33		13.62	0.26
Year 2 Feb 2016 (GR9)	EG	LD		7	5=1 Sport 2=2 Sports	14.56	0.28
		ED		8	1=1 Sport 7=2 Sports	14.89	0.23
		TD		32	15=1 Sport 13=2 Sports 4=3 Sports	14.70	0.28
	CG	LD	39	4		14.42	0.21
		ED		2		15.09	0.01
		TD		33		14.66	0.28

EG=Experimental Group, CG=Control Group; N= Number of participants for EG & CG; n= number of participants for each sub-group; SD= standard deviation Sports participation = number of participants per development group that participated in either one, two or three school sports

Table 2 and 3 show the results of a correlation analysis between changes in the body composition characteristics (height, weight, fat% and sitting height) and changes in motor fitness measurements (vertical jump, horizontal jump, seven-stage abdominal strength, sit-ups and squats) of the group over the study period of two-years (T1-T4), and also divided into six month periods (T1, T2, T3, T4). Changes in horizontal jump distance which assesses power show a significant medium correlation with changing height at T3-T4 while changes in vertical jump height (power) show a medium negative correlation with changes in fat percentage, also at T3-T4. Changes in strength (Table 2) as measured by sit-ups showed a moderate relationship at T3-T4 with changes in body mass while performance in the squat test show a significant medium correlation with changes in fat percentage at T1-T2. Overall these relationships confirmed an interrelationship between body composition and motor fitness capabilities which subsequently motivate further analysis of the results which are displayed in Tables 4 and 5.

Table 2: CORRELATIONS BETWEEN CHANGES IN ANTHROPOMETRIC CHARACTERISTICS AND STRENGTH

Variable	7Stage abdominal strength				Sit-ups				Squats			
	T1-T2	T2-T3	T3-T4	T1-T4	T1-T2	T2-T3	T3-T4	T1-T4	T1-T2	T2-T3	T3-T4	T1-T4
Height												
T1-T2	-0.11	-0.08	-0.02	-0.10	-0.09	-0.05	0.02	-0.03	-0.06	0.11	-0.10	0.04
T2-T3	0.18	0.03	-0.04	0.15	0.03	0.14	-0.15	-0.04	-0.01	-0.03	-0.14	-0.07
T3-T4	0.14	-0.01	0.06	0.18	-0.05	0.01	-0.01	-0.01	-0.01	0.01	0.06	0.07
T1-T4	0.16	0.00	-0.02	0.15	-0.03	0.07	-0.09	-0.04	0.02	0.04	-0.13	0.00
Mass												
T1-T2	-0.05	-0.03	-0.12	-0.11	0.01	0.09	-0.18	-0.14	0.10	0.07	-0.11	0.08
T2-T3	0.26*	-0.13	0.02	0.10	0.12	0.03	0.01	0.18	0.10	-0.03	-0.12	-0.03
T3-T4	0.26*	-0.06	0.02	0.15	0.18	-0.05	-0.22*	-0.10	0.15	-0.11	0.01	0.01
T1-T4	0.26*	-0.17	0.00	0.10	0.14	0.05	-0.16	0.02	0.20	-0.02	-0.13	0.03
Fat%												
T1-T2	-0.08	0.14	0.01	0.04	0.10	-0.03	0.13	0.22*	0.30**	0.27*	0.08	0.32**
T2-T3	0.04	-0.13	-0.14	-0.13	-0.09	-0.00	0.07	-0.01	-0.17	-0.05	-0.20	-0.20
T3-T4	-0.11	0.04	0.09	-0.03	-0.04	0.08	-0.21	-0.19	0.06	-0.02	0.09	0.01
T1-T4	-0.06	-0.02	-0.03	-0.10	-0.02	0.05	-0.06	-0.02	0.08	0.13	-0.15	0.04
Sitting Height												
T3-T4	0.02	-0.11	0.18	0.14	-0.01	0.19	-0.06	0.08	0.04	0.02	0.06	0.05

Marked correlations are significant at $p < 0.05$; $r = 0.1$ = small*; $r = 0.3$ = medium**; $r = 0.5$ = large***;

T1-T2=Difference between measurements one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurements three and four (six-months); T1-T4=Difference between first and last measurement (two-year period)

Table 3: CORRELATIONS BETWEEN CHANGES IN ANTHROPOMETRIC CHARACTERISTICS AND POWER

Variable	Vertical jump				Horizontal jump			
	T1-T2	T2-T3	T3-T4	T1-T4	T1-T2	T2-T3	T3-T4	T1-T4
Height								
T1-T2	-0.02	-0.13	0.13	-0.08	-0.08	-0.14	0.09	0.02
T2-T3	0.07	0.15	-0.05	0.02	0.15	-0.09	0.12	0.15
T3-T4	0.12	-0.08	0.08	0.12	0.08	-0.09	0.24*	0.09
T1-T4	0.09	0.04	0.02	0.13	0.12	-0.07	0.22*	0.14
Mass								
T1-T2	0.09	-0.05	0.09	0.05	0.16	-0.01	-0.0	0.12
T2-T3	-0.05	-0.08	-0.06	-0.11	-0.09	-0.16	0.27*	-0.11
T3-T4	-0.14	0.11	-0.07	-0.04	-0.04	0.07	0.06	0.05
T1-T4	-0.04	-0.08	0.01	-0.06	0.01	-0.10	0.29*	0.04
Fat%								
T1-T2	0.04	-0.07	0.07	0.07	0.03	-0.08	0.11	0.01
T2-T3	-0.09	0.02	0.06	-0.11	-0.06	-0.06	0.12	-0.09
T3-T4	-0.200	0.13	-0.24*	-0.24*	0.01	0.03	0.02	0.04
T1-T4	-0.13	0.06	-0.11	-0.18	0.05	-0.03	0.16	0.07
Sitting height								
T3-T4	0.01	-0.32**	0.100	-0.14	-0.01	-0.10	0.11	-0.10

Marked correlations are significant at $p < 0.05$; $r = 0.1$ = small*; $r = 0.3$ = medium**; $r = 0.5$ = large***;

T1-T2=Difference between measurements one and two (six-months); T2-T3=Difference between measurements two and three (six-months); T3-T4=Difference between measurements three and four (six-months); T1-T4=Difference between first and last measurement (two-year period)

Table 4 contains the descriptive results of the anthropometric measurements (height, mass, fat percentage, sitting height, sitting height ratio), and the changes that were found in these measurements of both groups over the two-year period. Sitting height and sitting height ratio are only reported in year two (T3 & T4). The results include means but also mean differences between measurements between different testing opportunities and over the two-years. Although the p-values of differences that were found ($p < 0.05$) are reported, it should be noted that the groups were not randomly selected which makes the p-value mostly irrelevant, therefore more emphasis was put on the practically significant effect sizes that were obtained of differences and which were interpreted according to the guidelines as set by Cohen (1992). The height of TD of both EG (10.76cm) and CG (11.61cm) increased statistically significantly in height over the two-years. Height of all three growth groups of both EG and CG also increased significantly every six-months ($p < 0.5$), and these increases were also of small practical significance, ED > 0.3). Typical developers showed the highest increases in height followed by the LD and the ED groups respectively. TD of both groups showed significant increases of 3 – 5cm every six months with a total of 10.57cm for the EG ($p < 0.05$, $d \geq 0.85$) and 11.47cm for the CG ($d \geq 0.85$). These height increases from T1-T4 were of large practical significance. The total height increase in the LD group was 5.11cm (EG) ($d \geq 0.55$) and 6.20cm (CG) ($d \geq 0.55$), while early developers in both groups only showed increases of 3.97cm (EG) ($d \geq 0.25$) and 3.05cm (CG) ($d \geq 0.25$) respectively over the two-year period.

Increases in weight differed from the pattern that was seen in height especially in the different developmental groups over the two-year period. The weight increase of the ED (7.73kg) and LD (7.65kg) of the EG is lower when compared to the weight increase of the TD (12.04kg) in the same group. The ED (13.35kg) and LD (10.77kg) of the CG showed an equivalent and larger increase in weight compared to that of the TD (10.75kg) in the CG. A statistically significant increase in weight over the two-years is seen in all the sub-developing groups of both EG and CG, however, little change in the fat percentage of all three sub-groups of the EG compared to that of the CG is evident from the results over the two-years.

Table 5 reports the results that were obtained for the motor fitness measurements (vertical jump, horizontal jump, seven-stage abdominal strength, sit-ups, squats), of both groups over two-years. Both the EG and CG showed statistically as well as practically significant increases in strength and power over the two-years. Large ($d \geq 0.85$) practical significant increases were found in the TD of both groups in vertical and horizontal jumps performance (power) and in their seven-stage abdominal strength performance (maximal strength), while small ($d \geq 0.25$) and medium ($d \geq 0.55$) practically significant increases were found in the sit-ups (strength endurance) and squats (maximal strength) of the same developmental group. The TD sub-group of the CG showed bigger increases in all the tests over the two-year period. The biggest increases in strength and power in TD of both groups were found between T2 and T3 (age 14.17 – 14.68 years). TD showed the biggest increase in stature and body mass. The ED of the intervention group showed large ($d \geq 0.85$) significant increases in strength (maximal strength; squats and seven-stage abdominal strength and strength endurance; sit-ups) over the two-years compared to the increases that were seen in the CG which were not significant.

Table 4: DESCRIPTIVE CHARACTERISTICS AND SIGNIFICANT DIFFERENCES BETWEEN FOLLOW-UP ANTHROPOMETRIC MEASUREMENTS OF BOTH GROUPS (EG) (CG), ALSO DIVIDED INTO SUBGROUPS

	Means for 4 measurement								Difference between measurements				Difference over two years			
	T1		T2		T3		T4		T1-T2		T2-T3		T3-T4		T1-T4	
	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
Height (cm) (MSE = 1.24 ; Variance participants = 53.82) (Sub-group2* Test p-value = 0.00)																
LD	168.02	162.92	171.02	164.70	172.84	166.47	173.85	168.65	3.00#	1.78	0.44	1.77	1.67	2.65	5.11##	6.2##
ED	175.91	175.11	177.38	176.26	178.58	177.02	179.80	177.92	1.47	1.15	0.87	0.30	1.62	1.60	3.97#	3.05#
TD	162.93	161.51	166.19	164.79	169.98	168.94	173.69	173.12	3.26#	3.28#	4.40#	5.16##	2.91#	3.03###	10.57###	11.47###
Weight (kg) (MSE = 6.57 ; Variance participants = 109.39) (EGCG* Sub-group2* Test p-value = 0.017)																
LD	60.78	56.89	64.97	59.54	66.53	64.74	68.78	67.44	4.18#	2.65	0.9	5.20#	2.57	2.92	7.65##	10.77###
ED	71.08	71.25	73.78	72.80	77.11	79.67	78.78	84.48	2.70	1.55	3.17	6.65##	1.86	5.15#	7.73##	13.35###
TD	52.15	55.99	55.38	59.63	60.58	62.98	64.28	66.80	3.22	3.63	5.49#	3.83	3.31	3.27##	12.04###	10.75###
Fat percentage (%) (MSE = 7.054 ; Variance participants = 10.87) (EGCG* Sub-group2* Test p-value = 0.217) (p-value = 0.128 EGCG)																
LD	11.48	12.38	10.74	13.11	10.46	13.09	11.06	12.80	-0.74	0.73	-0.13	-0.02	0.53	-0.34	-0.33	0.36
ED	9.88	9.09	9.15	9.29	9.54	14.08	10.06	13.05	-0.73	0.20	0.43	4.83###	0.47	-1.10	0.18	3.93###
TD	10.08	12.95	9.69	12.58	9.50	11.79	9.93	11.13	-0.39	-0.37	-0.25	-0.89	0.43#	-0.53	0.93	-1.81
Sitting height (cm) (MSE = 1.41 ; Variance participants = 14.10) (Sub-group 2 p-value = 0.002)																
LD					84.20	80.25	85.84	81.80					0.42#	0.39		
ED					89.75	87.35	91.08	90.00					0.34	0.67##		
TD					82.96	82.57	85.06	84.81					0.60##	0.57##		
Sitting height ratio (MSE = 4.58; Variance participants = 0.00) (Sub-group 2 p-value = 0.019)																
LD					0.49	0.48	0.49	0.48					0.26	0.07		
ED					0.50	0.49	0.50	0.50					0.20	0.72##		
TD					0.48	0.48	0.49	0.49					0.26	0.33		

