



**Longitudinal changes and interrelationships between
anthropometric characteristics and motor and physical
fitness abilities in adolescent girls**

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This thesis was done in article format. The study was planned and performed by three researchers. The contribution of each author will be tabulated with a statement of each co-author's role in the study. This also allows BP Gerber to submit the articles in this thesis for degree purposes.

Authors' name and Surname	Role of the author in this study
Mr. Barry Gerber (BG) (MA. Kinderkinetics)	BG helped with the data collection of the study for 2 of the 3 years. BG also captured and processed the raw data. BG is also the first author of the 4 scientific papers.
Prof. Anita E. Pienaar (AP) (PhD. Human Movement Science)	AP , the promoter, and AK were jointly responsible for the planning and managing of the thesis. AP was the promoter of the study and made a significant contribution to the writing of the scientific papers.
Prof. Ankebé Kruger (AK) (PhD. Sport Science)	AK was responsible for planning and managing the thesis with AP . AK was the co-promoter during the study. AK made a significant contribution to the writing of the scientific papers.

Solemn statement by promoters

We hereby declare that the above articles have been approved and that our roles in the thesis as set out above is correct and reflects our contributions to the study. We hereby consent that the articles can be submitted as part of the thesis of Mr. Barry Gerber.



Prof. Anita E. Pienaar



Prof. Ankebé Kruger

FOREWORD

Two of my close friends within the academic world, who had already completed his PhD, once told me that the journey to complete a PhD breaks something in you that no-one will understand till the day they walk the path to a completed PhD (Wihan Pheiffer and Christo Bisschoff). How true were these words and I will never forget this journey for the rest of my life. Although it was mentally hard and an emotionally draining journey it was a humble experience where I learned so much of the ins and outs of research. But more than anything I learned so much more about myself and my capabilities. Although I feel mentally and emotionally drained and tired in so many ways after the completion of this thesis, I feel more capable in life, and I am ready to take on the world and my research career after learning so much during the last five years.

Thank you to everyone who was part of this journey. With this in mind, I would like to thank certain role-players during this journey without whom I could not have completed this PhD.

Above all, I want to thank our Almighty God for the opportunity to be able to take part in a research project and to be able to complete my PhD. Without the strength and knowledge given to me by our God, I would not have been able to persevere.

Matthew 