MSE = Mean Square Error; LD = Late Developers; ED = Early Developers; TD = Typical Developers

Statistically significant p-values; p<0.05 considered statistically significant

Practically significant effect (#=Small; ##=Medium; ###=Large)

Table 5: DESCRIPTIVE CHARACTERISTICS AND SIGNIFICANCE OF DIFFERENCES BETWEEN FOLLOW-UP FITNESS MEASUREMENTS (STRENGTH & POWER) OF BOTH GROUPS (EG) (CG), ALSO DIVIDED INTO SUBGROUPS

	Means for four measurement								Difference between measurements				Difference over two-years			
	T1 M±SE		T2 M±SE		T3 M±SE		T4 M±SE		T1-T2		T2-T3		T3-T4		T1-T4	
	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG	EG	CG
Vertical jump (cm) (MSE = 18.4 ; Variance participants = 27.1) (Test p-value = 0.00)																
LD	36.73	27.48	36.52	33.86	43.47	37.61	41.18	32.33	-0.21	6.37###	6.5###	3.75##	-2.07	-5.12##	4.21##	5.0##
ED	39.41	41.34	37.72	40.09	42.20	46.99	42.88	40.26	-1.68	-1.25	4.37##	6.75###	0.81	-6.5###	3.5#	-1.0
TD	33.75	31.18	34.31	33.10	40.13	37.02	40.11	37.98	0.56	2.22	6.02###	3.95##	-0.28	0.88##	6.29###	7.06###
Horizontal jump (m) (MSE = 0.018 ; Variance participants = 0.033) (Test p-value = 0.00)																
LD	1.76	1.60	1.80	1.73	1.97	1.86	2.015	1.95	0.03	0.12##	0.16##	0.12##	0.04	0.09#	0.24###	0.34###
ED	1.94	1.90	1.93	1.93	2.01	2.02	2.06	2.01	-0.01	0.02	0.07	0.09#	0.05	-0.007	0.12	0.11#
TD	1.75	1.63	1.78	1.65	1.89	1.81	1.99	1.89	0.03	0.01	0.11#	0.17##	0.08#	0.06###	0.23###	0.25###
7Stage abdominal strength (unit) (MSE = 1.27 ; Variance participants = 0.495) (Test p-value = 0.00)																
LD	3.57	2.48	3.42	3.73	5.11	3.48	4.26	4.74	-0.14	1.25###	1.71###	-0.25	-0.85##	1.25###	0.71#	2.25###
ED	2.98	3.47	3.60	3.97	4.34	4.96	5.35	5.48	0.62#	0.5#	0.75##	1.0##	1.00##	0.5#	2.37###	2.0###
TD	3.03	2.94	3.40	3.57	4.85	4.99	5.09	5.27	0.37	0.63#	1.43###	1.39###	0.25	0.30###	2.06###	2.33###
Sit-ups (unit) (MSE = 167.08 ; Variance participants = 31.96) (Test p-value = 0.00)																
LD	55.29	44.32	50.72	55.07	59.00	55.82	60.51	56.02	-4.57	10.75##	8.14##	0.75	1.57	0.25	5.14#	11.75##
ED	57.59	56.11	54.21	53.61	69.37	44.66	69.71	60.08	-3.37	-2.5	15.12###	-9.0##	0.37	15.5###	12.12###	4.0
TD	55.55	49.9	61.83	53.35	69.11	61.18	60.69	56.09	6.28#	3.45	7.34#	7.93##	-8.5##	-5.21	5.12#	6.18#
Squats (MSE = 0.029 ; Variance participants = 0.031) (Test p-value = 0.00)																
LD	1.45	1.18	1.42	1.31	1.53	1.39	1.54	1.47	-0.02	0.12##	0.12##	0.08	-0.001	0.07	0.09#	0.28##
ED	1.43	1.48	1.37	1.45	1.46	1.34	1.63	1.39	-0.05	-0.03	0.09#	-0.10	0.16##	0.04	0.2##	-0.09
TD	1.40	1.25	1.40	1.23	1.42	1.31	1.54	1.39	0.00	-0.01	0.18	0.06	0.13#	0.09##	0.14##	0.14

MSE = Mean Square Error; LD = Late Developers; ED = Early Developers; TD = Typical Developers

Statistical significant p-values; p<0.05 is considered statistically significant

Practical significant effect (#=Small; ##=Medium; ###=Large)

4.5 DISCUSSION

The aim of this study was to determine whether the growth spurt had an influence on the development of strength and power training on boys during mid-adolescence by comparing a group of boys who participated in a sport conditioning programme to a control group who did not participate in sports or such a training programme. In addition, each of these groups was also grouped into sub-groups that represented boys who were in different developing stages, as the timing of the growth spurt has differential effects on strength and power during different stages of development (early, late and typical developers).

Results showed an average increase of 6.71cm in height and 10.38kg in weight in the group over the two-year period which agrees with other findings. A large practically significant difference between the increase in fat percentage of the EG and the CG is reported in this study. Research indicates that motor performance and fitness, that includes strength and power, of boys are influenced by three areas of growth during the developing years, namely neural, structural and genital (3). Structural growth which refers to increases in height and weight shows a steep increase during the adolescent phase (3; 24). Body weight has a growth pattern similar to height with a peak in weight increase that coincides with Peak Height Velocity (PHV) in boys at age 14 (19; 37; 44). Santrock (40) reports that boys can reach up to 50% of their adult weight during adolescence and gain on average 9.5kg/year during this accelerated growth phase (37).

Small but significant relationships were furthermore found between body composition characteristics and motor capabilities where changes in height, mass and fat percentage related significantly during different periods of the two-years of the study with these fitness characteristics. Increasing height during the second six months (T2-T3) and over the overall period (T1-T4) had a significant relationship with strength and power development. In the squat test that measure maximal leg / lower body strength it was found that the Experimental group who participated in school sports and in the additional training programme showed higher mean scores compared to the late and typical developer sub-groups at every test interval and at T3 and T4 compared to the CG. At T1 the mean scores of all three developmental groups of the EG was already equal or higher than the scores at T4 of the CG. Increases in strength and power coincided in this study with the time of maximal growth (T2-T3; age 14.17-14.68yrs) of the group. In this matter De Ste Croix (10) reports a strength acceleration phase during puberty, for about two-years, after which strength continues to increase linearly into late adolescence. Rowe *et al.* (39) state that although physical stature, age, weight and gender play a significant role in the potential strength of a person, only 40-70% of strength development is influenced by these factors. Thus, even though the improvement of strength and power of the TD boys were

during the period of no intervention, the improvement can be due to testosterone secretion which increases fourfold during early puberty with a further twenty fold increase during mid-puberty (39), since the biggest increase in strength for the CG was during the same time. In addition as indicated by several researchers, neurological adaptation also plays an important role in strength development (10; 32), and this neural adaptation could also be the result of the extra training programme that the EG was subjected to during the first six-months (time of intervention programme). The results obtained by the early developers of the experimental group strengthen this argument. These boys had already passed through their growth spurt, where their total increase in height over the two-years was only 3.97cm (EG) and 3.05cm (CG). During this period an increase in maximal strength (squat test) of 0.2 is found in the ED of the EG which showed medium practical significance compared to a decrease of -0.09 that was found in the ED of the CG. The same trend was also found in the power results of the early developers in the EG, where their vertical jump height improved with 3.5cm compared to a decrease of -1.0cm in the CG. It can thus be concluded that the training programme had an improving effect on power and strength of ED boys.

During puberty, an increase in testosterone production of up to 20-fold, is reported for boys which results in a marked increase of muscle mass (5). In the development of strength the male sexual hormone is of significance because of its anabolic (protein incorporating) component (17). This effect facilitates the synthesis of muscle protein. Consequently early maturing boys are stronger than those who are slower to mature. However, according to Naughton *et al.* (29) this difference in strength is levelled out at the end of puberty. Again these findings are confirmed by our results, especially if we consider the results that were found in the CG who served as a reference group for growth without the effect of additional training during this period of two-years. At T1 the ED of the CG were already stronger than the TD and even more so when compared to the LD at the end of the study at T4 when the height of these three groups has evened out and the strength of the TD and LD caught up with that of the ED. From the results of the EG we can conclude that the training programme had a significant effect on all three development groups as all the groups showed a significant increase in strength from T1 to T4.

Power is the result of applying force (strength) quickly (42). Muscle mass seems to have a great influence on the power of adolescents as reported by Kriemler *et al.* (20) who found that the significant difference ($p < 0.05$) that they found between the vertical and the reaching height was dependent on the adolescents' muscle mass. A significantly positive correlation ($R^2 = 0.78 - 0.86$, $p < 0.01$) between muscle volume and muscle power is also reported by O'Brien *et al.* (30) in children and young adults. Higher power could therefore be attributed to the fact that a larger

lean body mass and muscle mass produces greater anaerobic power (27). This finding is confirmed by the results of our study where the TD of CG showed no increase in fat percentage (-1.81%) over the two-years, as well as the best improvement in vertical jump height (7.06cm) over the two-years. Compared to this the ED of CG showed an increase in fat percentage (+3.93%), with the smallest improvement in vertical jump height (-1.0cm) as well as in horizontal jump distance (0.11cm).

Intervention effects of the strength programme were found although small in magnitude. The intervention programme had limitations which might have influenced these effects that should be acknowledged. As partaking in this conditioning programme was part of the school roster, the only time that was left for this additional strength training was two times per week after school, of which one session was used to improve speed and agility. The researcher was therefore left with only one session per week for strength training, while it is reported that at least three days of strength training are needed to improve strength optimally at this age. If this principle regarding the frequency and intensity of strength training could have been applied, it might have provided a different outcome on strength training during adolescence. The fact that the EG was also only subjected to an intervention programme for six-months at the beginning of the year during (Feb-Aug) the specific sporting season with six-months of rest that follows, might also have had a reductive effect on the improvement of strength and power that was generated by the programme during that period. The content of the intervention program can also be described as general, rather than sport specific, as it had to accommodate the fitness needs of the different school sports codes (athletics, cricket, field hockey, rugby) that it had to address. In this regard, athletes and cricketers need power, while rugby players need maximal strength. The limited time of the programme had to address these different needs which might have influenced the specificity of development of both strength and power. Although adherence to the programme was good, regular partaking in the programme needs to be fit in by the boys between all the other activities that they also have to participate in. In addition it should also be remembered that boys of this age are still quite active although they do not necessarily participate in school sports and this habitual physical activity could also have contributed to the improvement that was seen in the CG.

Although the study was done over a longitudinal period of two-years, which is a strength of the study, the study design still had limitations, especially regarding the small groups that were compared with each other. In addition, the researchers were not able to monitor the complete developmental time period of pubertal changes in the study due to practical reasons such as the age when children move from primary school to high school where this study was conducted. More research, based on bigger groups, is therefore needed to confirm these findings, as well

as longitudinal studies that span the full pubertal period, which includes the ages between 11 and 16 years.

4.6 PRACTICAL APPLICATIONS

From the results we can conclude that the participants in the EG obtained a positive effect of the programme, although to a limited extent on strength development. Although the strength training during the mid-adolescence period had a rather small effect on the improvement of strength and power in the boys before they reach PHV and peak gains is seen in fat free muscle mass, as it was in the case of the TD, it did show a positive effect on their neural adaptation to strength training. This might contribute to improved sport performance and functional strength, as well as with the prevention of injuries like back and neck injuries from scrumming in rugby or bicep impingement from repetitive bowling in cricket and hamstring ruptures from sprinting (athletics). This conditioning effect of the programme was clear, as limited injuries were reported in the group that participated in the programme during the pubertal growth period that is known for a number of growth related injuries to occur especially in contact sport (28).

When the training guidelines as set in the LTAD model are taken into consideration it can be concluded that this programme was well designed for the majority of the group which included typical, early and late developers. Balyi *et al.* (4) states in this regard that although sports participants may exhibit special talent during the Train-to-Train stage which falls in the mid-adolescence period, they still need to allocate more time to training skills and improve physical capacities such as strength, power, speed and agility rather than competing in formal settings during this period. Lastly, research also confirmed an interaction between growth, maturation and training. Accordingly late developers benefit most from training associated with neural adaptation, whereas early developers benefit most from training that may be associated with both neural and morphological adaptations. It will therefore be better to train and develop all motor fitness skills of boys in their mid-adolescence rather than training sport specific motor fitness capabilities, e.g. only maximal strength for a rugby player. Training of only sport specific motor fitness capabilities might also lead to overuse injuries and muscle imbalances that can once again cause posture related injuries during this vulnerable growth period.

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Discloser of professional relationship. The researcher does have a private practice on the school grounds and does render rehabilitation and sport conditioning services to the school. Although the coaches might benefit from results of this study in regards to better understanding of the development of mid-adolescent boys, the results or study itself have no promotional value for the school.

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CHAPTER 5**SUMMARY, CONCLUSION, SHORTCOMINGS AND
RECOMMENDATIONS**

- 5.1 SUMMARY
 - 5.2 CONCLUSIONS
 - 5.3 RECOMMENDATIONS
 - 5.4 SHORTCOMINGS AND FUTURE RESEARCH RECOMMENDATIONS
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5.1 SUMMARY

This study investigated the effect of the growth spurt, a period that is characterised by acceleration in growth on the training of strength, power, speed and agility in boys during mid-adolescence. Firstly it was intended to determine whether the growth spurt will have an effect on the development of speed and agility in mid-adolescent boys who were subjected to a training programme in comparison with a control group who did not participate in sports or the training programme. Secondly the study wanted to determine the effect of the growth spurt on the development of strength and power during mid-adolescence. Chapter 1 contains a full discussion of the problem statement, objectives and hypotheses.

Chapter 2 provides a literature review regarding studies that have been done on the influences of the growth spurt during mid-adolescence in boys that includes the development of anthropometrical characteristics (height, body mass, fat percentage) and motor- and fitness capabilities during this period and the relationship among these variables. It also reviewed the findings of studies regarding the training of speed, agility, strength and power during the mid-adolescence period.

This literature review revealed that approximately the first two decades of human life are dominated by growth, maturation and development in all aspects of life. These include physical, emotional and cognitive development. Stature undergoes several periods of accelerated growth, with the biggest changes during adolescence. The literature review also revealed that the largest increase in length occurs between the ages of 13–15 years, with peak height velocity of up to 12cm per year around the age of 14 years in boys. Body mass has a similar growth curve to that of length with an increase of up to 9.5kg per year between the ages of 13- to 15-years and reach peak mass velocity at age 14 years. Sitting height shows a linear development with acceleration in growth around the age of 13.5 years. Between the ages of 12- to 15-years, sitting height is reported to be about 50% of the total height.

Literature findings regarding the development of motor- and fitness capabilities that includes speed, agility, strength and power was also investigated. The literature findings reveal that speed develops systematically during the 12 months before PHV and reaches a peak that coincides with the peak of PHV, after which speed reaches a plateau about 12-18 months after PHV. Improvements in speed are reported to correlate with changes in stature and sitting height and body mass. Agility shows a similar developmental curve as speed. Agility starts to develop 12 months before peak height growth and reaches its peak at the start of peak height growth, after which a plateau is reached. It is reported that agility can increase with up to 20% during puberty and that it is affected by body composition (lower body fat vs. higher muscle mass) as well as by stature, relative limb length, and height of the centre of gravity. This literature review reveals that strength increases in a linear pattern in boys from early childhood until the onset of puberty (13-14 years). A strength acceleration phase is reported during puberty, of about two-years, after which strength continues to increase linearly into late adolescence. One of the main factors responsible for the increase in strength with the onset of puberty is testosterone. Strength of the upper and lower extremities furthermore does not show the same developmental trends where the strength in the lower extremities shows accelerated increases about one year before the upper-body. It is reported that strength of the legs increases about two-years before PHV and in the upper-body only one year before PHV. Power shows a similar estimated velocity curve to that of height with a velocity increase of 1.5cm/year, 12 months before peak height velocity and reaching a peak coincident with peak height velocity in boys between the ages of 12–14 years. Most of the research on the training of motor- and fitness capabilities is done on different types of strength training of adolescents and the effect it has on the improvement of the other capabilities. Research further more showed that there are a few windows of optimal trainability during adolescence for motor fitness capabilities.

Trainability refers to the individual's responsiveness to a training stimulus at various stages of growth and maturation. By monitoring growth one can identify the sensitive periods of accelerated adaptation to training of motor fitness capabilities in boys aged 12–15 years. Taking into consideration that boys during mid-adolescence have increased testosterone levels, increased body weight and muscle mass as well as increasing limb length, it is argued by researchers that the period after PHV is the perfect time to train and improve strength and power in boys. Due to the disproportion of body segments and the increase in complexity of neural networks during adolescence, especially during the years pre-PHV when boys lack the necessary motor coordination and strength to effectively orientate, stabilize, and apply force through their lower limbs to produce optimal speed. The years after PHV are identified as the sensitive period for training speed and agility.

Chapter 3 is presented in the form of an article and will be submitted to the *American Journal of Human Biology*. This article determined whether a speed and agility training programme can counter the possible negative effects of growth on boys aged 13- to 15-years. A convenience sampling method was used and 86 boys between the ages of 13.6 years (age at baseline during the first measurements) and 15.2 years (age at last measurements) were recruited to participate in the study. They were divided into an experimental group (n=47) who participated in structured school sports. A reference group (n=39) consisted of similar aged boys, selected based on the criteria that they did not participate in any structured sport or training programmes in order to be able to compare the EG with a unmitigated growth group. Both groups were subjected to standard anthropometric protocols measuring height, sitting height, weight and skinfolds to determine fat percentage and a combination of motor fitness protocols for speed (10 m and 40 m speed) and agility (agility T-test, and shuttle runs). Four measurements, one every six months from February 2015 to August 2016 were taken over a two-year period. During this period the EG was subjected to a training programme to improve strength, power speed and agility for the first six-months of every year two times per week for 45 minutes. Data were analysed for descriptive purposes using means (M), standard deviations (SD), minimum and maximum values and lower and upper quartiles (Statsoft, 2015). Spearman correlation analysis was done to determine changes in anthropometric and physical and motor fitness measurements. A hierarchical linear model was used with subject number as the primary unit of measurement, and AR(1) covariates structure to analyse the differences between the three measuring points over a period of two-years within each group for all the speed and agility variables. Practical significance of differences between means was determined according to Cohen's d-value 0.25 (small), 0.55 (medium), and 0.85 (large) (Cohen, 1992). It gives the results that were found regarding developmental changes of anthropometric measurements (stature, body mass, fat percentage, sitting height, sitting height ratio) and motor fitness capabilities (speed, agility) of mid-adolescent boys during this period. Results of the correlation analysis between body composition changes and changes in speed and agility showed small but significant relationships mostly between T2-T3 which was between the ages of 13.68–14.18 years. Increasing height during the same period had a significant relationship with speed and agility performance. For the hierarchical linear analysis each group (EG & CG), was sub-divided into three subgroups based on their age at PHV, classified as early (ED) (EG, n=8; CG, n=2), late (LD) (EG, n=7; CG, n=4) and typical (TD) developers (EG, n=32; CG, n=33). The TD of both groups showed the biggest increase in speed during the first six-months (T1-T2) followed by an increase in agility during the second six-months. During T1-T2, the time during which the biggest increase in leg length and a subsequent loss of motor coordination had been expected in a number of participants (TD and LD), the agility of the EG showed a bigger increase than the CG. The ED of CG only started to show a significant increase at T3-T4, the time during which all

growth-related imbalances were sorted out based on their growth history in the study. Both groups showed improvement in speed and agility over the two-year period of growth. Over the time period of two-years the results of the CG showed a statistically significant higher improvement in both speed and agility for the full period compared to the EG who were subjected to an intervention programme but the results showed that the EG had better values in the beginning of the study implicating more skill and conditioning at the start of the study which is most probably the result of competing in sport from an early age. The strength and agility programme that they participated in contributed to maintaining of these higher scores from the beginning in the EG group throughout the two-years compared to the control group (CG) who did not participate in sport or the intervention programme. The improvements that were found in the CG are therefore considered to be the result of natural development of speed and agility as also confirmed by other research studies. Unstructured play and other habitual physical activities of the CG were however, out of the control of the researchers and could also have contributed to the improvement in this group as boys of this age are still considered to be quite active in their daily lives. It is concluded that the strength, speed and agility training had a conditioning effect on the boys in the EG which is a favourable finding in the sense that it can contribute to prevention of especially overuse injuries like ankle sprains, muscle strains, shin splints and stress fractures and other growth-related injuries and pains like mechanical lower back pain and chondromalacia patella and cruciate ligament ruptures during their sports participation. These injuries are usually high in the growth spurt phase and are mainly caused by a lack of agility and poor muscle recruitment. Very few of these injuries were reported in the EG who only reported two ankle and one hamstring strain among the 47 boys over the two-year period.

Chapter 4, presented in the form of an article and submitted to the *Journal of Strength and Conditioning Research*, aimed to determine whether a strength and power training programme will counter the possible negative effects of the growth spurt on these fitness capabilities during mid-adolescence in boys. A convenience sampling method was used and eighty six boys between the ages of 13.6-15.2 years were divided into an experimental group (n=47), subjected to a training programme for the first six-months of every year, and a reference group (n=39), of similar aged boys who did not participate in any structured sport. Both groups were sub-divided further into sub-groups based on their age at PHV, classified as ED, LD, TD. Both groups were subjected to standard anthropometric protocols measuring height, sitting height, weight and skinfolds to determine fat percentage and a combination of motor fitness protocols for strength (squat, sit-ups, seven-stage abdominal strength) and power (vertical jump, horizontal jump) over two-years, these include four measurements, one every six-months from February 2015 to August 2016. During this period the EG was subjected to a training programme two times per

week for 45 minutes to improve strength, power, speed and agility for the first six-months of every year. The results from the four measurements, regarding developmental changes of anthropometric measurements (Height, body mass, fat percentage, sitting height, sitting height ratio) and motor fitness capabilities (strength, power) of mid-adolescent boys during this period were analysed for descriptive purposes using means (M), standard deviations (SD), minimum and maximum values and lower and upper quartiles (Statsoft, 2015). Spearman correlations analysis was done to determine changes in anthropometric and in physical and motor fitness measurements. A hierarchical linear model was used with subject number as the primary unit of measurement, and an AR(1) covariates structure to analyse the differences between the three measuring points over a period of two-years within the group for all variables. Practical significance of differences between means was determined according to Cohen's d-value 0.25 (small), 0.55 (medium), and 0.85 (large) (Cohen, 1992).

Small but significant interrelationships were found between body composition characteristics and motor capabilities (strength, power) where changes in height, mass and fat percentage related significantly during different periods of the two-years with these characteristics. The ED of the EG of boys who had already passed through their growth spurt showed an increase in strength compared to a decrease that was found in the ED group of the control group (CG). The LD and TD of EG benefit from the neural adaptation caused by the extra training programme, while the ED, who had already passed through their growth spurt, benefited from muscle hypertrophy as a result of the extra strength training that the EG was subjected to. From this it can be concluded that a strength and power training programme will have a positive conditioning effect on neural adaptation in boys before they reach PHV and a positive improvement in strength and power after PHV due to an increase in lean muscle mass.

5.2 CONCLUSIONS

The results of the study as summarised were used to test the hypothesis of the study.

5.2.1 Hypothesis 1

Hypothesis 1 states that when boys aged 13- to 15-years participate in a speed and agility training programme, possible negative effects of growth on these fitness capabilities during mid-adolescence can be countered.

This hypothesis was tested in mid-adolescent boys, by comparing a group of boys who participated in a strength, power, speed and agility training programme to a CG who did not participate in such a training programme. In addition, each of these groups was also grouped in three different subgroups that represented different developing stages of growth, as the timing

of growth spurt has differential effects on children's development of speed and agility during different stages of development (early, late and typical developers), and these groups were also compared. This hypothesis is therefore also tested based on the results obtained for each of these developing groups as their growth spurts were at different time periods of the study. The effect of the training programme was mainly determined from the results that were obtained over the full period (T1-T4) of the study, for speed and agility, while taking into consideration the influences during the time of the growth spurt in each of these sub-groups.

Speed

The early developers (ED) who participated in the training programme and who were already beyond their growth spurt showed an overall practically significant improvement ($d > 0.25$) for speed of -0.06s (10m) and -0.26s (40m), compared to a decline in speed in the control group over this same period (T1-T4) of 0.11s (10m) and 0.4s (40m). Compared to the results obtained in the control group, the training programme also had a positive effect on the fat percentage of the EG, as their weight (body mass) gradually increased every six-months with a total increase of 7.73kg with only 0.18% increase in fat percentage. The CG showed big increases over the last two six-months (T2-T3 & T3-T4) with a total increase of 13.35kg (T1-T4) and a total increase of 3.93% in fat percentage. From these results it can be concluded that the training programme had a positive influence on the speed of the early developing boys who had already passed through their growth spurt and who were now in a phase where they would gain less from biological development of speed and more from training. The programme also contributed to a more appropriate weight gain and fat percentage compared to boys that did not participate in any training programme that is also conducive for speed performance.

The typical developing (TD) boys of both the EG and CG had their biggest growth spurt in height (EG = 4.40cm; CG = 5.16cm) during the second six-months (T2-T3), age 14.17 – 14.68 years. During this time a small significant ($d > 0.25$) decline in 10m speed development was seen in both groups. During this period (T2-T3) growth in height was 4.40cm for EG and 5.16cm for CG and increase in weight (body mass) of 5.49kg for EG and 3.83kg for CG is seen during the same period. This decline in speed can thus be the result of odd body proportions caused by differential rates of growth in different body segments. Although similar trends of an improvement before PHV (T1-T2) and a deterioration at PHV (T2-T3) is seen in both EG and CG, the improvement during the first six-months during which the EG was subjected to the additional strength and agility programme was statistical significantly bigger than that was seen in the CG while the deterioration during the second six-months was less in the EG compared to the CG. A conditioning effect rather than a training effect can therefore be seen in the EG during

the period of accelerated growth (T2-T3), leading to the conclusion that the negative effect of the growth spurt can be countered to a degree by a speed training programmes in TD boys.

As for the late developers, where the effects of the growth spurt hasn't realised yet and the increases in height was less than 3.0cm during any given six-months periods, speed (10m) showed improvement during T1-T2 in both EG and CG and in their total improvement, which had medium statistical significance for both groups. A positive training effect was therefore found in the Late developers of the EG, where speed continues to improve while a drop in speed was found in the CG after T2-T3.

These results confirm that the hypothesis as stated above, can be accepted for speed.

Agility

When analysing the results of the ED groups, who had passed through their PHV, and who had already experienced the benefit of early maturing on agility, a training effect of the programme was found. The EG showed an overall improvement of -0.6s (T-test) and a small deterioration - 3.25m (Shuttle runs), compared to a deterioration of 0.15s (T-test) and -120.5m (Shuttle runs) of the CG over the same period (T1-T4). The biggest improvement for both groups was during T3-T4. This may be due to the fact that speed (evident from the results in this study) and strength, which are the building blocks of agility, had already increased in these groups, since their segmental growth had even out and their secretion of testosterone has started.

The agility of the TD boys of EG and CG showed consistent increase every six-months with the biggest increase showing moderate significance, during the second six-months (T2-T3; when they were aged between 14.17-14.68) which is the same time of maximal growth in this group. The increase in agility for the boys in the EG was however better than that of the CG during both the first and the second six-months which can be the result of the extra strength and agility training that the EG received.

The agility of the LD group showed the same development trends as for speed, with little differences in the development or improvement of the two-groups over the two-years. However, the EG had better scores during each testing opportunity which can be attributed to the training programme that they participated in.

These results confirm that the hypothesis as stated above needs to be partially rejected for agility.

The overall results indicated that although the growth spurt had an influence on the speed of TD it doesn't seem to affect their agility. The speed and agility of the TD in the EG showed a better

development during the same time of the intervention (T1-T2), the overall speed and agility improvement of the ED in the EG compared to the deterioration of the CG and the small difference between the results of the EG and CG of the LD shows that the growth spurt does have an influence on the development of speed and agility in boys during adolescence but this negative effect can be countered by a well-designed training programme.

Based on these overall results for speed and agility, hypothesis 1 is only partially accepted for speed and agility.

5.2.2 Hypothesis 2

Hypothesis 2 states that a strength and power training programme will counter the possible negative effects of growth on these fitness capabilities during mid-adolescence in boys.

This hypothesis was tested in mid-adolescent boys, by comparing a group of boys who participated in a sport conditioning programme to a reference group who did not participate in such a training programme. In addition, each of these groups was also grouped in three different sub-groups that represented different developing stages of development, as the timing of growth spurt has differential effects on children's development of strength and power during different stages of development (early, late and typical developers), and these groups were also compared. This hypothesis is therefore also tested based on the results obtained for each of these developing groups as their growth spurts were at different time periods of the study. The countering effect of the training programme will mainly be determined from the results that were obtained over the full period (T1-T4), for strength and power, while taking into consideration the influences during the time of the growth spurt in each of these sub-groups.

Strength

The biggest statistically significant change was found in the ED of EG over the full period (T1-T4) of the study. The squat test, maximal strength, of the EG improved by 0.16, a medium significance and the CG deteriorate with -0.09 over the two-years (T1-T4). Although both the EG and the CG showed a large statistically significant increase in the seven-stage abdominal strength test the improvement of the EG was bigger. Sit-ups (strength endurance test) of the EG improved with 12.12 sit-ups during the full period (T1-T4), compared to the mean improvement of four sit-ups as found in the CG during the same time. This increase in strength can be attributed to morphological (height and weight increases) and hormonal changes (increase in testosterone secretion) that took place during an earlier chronological age of this group and which contributed to the bigger improvement of the motor fitness abilities (strength) of the EG

that was subjected to a training programme. The results of the ED showed that the training programme had a significant improvement on the development of power and strength of the EG.

As for the TD it was found that their biggest growth spurt was between T2 – T3 (age 14.17-14.68 years). During this time period a big increase in weight and a decrease in fat percentage were found in the TD boys of both EG and CG. It was also during this period (T2-T3) that the biggest improvement in all three strength tests was seen in the TD of both groups. However, the effect of the training programme is seen in the fact that the increases in the squat and seven-stage abdominal strength (maximal strength) were better in the EG than the CG. This can be due to the neural adaptation that took place during the intervention that took place during the first six-months.

In the late developing group, where the effects of the growth spurt had not made an impact yet, a statistically significant better improvement in strength was found in the CG over the full period (T1-T4). However, the EG showed better results with each test opportunity compared to the CG, leading to the conclusion that the training programme had a conditioning effect on the motor fitness capabilities (strength) of the EG from which they will capitalize once morphological (height and weight increases) and hormonal changes (increase in testosterone secretion) started to take place.

These results indicate that hypothesis 2 regarding strength can only be partly accepted as growth had a positive effect on the development of strength in ED and TD of both groups and the training effect of the programme was only evident in the ED of the EG who had already passed through their PHV.

Power

The early developers in the EG who participated in the training programme and who were already beyond their growth spurt, showed an overall practically significant improvement of 3.5cm in vertical jumping, compared to the deterioration of -1.0cm that was found in the CG. The training programme also had a positive effect on the lean muscle mass of the EG during this time, as their weight increased by 7.73kg with only a small increase of 0.18% in fat percentage. The CG showed big increases of 13.35kg in weight and 3.93% in fat percentage over the same period.

During the same time (T2-T3) in which the typical developers experienced their biggest growth spurt, the biggest increase in vertical jump performance was found in the EG group, an increase of 6.02cm (EG) compared to 3.95cm for the CG. This can be due to the increase of lean muscle

mass in conjunction with the improvement of strength during the same time period (T2-T3) for the EG which is a direct effect of the training programme of the first six-months.

As for the late developers no development trends were evident for power but from the study results it's evident that strength and power training have a positive effect on the power of boys, as the EG scored higher at each test opportunity.

These results indicate that hypothesis 2 regarding power can only be partly accepted as growth had a positive effect on the development of power in ED and TD of both groups and the training effect of the programme is only evident in the ED of the EG who has already passed through their PHV.

Based on these results, Hypothesis 2 can only be partially accepted as results indicated that the growth spurt had a positive effect on the training of strength and power of TD and ED, with little or no effect on LD who hadn't reached their PHV yet.

5.3 RECOMMENDATIONS

It is concluded from the findings of this study that the growth spurt during the mid-adolescent period of boys has an influence on the development of motor fitness capabilities such as speed, agility, strength and power. This influence can be both positive and negative, positive in the sense that biological maturity during this period will contribute to improved speed and agility, strength and power, while in a negative sense, a heightened incidence of stress-related injuries can be found during this unstable period of accelerated growth.

The findings of the study revealed positive effects of the training programme, although modest in effect, and also differential in effect among boys who were in different growth stages for speed, agility, strength and power capabilities during this period of accelerated growth and development. It was, however, also found that the improvement of the specific motor fitness capabilities was not the only effect, but a general conditioning effect was also established in the intervention group. Both these effects can contribute to improved sports skill performance and prevention of overuse injuries at this vulnerable maturational age.

The results of this study can be helpful in providing guidelines for training but also for long-term planning of training of adolescent boys especially during the mid-adolescent period and the period following that. The following important guidelines can be given.

- Coaches should firstly be knowledgeable regarding the developmental stage of a boy as it is important to use this knowledge to plan the most optimal training or conditioning programme

around his growth strengths and limitations. Our results confirmed an interaction between growth, maturation and training. It is concluded from the results that late developers will benefit most during this period of training associated with neural adaptation, whereas early developers will benefit most from training that may be associated with both neural and morphological adaptations.

- It should be emphasized that programming for adolescent boys should always take an individualized approach and the needs of each athlete should be taken into consideration along with his stage of development (late, typical or early developer) to maximize the likelihood of continued progress through a long-term programme.
- It is thus recommended that school sport coaches and teachers of boys should receive training on how to determine growth stages among them and how to plan training programmes accordingly.
- Long-term planning for training of the mid-adolescent boys should include sprint-specific training as well as strength and plyometric training to develop a range of interrelated physical abilities that will contribute to the holistic development and conditioning of the young athlete for later stages. It is recommended that mid-adolescent boys can be exposed to similar generic training programmes as those developed for this study to assist them in providing the generic engine of all motor fitness capabilities rather participating in a sport-specific fitness programme. Participating in a more general conditioning programme at this age will help with the prevention of growth-related injuries as well as overuse injuries that can be caused by repeated stresses from a specific sport and it is secondly better to develop a diversity of motor fitness capabilities before the age of sixteen when growth differences between early, late and typical developers are equalled out and a better idea of sports specialization per individual can be formed.
- It would, however, be more beneficial for adolescent boys to train these motor and physical fitness capabilities (strength, power, speed, agility) more frequently than has been the case in this study. It would therefore be recommended that the frequency of this generic programme be increased to four sessions per week instead of two. Increased frequency can increase the training effect of the programme, not only in the development of the specific motor fitness capability but also the improvement of neural adaptation and muscle memory of boys during this period.
- All of the above should be viewed as evolving guidelines as more research in this field is still needed. The coach can however, use these guidelines and knowledge of sensitive periods

for accelerated adaptation to training of motor fitness capabilities and age at PHV, to assist them in producing a long-term plan for developing strength, power, speed and agility and to inform the type of exercises that are most appropriately aligned to different stages of growth and maturation.

5.4 SHORTCOMINGS AND FUTURE RESEARCH RECOMMENDATIONS

During the planning and execution of this study, all possible planning and precautions have been made to complete the study in a valid and reliable manner but shortcomings were identified that need to be outlined. In order to make the results more generalizable and increase the outcome of future similar studies, the following shortcomings are highlighted with possible recommendations in this regard.

5.4.1 This was a cross-sectional study that involved participants from only one high school in South Africa, which limits the generalizability of the findings. The positive results of the study, but also the limitations that were identified, urge more research on this topic. Similar research studies are thus recommended but should be designed and conducted on boys representing the diversity of the South African population and all provinces across South Africa.

5.4.2 The study was based on a sample of availability that included mainly white learners which limits the generalization of the results to other racial groups who are also part of the South African society. It is recommended that the selection of subjects for future studies be of such a nature as to result in greater generalization and representation of the racial diversity of the South African population.

5.4.3 Environmental conditions were not always identical throughout the course of the study and could possibly have affected the outcome of the results. It is recommended that tests be conducted as far as possible within a controlled environment by the same administrators and in similar circumstances for every test opportunity.

5.4.4 The intervention programme stretched over a six-month period with a school holiday of 14 days in between at three months. During this holiday period the researcher had no control over the boys motivation to continue with the programme on their own, and consequently also the frequency and intensity of performing the exercises, or whether they did it at all. This may have affected the effects of the training programme. It is recommended that the effects of similar intervention programmes should rather be tested over shorter periods of six weeks.

- 5.4.5 Due to a busy school activity schedule it could have happened that participants in the EG group skipped two consecutive training sessions which might have influenced the improvement of certain motor fitness capabilities. The importance of keeping record of attendance by the researcher to determine the influence of attrition is highlighted, but also the importance of attendance of every session should be communicated with participants and they should also be encouraged to give their best during each session.
- 5.4.6 The group sizes of LD and ED were small and this made the analysing of their results difficult. It is recommended that future studies make use of a bigger sample in order to include more participants that represent all developmental stages.
- 5.4.7 As for the CG it should be noted that the study had no control over their habitual or unstructured physical activities like for instance bike riding, swimming or walking to school and informal play activities that boys of this age usually engage in. It is recommended that information of this nature should be made available to researchers of similar studies in order to be able to control for these effects.
- 5.4.8 It might be that another reference group could have added value to the comparisons and could have contributed to cleaner results. It is recommended in this regard that the research design of this study can be improved, by adding another reference group where one group represents participants who participate in no sports, one group who participate in sports and a third group who participates in sports and are subjected to a training programme.

This chapter then concludes the study by linking the specific research objectives to what has been achieved.

APPENDIX A: AUTHOR GUIDELINES: AMERICAN JOURNAL OF HUMAN BIOLOGY

ONLINE SUBMISSION

Manuscripts

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Colour figures: The journal accepts colour figures for publication that will enhance an article. Authors who submit colour figures will receive an estimate of the cost for colour reproduction in print. If they decide not to pay for colour reproduction in print, they can request that the figures be converted to black and white at no charge. All colour figures can appear in colour in the online version of the journal at no charge (Note: this includes the online version on the journal website and Ovid, but not the iPad edition currently)

8. Tables

Tables must be double-spaced on separate sheets and include a brief title. Provide generous spacing within tables and use as few line rules as possible. When tables are necessary, the information should not duplicate data in the text. All figures and tables must include standard deviations or standard errors.

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The units of measurement shall be Systeme International d'Unite's (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the British Medical Journal (1:1334 – 1336, 1978) and the Annals of Internal Medicine (106: 114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., mL_min-1_kg-1.

The basic and derived units most commonly used in reporting research in this Journal include the following: mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (°C); energy, heat, work—joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N_m); frequency— hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol).

Selected conversion factors:

- _ 1 N = 0.102 kg (force);
- _ 1 J = 1 N_m = 0.000239 kcal = 0.102 kg_m;
- _ 1 kJ = 1000 N_m = 0.239 kcal = 102 kg_m;
- _ 1 W = 1 J_s-1 = 6.118 kg_m_min-1.

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APPENDIX C: INFORMED CONSENT

**PARTICIPANT INFORMATION LEAFLET AND PARENT
CONSENT FORM FOR BOYS AGED 13 TO 15 ATTENDING
HOËRSKOOL NELSPRUIT.....**

TITLE OF THE RESEARCH PROJECT: The effect of the growth spurt on Strength, Power, Speed and Agility training in Boys during mid-adolescence

REFERENCE NUMBERS: (NWU-00330-15-A1 J Badenhorst)

PRINCIPAL INVESTIGATOR: Joanita Badenhorst

ADDRESS: Hoërskool Nelspruit, 1 Cameron Street Nelspruit

CONTACT NUMBER: 084 625 1506

Your son is invited to take part in a research project that forms part of my Master's degree study in Biokinetics at the North-West University. In order to use the data collected during the named research project, I need the permission of the parents or legal guardian for your child's participation. Please take some time to read the information presented, which will explain the details of this project. Feel free to ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied and that you clearly understand what this research entails and how you can be involved. Also, participation is **entirely voluntary** and you are free to decline participation. If you say no, this will not affect your son negatively in any way whatsoever. You are also free to withdraw your son from the study at any point, even if you have agreed to participate.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00330-15-A1)** and will be conducted according to the ethical guidelines and principles of the international Declaration of Helsinki and the ethical guidelines of the National Health Research Ethics Council. It might be necessary for the research ethics committee members or relevant authorities to inspect the research records.

➤ **What is this research study about?**

- *This study will be conducted at Hoërskool Nelspruit and will involve anthropometric measurements and fitness evaluations with experienced health researchers trained in Biokinetics. Although all the Grade 8 and 9 boys will do*

the evaluations as part of the Life Orientation syllabus, the data of only 70 participants and their parents who give consent will be included in this study.

- *The objective of this research is: to determine the role of the growth spurt in speed, agility, strength and power training of 13 to 15 year old mid-adolescent boys in Nelspruit.*

Why has your son been invited to participate?

- *Your child has been invited to participate because he is a boy between 13 to 15 years of age. During this age the growth spurt has a significant influence on the physical fitness and motor performance of boys*
- *He has also complied with the following inclusion criteria: He is a grade 8 learner of Hoërskool Nelspruit. He is healthy with no physical disabilities or health risks that prevent him from taking part in physical activities or school sport.*
- *Boys will be divided in to two-groups, boys who take part in one or more school sports like athletics, rugby, cricket and a control group of boys who do not take part in any sports out of free will.*

He will be excluded:

- *If he has a serious health issue, injury or other disability that prevents him from taking part in physical activities or sport.*
- *If he competes or trains in sport that is not part of the school sport system e.g. martial arts, horse riding, mountain biking or gymnastics.*
- *If he has been ill or injured for longer than three weeks.*
- *If he does not comply with the training schedule or moves to another town or school.*

➤ **What will the participant's responsibilities be?**

- *He will be expected to do at least two of the three scheduled evaluations throughout the year. These evaluations will be scheduled in accordance with the school programme in order to fit the time schedule of all participants. These evaluations will take place in groups. The study will span over two-years.*

➤ **What are the benefits of taking part in this research?**

- *The **direct benefits** for a participant will be:*
 1. *His current fitness level will be determined.*
 2. *He will be able to compare his scores to the average of the group.*
 3. *He will be able to monitor his progress from one evaluation to the next and from one year to the next.*
 4. *Boys will have access to a qualified Biokineticist to help them improve their physical state.*
- *The **indirect benefits** will be*
 1. *Biokineticists, Sport Scientists and coaches will have a better understanding of how changes in body composition and stature due to the growth spurt will affect speed, agility, strength and power training of the mid-adolescent boy.*

2. It will subsequently also help these experts to plan and develop proper training programmes for the preparation of adolescent boys for sport participation at higher levels.
3. Adolescents will also benefit from this knowledge as well-structured conditioning programmes can be compiled by experts to improve their speed, agility, strength, and power in preparation for sport performance later in their lives. Their results will be made available to them so that they can use it in their own preparation for sport.

➤ **Are there risks involved in taking part in this research?**

- The risks of this study are low. Due to the physical nature of the study there is a risk of injury, but this will be managed at all times by the Biokineticist who conducts the session. Injuries of a more serious nature will be treated by the residing sports doctor. A feeling of incompetence may develop if a boy is unable to do certain tasks or perform worse than the group, the Biokineticist will encourage these boys to stay in the training programme to improve their scores with the next evaluation and not to compete with the group but with themselves. In severe cases they will be referred to the schools psychologist. Some boys may be shy to take off their shirt in front of other people, a very private area will be made available for the measurements where only the two researcher and the participant will be allowed to protect both the participants and researcher. Boys will have to remove their shoes and socks but will be allowed to keep on their trousers. They can also keep on their shirts, but it will have to be lift up slightly to measure the supraspinatus-, iliac- an umbilicus skinfolds for fat percentage. Participants will be assured of their privacy during these measurements. Exhaustion will be managed by means of regular rest and water breaks. The evaluations will be rescheduled, in the case of bad weather on the day of evaluation.
- The **benefits of this study outweigh the risks**, which are considered minimal as the researchers attempted to put methods and procedures in place to counter any foreseeable risk.

➤ **What will happen in the unlikely event of some form of discomfort occurring as a direct result of taking part in this research study?**

- Should the participant have the need for further discussions of any aspect of participation or any part of the process that made him uncomfortable an opportunity will be arranged for him to speak to the researcher, or the schools psychologist in severe cases

➤ **Who will have access to the data?**

- Anonymity will be given by replacing names of the participants with numbers. Confidentiality will be ensured by recording each participant's results on a separate data card. Reporting of findings will be anonymous by reporting results as averages and percentages of the group and not as raw individual data. Only the researchers will have access to the data. Data will be kept safe and secure by locking away hard copies and electronic data will be password protected. As

soon as raw data has been transcribed it will be deleted from the records. Data will be stored for seven years.

What will happen with the data/samples?

- *This is a once off collection and data will be analysed in South Africa*

Will you be paid to take part in this study and are there any costs involved?

You will not be paid or receive any form of compensation or reimbursement for participation in the study.

There will be no costs involved for the participants to do the evaluation or to receive feedback and reports.

Additional information

- You can contact Joanita Badenhorst at 0846251506 if you have any further queries or encounter any problems.
- You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.
- You will receive a copy of this information and consent form for your own records.

How will you know about the findings?

- The findings of the research will be shared with you by means of a personal report that you will receive annually after the evaluations in August / September of each year. Findings will be shared with the coaches and school governing body as guidelines and not as raw data.
- Participants are welcome to contact the researcher to discuss their report and the findings.
- Parents are welcome to make an appointment with the researcher to discuss their child's progress or any questions they may have regarding the report or findings of the research project.

Declaration by participant

By signing below, I agree that my son may take part in the research study titled: **The role of the growth spurt on strength, power, speed and agility training of mid-adolescent boys**. I also give consent that the researcher may use the data collected in her study and share the findings with other researchers in a published article

I declare that:

- I have read this information and consent form and it is written in a language in which I am fluent and comfortable.
- I have had a chance to ask questions to both the person obtaining consent, as well as the researcher, and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressured to participate.
- My son may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- My son may be asked to leave the study before it has been completed if the researcher feels it is in the participant's best interests, or if the participant does not follow the agreed upon study plan.

Signed at (*place*) on (*date*) 20....

.....
Signature of parent/guardian

.....
Signature of witness

Declaration by person obtaining consent

I (*name*) declare that:

- I have explained the information in this document to
.....
- I have encouraged him/her to ask questions and took adequate time to
answer them.
- I am satisfied that he/she adequately understands all aspects of the research,
as discussed above.
- I did/did not use an interpreter.

Signed at (*place*) on (*date*) 20....

.....
Signature of person obtaining consent

.....
Signature of witness

Declaration by researcher

I Joanita Badenhorst declare that:

- I have explained the information in this document to
.....
- I have encouraged him/her to ask questions and took adequate time to
answer them.
- I am satisfied that he/she adequately understands all aspects of the research,
as discussed above
- I did/did not use an interpreter.

Signed at (*place*) on (*date*) 20....

.....
Joanita Badenhorst - researcher
(Biokineticist)

.....
Signature of witness



PARTICIPANT INFORMATION LEAFLET AND CHILD ASSENT FORM FOR BOYS AGED 13 TO 15 ATTENDING HOËRSKOOL NELSPRUIT

**TITLE OF THE RESEARCH PROJECT: The effect of the growth spurt on
Strength, Power, Speed and Agility training in Boys during mid-
adolescence**

REFERENCE NUMBERS: (NWU-00330-15-A1 J Badenhorst)

PRINCIPAL INVESTIGATOR: Joanita Badenhorst

ADDRESS: Hoërskool Nelspruit, 1 Cameron Street Nelspruit

CONTACT NUMBER: 084 625 1506

You are being invited to take part in a research project that forms part of my master's degree study in Biokinetics at the North West University. In order for me to make you part of my research project, I will need your assent. Please take some time to read the information presented here, which will explain the details of this project to you. Please ask the researcher any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and what the procedures are. Also, your participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00330-15-A1)** which made sure that the study **will be conducted according to guidelines which will respect you as a child. This ethics committee can also inspect the research records to make sure that we adhere to these principles**

➤ **What is this research study all about?**

- *We as researchers know little about the effect of natural growth during the adolescent years of boys on factors like speed, agility, strength and power and we would like to know this to improve your sport performance and help you to develop these factors at the right time without getting injured. In order to be able to do so we need measurements of boys between the ages of thirteen and*

fifteen. All the measurements will be done by experienced health researchers trained in Biokinetics.

- Once we have obtained the measurements we can use the results to see what we can do to improve adolescents' sports readiness and performance as we will have a better understanding of the effect of growth on motor-fitness and things that need to be changed. We can then make plans to help adolescents to develop the right factors at the right time for better sport performance, while we can also give coaches and teachers guidance on how to train adolescents to be better athletes. The following measurements will be taken to evaluate the effect of growth on motor-fitness that we are interested in: Growth measurements that will be taken in a private area that will include weight, height, six skinfolds, one on the back of the arm, one on the hip, one next to your bellybutton, one on the thigh and one on the lower leg. A Health Screening Questionnaire will be completed in the school's gymnasium. Physical fitness testing will start in the gymnasium with test like, push ups, sit-ups, pull ups, seven-stage abdominal strength, bench presses and squats. The rest of the test will be done on the sports field such as 10m and 40m sprinting and agility tests.
- This study will be conducted at Hoërskool Nelspruit and all the boys in Grade 8 and 9 will do these evaluations as part of the Life Orientation syllabus, but only the data of 70 participants who give parental permission and child assent and who meet the inclusion criteria will be included in this study.
- **Why have you been invited to participate?**
 - The growth spurt (a lot of growth in a short period of time which typically happens over a period of three years) has a significant influence on the physical fitness and motor performance of boys aged between 13 and 15 years. You fall in this age group.
 - Your parent gave parental permission for us to invite you to participate in the measurements today.
 - Participants will be divided into two-groups, one group will consist of boys who take part in one or more school sports like athletics, rugby or cricket and the second group will be boys who do not take part in any sports out of free will.
 - You have also complied with the following inclusion criteria: You live in Nelspruit or the surrounding area. You are healthy with no physical disabilities or health risks that prevent you from taking part in physical activities of sport.
 - You will be excluded if: you have a serious health risk, injury or other disabilities that prevent you from taking part in physical activities or sport.
If you compete or train in sport that is not part of the school for e.g. martial arts, horse riding, mountain biking or gymnastics.
If you become ill or injured for longer than three weeks.
If you don't comply with the training schedule. If you move to another town
- **What will your responsibilities be?**
 - You will be expected to do at least two of the three possible scheduled evaluations throughout the year. These evaluations will be scheduled in

accordance with the school programme in order to fit the time schedule of all participants. These evaluations will take place in groups. The study will span two-years.

➤ **Will you benefit from taking part in this research?**

- *The direct benefits for you as a participant will be*
 - 5. *Your current fitness level will be determined.*
 - 6. *You will be able to compare your scores to the average of the group*
 - 7. *You will be able to monitor your progress from one evaluation to the next and from one year to the next.*
 - 8. *You will have access to a qualified Biokineticist who will be able to assist you to improve your physical state.*
- *The indirect benefit will be*
 - 4. *Biokineticists, Sport scientist and coaches will have a better understanding of how changes in body composition and stature due to the growth spurt will affect speed, agility, strength and power training of the mid-adolescent boy.*
 - 5. *It will subsequently also help these experts to plan and compose proper programmes for the preparation of adolescent boys for sport participation on higher levels.*
 - 6. *Adolescents will also benefit from this knowledge as well-structured conditioning programmes can be compiled by experts to improve their speed, agility, strength, and power in preparation for sport performance later in their lives*

➤ **Are there risks involved in your taking part in this research?**

- *The risks in this study are low. Due to the physical nature of the study there is a risk of injury, but this will be managed at all times by the Biokineticist who is also trained to work with children and will be able to adapt to any of your needs on the testing day. Serious injuries like fractures or lacerations will be treated by the residing doctor. You may develop a feeling of incompetence if you are unable to do certain tasks or perform worse than your friends, the Biokineticists will be able to help you to focus on the improvement of your own results and not to compete with someone else, and you will also have access to the school's sports psychologist to help you with self-esteem. Shyness may be of concern, a very private area will be made available for the measurements where only the two researchers and the participant will be allowed to protect both the participants and researcher. You will have to remove your shoes and socks but will be allowed to keep on your trousers. You may also keep on your shirts, but it will have to be lifted up slightly to measure the skinfolds on your back, hip and at your belly button for fat percentage measuring. Participants will be assured of their privacy during these measurements. The rest of your evaluations you will do together with the rest of the group. Exhaustion will be managed by means of regular rest and water breaks. In the event of bad weather on the day of the evaluations, the evaluations will be rescheduled for the next suitable date.*
- *The benefits of this study are more and better than the risks of the study.*

- **What will happen in the unlikely event of some form of discomfort occurring as a direct result of your taking part in this research study?**
- *Should you have the need for further discussions of any aspect of participation or any part of the process that made you uncomfortable an opportunity will be arranged for you to speak to the researcher or the schools psychologist in serious cases*
- **Who will have access to the data?**
- *We assure you that only the researchers will have access to the information that will be obtained from you, and we assure you of the confidentiality of all the information that are obtained from you. Anonymity will be given by replacing your name with a number. Confidentiality will be ensured by recording your results on to your own data card. The school will receive guidelines based on the results, and you will receive a report on your performance and progress. The results will be published in the form of a postgraduate study and as an article that will be read by researchers. The hard copies of the data will be destroyed after seven years by means of a paper shredder.*

What will happen with the data/samples?

- *This is a once off collection and data will be analysed in South Africa*

Will you be paid to take part in this study and are there any costs involved?

You will not be paid or receive any form of compensation or reimbursement for participation in the study.

There will be no costs involved for you to do the evaluation or to receive feedback and reports.

Is there anything else that you should know or do?

- You can contact Joanita Badenhorst at 0846251506 if you have any further queries or encounter any problems.
- You can contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 2089; carolien.vanzyl@nwu.ac.za if you have any concerns or complaints that have not been adequately addressed by the researcher.
- You will receive a copy of this information and consent form for your own records.

How will you know about the findings?

- The findings of the research will be shared with you by means of a personal report. Findings will be shared with the coaches and the School Governing Body as guidelines and not as raw data.
- Participants are welcome to contact the researcher to discuss their report and the findings.

Declaration by participant

By signing below, I agree to take part in a research study titled: **The effect of the growth spurt on strength, power, speed and agility training in boys during mid-adolescence**. I also give consent that the researcher may use the data collected in her study and share the findings with other researchers in a published article

I declare that:

- I have read this information and consent form and it is written in a language in which I am fluent and comfortable.
- I have had a chance to ask questions to both the person obtaining consent, as well as the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the study before it has finished, if the researcher feels it is in my best interests, or if I do not follow the study plan, as agreed to.

Signed at (*place*) on (*date*) 20....

.....
Signature of participant

.....
Signature of witness

Declaration by person obtaining consent

I (*name*) declare that:

- I explained the information in this document to
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) on (*date*) 20....

.....
Signature of person obtaining consent

.....
Signature of witness

Declaration by researcher

I Joanita Badenhorst declare that:

- I explained the information in this document to
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I did/did not use an interpreter.

Signed at (*place*) on (*date*) 20....

.....
**Joanita Badenhorst - researcher
(Biokineticist)**

.....
Signature of witness

APPENDIX D: HEALTH SCREENING QUESTIONNAIRE***JOANITA BADENHORST***

Biokinetika

Tel : 084 625 1506
 Posbus 127
 Nelspruit
 1200

Hoërskool Nelspruit
 Cameron Str 1
 Nelspruit

Whether you yourself decided to do something about your level of fitness and health, or you being referred to me by a medical practitioner, it is my intention to make sure that I understand your specific exercise needs, assess your current level of fitness and design an exercise programme that will ensure that you get the maximum benefit from it.

PATIENT / CLIENT	
Surname	
First Name	
ID Number	
Sex	Male ☐ Female ☐
Tel no : Home Work Cell	(Child)(parent)
Postal Address	
Residential Address	
House Doctor	[Tel]
Specialist	[Tel]

GENERAL HEALTH QUESTIONNAIRE**PHYSICAL ACTIVITY:**

Stress Never tense ☐
 Seldom tense ☐
 Regularly tense ☐
 Always tense ☐

Sleep Are you sleeping well and enough? YES ☐ NO ☐

In general, I wake up: Refreshed ☐ Unrefreshed ☐

Sport Type
 Sessions per week
 Duration of session

LIFE STYLE

Dietary Assessment Do you have a normal appetite and healthy diet? **YES** ☐ **NO** ☐
 Breakfast Lunch..... Dinner..... Snacks

How many times per week do you eat:

Red Meat	Fish/Chicken	Eggs	Vegt./fruit/salad	Dairy	Sweets

How many times per day do you drink:

Coffee/Tea	Carbonated Drinks	Alcohol	Milk	Fruit Juices	Water

HEALTH IN GENERAL

Can you walk 2 to 3km without getting short of breath or experiencing chest pains?

YES ☐ **NO** ☐

When you get tired or annoyed, do you experience any pain in your chest, left arm or neck?

YES ☐ **NO** ☐

Do you take any medication on a regular basis? If yes, please specify.

MEDICATION	REASON / AILMENT

CONSENT FORM

Has your doctor ever told you that you have high blood pressure? YES ☐ NO ☐

Do you experience any chest pains at any time? YES ☐ NO ☐

Do you often feel dizzy or faint? YES ☐ NO ☐

Has your doctor ever diagnose high cholesterol with you? YES ☐ NO ☐

Has your doctor ever diagnosed any joint or skeletal problem? YES ☐ NO ☐

Are there any other reason not mentioned above, why you should rather not participate in any exercise? YES ☐ NO ☐

If YES please specify

- ◆ I, the undersigned _____ hereby declare that all of the above mentioned information is true and correct.
- ◆ I further agree that, except where it is due to negligence or malice on the part of the Biokineticist, neither I, my executor, administrator, legal representatives, heirs nor assigns shall have any claim whatsoever upon the Biokineticist nor practice.
- ◆ I understand that I use all the apparatus and facilities at my own risk, and cannot hold Joanita Badenhorst or Hoërskool Nelspruit responsible for any damage or loss due to the use of the Centre.

Signature: _____

Date: _____

Signature: _____
(Biokineticist)

Date: _____

APPENDIX E: PROTOCOLS OF DIFFERENT TESTS AS PRESCRIBED BY THE VARIOUS INSTITUTIONS

- ISAK (International Standards for Anthropometric Assessment) (Marfell-Jones *et al.*, 2006)
- Sport Search Program (Australian Sports Commission, 1995)
- Navy Physical Readiness Test (Bartlett *et al.*, 2015)

ISAK (International Standards for Anthropometric Assessment)
(Marfell-Jones et al., 2006)

Stature was measured while standing with the back against the stadiometer (Seca 206, Germany) and the feet together. The heels, buttocks and upper back had to be in contact with the stadiometer and the head held in the Frankfort position. While the subject inhaled deeply in this position, the measurement was taken to the nearest 0.1 cm

Sitting height was measured while sitting flat on the stadiometer with the back against the stadiometer and the knees bent slightly. The head of the subject was held in the Frankfort position by the administrator and the measurement was taken to the nearest 0.1 cm after lowering the arm of the stadiometer onto the subject's head

Mass was taken with a calibrated electronic scale (SOEHNLE, Germany) with the subject standing upright with his weight evenly distributed on the scale and his arms next to his sides. The measurement was taken to the nearest 0.1 kg, while the subject had to look straight ahead.

Fat percentage was calculated by using a formula: $(\text{sum of 6 skinfolds} \times 0.1051) + 2.585$. The triceps, subscapular, iliac, abdominal, front thigh and calf skinfold thicknesses were measured by using a Harpenden calliper (Gima, Modena, Italy) according to standard procedures. Two measurements were taken at each site, and the average of the two readings was calculated as the score.

Sport Search Program
(Australian Sports Commission, 1995)

Speed was measured over a distance of 40m with the Fusion Sport Smart Speed-System (Fusion Sport Pty Ltd, 2009). The test is executed from a stationary position from where the participant has to accelerate and run through a series of infrared photoelectric gates that record horizontal velocity through each gate. The procedure involves sprinting 40m in total, running through the first pair of gates (10m) and the last pair of gates (40m). The better of two attempts for both 10m and 40m is taken in seconds to the nearest 0.01 sec, with two minute rest between attempts.

For agility the T-test requires the participant to touch a series of cones set out in "T" shape whilst side stepping and running as fast as possible. Place three cones five metres apart on a straight line (A, B, C) and a 4th cone (D) is placed ten metres from the middle cone (B) so that the four cones form a 'T'. The participant stands at the cone (D) at the base of the "T" facing the "T". The participant runs to and touches the middle cone (B), side-steps five metres to the left

cone (A) and touches it, side-steps ten metres to the far cone (C) and touches it, side-steps five metres back to the middle cone (B) and touches it and then runs ten metres backwards to the base of the 'T' and touches that cone (D). Time from start to finish is recorded. The better of two attempts is taken in seconds

The participants were measured for their vertical jumping ability using the Vertec (Questek). This apparatus included a sliding vertical pole attached to two weights at the base, which stabilized the apparatus. Movable horizontal levers are attached at the top of the pole and are marked in 1.27 cm. The levers can be set to begin at 228.6, 243.84, 259.08, or 274.32 cm. The initial setting for the levers was dependent upon the participant's reach. Vertical reach was measured by having each participant stand with his dominant side next to a wall. With feet on the ground, and hip as close as possible to the wall, the participant extended the arm closest to the wall and reached as high as possible without allowing any part of the feet to lose contact with the ground. This measurement was then recorded to the closest 1.27 cm. The participants' vertical jumps were measured after they were instructed to stand with their dominant side next to the apparatus, with feet shoulder-width apart. The participants then were instructed to perform a vertical jump and touch the vanes on the Vertec (Questek). The participants were instructed to reach with their dominant hand while at the top of their jump and to move as many levers as possible. Two vertical jumps were allowed, the average of the jumps was recorded. The height of the jump was the difference between the vertical reach and the vertical jump.

For the Horizontal or Standing Long jump test, the subjects were instructed to initially stand on a long jump mat and jump as far as possible. The distance from the starting point to the landing point at heel contact was used for statistical analysis. Three horizontal jumps were allowed, the average of the three jumps were recorded.

Navy Physical Readiness Test **(Bartlett et al., 2015)**

For the two minute sit-up test the participant starts on his back with bent knees and hands placed at the side of the head. An administrator was permitted to hold the feet or ankles of the participant to keep the feet on the floor. The upper body is raised until the elbows touch the thighs while the hands remain at the sides of the head; the body is lowered back to the floor until the shoulder blades touches the ground. No bouncing or arching of the lower back is allowed, and the buttocks and feet must remain in constant contact with the floor throughout the test. The maximum number of correctly performed sit-ups in two minutes was recorded

(Boddington et al., 2001)

The 5-m Multiple Shuttle test (5-m MST) required the subjects to sprint between a series of six beacons spaced five metre apart in a straight line to cover a total distance of 25m. Subjects were instructed to perform maximally throughout the whole test. Each subject started the test in line with the first beacon (A), and upon an auditory signal sprinted five metre to beacon B, touched the ground adjacent to the beacon with their hand, and returned back to beacon A, touching down on the ground adjacent to the beacon with the band again. The subject then sprinted ten metre to the third beacon C, and back to beacon A, etc., until an exercise period of 30 seconds had elapsed. The distance covered by each subject was recorded to the nearest 2.5m during each 30-second shuttle. Thereafter there was a 35-second recovery, during which the subjects walked back to beacon A, the participant did a total of six shuttle runs of 30s each. The totals of all six runs were recorded.

(Kuro, 2008)

The Seven-stage abdominal strength test starts where the participant lies on his back, with the knees at right angles and feet flat on the floor. The participant then attempts to perform one complete sit-up for each level in the prescribed manner, starting with level 1. Each level is achieved if a single sit-up is performed in the prescribed manner, without the feet lifting off the floor. As many attempts as necessary can be made. The highest level correctly completed is recorded.

Level	Rating	Description
0	very poor	cannot perform level 1
1	poor	with arms extended, the athlete curls up so that the wrists reach the knees
2	fair	with arms extended, the athlete curls up so that the elbows reach the knees
3	average	with the arms held together across abdominals, the athlete curls up so that the chest touches the thighs
4	good	with the arms held across chest, holding the opposite shoulders, the athlete curls up so that the forearms touch the thighs
5	very good	with the hands held behind head, the athlete curls up so that the chest touches the thighs
6	excellent	as per level 5, with a 2.5 kg weight held behind head, chest touching the thighs
7	elite	as per level 5, with a 5 kg weight held behind head, chest touching the thighs

Brown and Weir, (2001)

A relative load test was done to determine leg strength (squat test): participants perform the most repetitions that they can at a load that is a percentage of their estimated 1-RM. The equation from Mayhew *et al.* (1992:203) ($1\text{-RM} = 100 \times \text{rep mass} / (52.2 + 41.9 \times \text{exponential} [-0.055 \times \text{reps}])$) were used to determine the 1-RM of participants. One operator with two helpers was assigned to minimize the injury risk.

APPENDIX F: DATASHEET AND ANNUAL REPORT

For the determination of the anthropometric growth, and physical and motor capabilities, the test protocol consists of thirteen tests, which included four anthropometric tests (stature, mass, sitting height, and fat percentage) and eleven physical and motor fitness tests (10m and 40 m speed, agility t-test, and shuttle runs, vertical jump, horizontal jump, squats, sit-ups, seven-stage abdominal strength).

To follow is the data sheet used to record each participant's scores on all four test occasions and the report on each participants results over the two-year



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Biokineticist

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086 557 7438 (fax to mail)

Postbus 127, Nelspruit, 1200

PHYSICAL FITNESS REPORT

NAME

SURNAME

DATE OF BIRTH

Test Date	Feb 2015	Aug 2015	Feb 2016	Aug 2016
Height				
Mass				
Fat%				
Sit-ups				
7 Stage Ab Strength				
Vertical Jump				
Horizontal Jump				
Squats				
10m Sprint				
40m Sprint				
T-Test				
Shuttle Run				

REMARKS:

Joanita Badenhorst (Biokineticist)

Name & Surname: _____

Date of Birth: _____

Sport: _____

Item &/ Position: _____

Date: _____

JOANITA**BADENHORST**

BIOKINETICISTS

GYMNASIUM**ANTHROPOMETRY**

Age (today)		Height	Sit Height	Mass	Sit-&-Reach
Triceps	Scap	Iliac	Umbil	Thigh	Calf

STRENGTH

Squat	7 Stage Ab Strength
Push Ups (1min)	Sit-Ups (2min)

FIELD**SPEED**

10m		40m	

POWER

Horizontal Jump		Vertical Jump		
		R	J	J

AGILITY

6 Shuttles						T-Test	

APPENDIX G: TRAINING PROTOCOL

A speed, agility, strength and power training programme for two additional days per week was compiled by the researcher who is a registered Biokineticist who was also responsible for the adjustment and progression of each programme throughout the six-months. These sessions consisted of:

- **Session one** of the week was a 45min session for resistance training (own body weight exercise, elastic resistance bands, gym apparatus and free weights) and plyometrics (skipping ropes, plyometric jumping box). Each session consisted of 12 exercises that was made up of five strength exercises (leg extensions, leg curls, squats, sit-ups, bench press), four plyometric exercises (skipping, box jumps, front and sideways and depth jumps) and three combinations of strength and plyometric exercise (lunge jumps, squat jump with high pull, burpee to pull up). At the start of the six-months each exercise was done with light to medium weights for 15 to 20 repetitions, and every exercise was repeated three times, with emphasis on technique. As the participants improved their conditioning and skill in the proper technique the weight increased and repetitions decreased to ten repetitions.
- **Session two** of the week was made up of 45min of speed and agility training (speed ladders & hurdles, weighted sleds and parachutes) with the focus on improvement of feet speed, acceleration balance and proprioception. At the start of the six-months, the session focused on proper sprinting mechanics, short distances of 10 to 20 metre were used and no more than four hurdles and speed ladders with four blocks were used. As participants mastered the skills, techniques and exercises during the six-months the distances were increased up to 80m and the amount of hurdles and length of the speed ladders were also increased.

STRENGTH AND PLYOMETRIC TRAINING

	January week 1 - 4						February week 5 - 8					
	Date		Date		Date		Date		Date		Date	
	Reps	Weight	Reps	Weight	Reps	Weight	Reps	Weight	Reps	Weight	Reps	Weight
Leg Extension	20											
Leg Curls	15											
Squats	20											
Bench	15											
Sit-Ups	20											
Skipping	60											
Box Jump (front)	10											
Box Jump (sideways)	10											
Depth Jumps	6											
Lunge Jumps	14											
Squat Jump + High Pull	12											
Burpee-to-pull up	12											

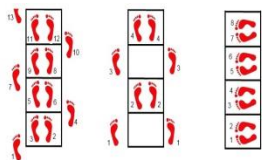
SPEED & AGILITY TRAINING

Programme One:



RUNNING MECHANICS: *Arms 90° at elbows, work through shoulders, keep arms close to body.
Knee 90° Ankle 90°
Body 45° angle with surface*

DRILLS: Arm Swing in sitting position (trains the 90° position of elbows + swing through shoulders)
Marching on the spot (arms 90° + close to body, knees 90° + lift high)
Running on the spot for 5sec
Running on the spot 5sec + 5m Sprint (verbal queue for proper mechanics)



AGILITY LADDERS:

Bunny hops – *jump from ankles*
Hop scotch – *soft knees with ground contact*
High Knees Forward – *proper running mechanics*
High Knees Sideways – *proper running mechanics, keep hips square*

SPEED & AGILITY TRAINING

Programme Two:



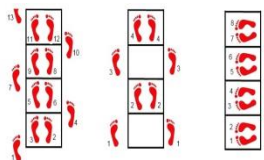
RUNNING MECHANICS: Re-run basic proper running mechanics

Arm Swing in sitting position (trains the 90° position of elbows + swing through shoulders)

Running on the spot 5sec + 5m Sprint (verbal queue for proper mechanics)

10m Cadence run – *arms 90°, Swing through shoulders, Knees high*

5m Cadence run + 10m Sprint – *focus on running mechanics*



AGILITY LADDERS:

Bunny hops – *jump from ankles*

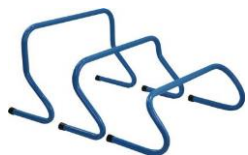
Hop scotch – *soft knees with ground contact*

Side Step In-Out

Side Step Out-In

High Knees Sideways – *proper running mechanics, keep hips square*

High Knees Forward + 5m Sprint – *proper running mechanics*



SPEED HURDLES:

Small 6" Hurdles

Bunny Hops - *jump from ankles; do not lift knees to high*

Kangaroo Hops – *Pull knees 90° + high in front of body, swing arms*

Cadence run – *focus on proper running mechanics*

APPENDIX H: LETTERS FROM EDITORS

JOURNAL OF STRENGTH AND CONDITIONING RESEARCH

Jonita

From: em.jscr.0.573a6b.de2cdde8@editorialmanager.com on behalf of Journal of Strength and Conditioning Research <em@editorialmanager.com>
Sent: Tuesday, November 14, 2017 12:57 PM
To: Joanita Badenhorst
Subject: JSCR Submission Confirmation for THE EFFECT OF THE GROWTH SPURT ON STRENGTH AND POWER DEVELOPMENT DURING MID-ADOLESCENCE IN BOYS

Nov 14, 2017

Dear Mrs Badenhorst,

We have received your new manuscript entitled "THE EFFECT OF THE GROWTH SPURT ON STRENGTH AND POWER DEVELOPMENT DURING MID-ADOLESCENCE IN BOYS".

You will be able to check on the progress of your paper by logging on to Editorial Manager as an author.

Additionally, you may view the Additional Information questions to obtain the copyright information by clicking here: [Additional Information](#)

1. Joanita Badenhorst, Honors in Biokinetics

Question: RETAINED RIGHTS: Except for copyright, other proprietary rights related to the Work (e.g., patent or other rights to any process or procedure) shall be retained by the author. To reproduce any text, figures, tables, or illustrations from this Work in future works of their own, the author must obtain written permission from Wolters Kluwer Health, Inc. ("WKH").

AMERICAN JOURNAL OF HUMAN BIOLOGY

Jonita

From: onbehalfof+AJHB+anthro.umass.edu@manuscriptcentral.com on behalf of American Journal of Human Biology
<onbehalfof+AJHB+anthro.umass.edu@manuscriptcentral.com>
Sent: Tuesday, November 14, 2017 12:23 PM
To: joanita.lemmer@gmail.com; jonita@nelliesh.co.za
Subject: American Journal of Human Biology - Manuscript number AJHB-17-0274

14-Nov-2017

Dear Mrs. Badenhorst,

Your manuscript entitled "ROLE OF THE GROWTH SPURT IN SPEED AND AGILITY TRAINING OF 13 TO 15 YEAR OLD MID-ADOLESCENT BOYS" has been successfully submitted online and is presently being given full consideration for publication in the American Journal of Human Biology.

Your manuscript number is AJHB-17-0274. Please mention this number in all future correspondence regarding this submission.

You can view the status of your manuscript at any time by checking your Author Center after logging into <https://mc.manuscriptcentral.com/ajhb>. If you have difficulty using this site, please click the 'Get Help Now' link at

APPENDIX I: PROOF OF TRANSLATION PROCESS*Declaration*

*This is to declare that I, Annette L Combrink, accredited
language editor and translator of the South African
Translators' Institute, have language-edited the dissertation
by*

Joanita Badenhorst (26483734)

**THE EFFECT OF THE GROWTH SPURT ON STRENGTH,
POWER, SPEED AND AGILITY TRAINING IN BOYS DURING
MID-ADOLESCENCE**



*Prof Annette L Combrink
Accredited translator and language editor
South African Translators' Institute
Membership No. 1000356
Date: 14 November 2017*

APPENDIX J: TURN IT IN REPORT

Turn_It_In_(1).pdf

ORIGINALITY REPORT

19%

SIMILARITY INDEX

10%

INTERNET SOURCES

13%

PUBLICATIONS

9%

STUDENT PAPERS

PRIMARY SOURCES

1	Gerber, Barend P., Anita E. Pienaar, Ankebe Kruger, and Suria Ellis. "Interrelations between anthropometric and fitness changes during mid-adolescence in boys: A 2-year longitudinal study : Changes in Anthropometry, Physical and Motor Fitness", American Journal of Human Biology, 2014. Publication	4%
2	dspace.nwu.ac.za Internet Source	1%
3	repository.nwu.ac.za Internet Source	1%
4	Rojapon Buranarugsa. "Biological Maturation and response to complex strength training in adolescent thai soccer players", Repositório Aberto da Universidade do Porto, 2014. Publication	1%
5	Malina, Robert M.. "Top 10 Research Questions Related to Growth and Maturation of Relevance to Physical Activity, Performance,	<1%

and Fitness", Research Quarterly for Exercise and Sport, 2014.

Publication

6	MICHELE K. BODDINGTON. "VALIDITY OF A 5-METER MULTIPLE SHUTTLE RUN TEST FOR ASSESSING FITNESS OF WOMEN FIELD HOCKEY PLAYERS :", The Journal of Strength and Conditioning Research, 02/2004	<1 %
7	www.researchgate.net	<1 %
8	LEE N. BURKETT. "THE BEST WARM-UP FOR THE VERTICAL JUMP IN COLLEGE-AGE ATHLETIC MEN :", The Journal of Strength and Conditioning Research, 08/2005	<1 %
9	Oliver, Jon L., Rhodri S. Lloyd, and Michael C. Rumpf. "Developing Speed Throughout Childhood and Adolescence : The Role of Growth, Maturation and Training", STRENGTH AND CONDITIONING JOURNAL, 2013.	<1 %
10	www.kinsi.si	<1 %
11	Submitted to North West University	<1 %

APPENDIX K: ETHICAL CLEARANCE LETTER



NORTH-WEST UNIVERSITY
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NOORDWES-UNIVERSITEIT

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**Institutional Research Ethics Regulatory
Committee**

Tel +27 18 299 4849
Email Ethics@nwu.ac.za

ETHICS APPROVAL CERTIFICATE OF PROJECT

Based on approval by **Health Research Ethics Committee (HREC)**, the North-West University Institutional Research Ethics Regulatory Committee (NWU-IRERC) hereby approves your project as indicated below. This implies that the NWU-IRERC grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the project may be initiated, using the ethics number below.

Project title: The role of the growth spurt on strength, power, speed and agility training of mid-adolescent boys.																												
Project Leader: Prof AE Pienaar																												
Ethics number:	<table border="1"> <tr> <td>N</td><td>W</td><td>U</td><td>-</td><td>0</td><td>0</td><td>3</td><td>3</td><td>0</td><td>-</td><td>1</td><td>5</td><td>-</td><td>A</td><td>1</td> </tr> <tr> <td colspan="3">Institution</td> <td colspan="3">Project Number</td> <td colspan="3">Year</td> <td colspan="3">Status</td> </tr> </table> Status: S = Submission, P = Pre-Submission, F = Provisional Authorisation, A = Authorisation	N	W	U	-	0	0	3	3	0	-	1	5	-	A	1	Institution			Project Number			Year			Status		
N	W	U	-	0	0	3	3	0	-	1	5	-	A	1														
Institution			Project Number			Year			Status																			
Approval date: 2015-11-30	Expiry date: 2016-11-30																											
Risk	Minimal																											

Special conditions of the approval (if any): None

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:

- The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC:
 - annually (or as otherwise requested) on the progress of the project,
 - without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.
- The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-IRERC. Would there be deviation from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.
- The date of approval indicates the first date that the project may be started. Would the project have to continue after the expiry date, a new application must be made to the NWU-IRERC and new approval received before or on the expiry date.
- In the interest of ethical responsibility the NWU-IRERC retains the right to:
 - request access to any information or data at any time during the course or after completion of the project;
 - withdraw or postpone approval if:
 - any unethical principles or practices of the project are revealed or suspected,
 - it becomes apparent that any relevant information was withheld from the NWU-IRERC or that information has been false or misrepresented,
 - the required annual report and reporting of adverse events was not done timely and accurately,
 - new institutional rules, national legislation or international conventions deem it necessary.

The IRERC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the IRERC for any further enquiries or requests for assistance.

Yours sincerely

**Prof LA
Du Plessis**

Digitally signed by Prof LA Du Plessis
DN: cn=Prof LA Du Plessis, o=North-
West University, ou=Campus Rector,
email=Linda.DuPlessis@nwu.ac.za,
c=ZA
Date: 2016.01.28 07:51:41 +02'00'

Prof Linda du Plessis

Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)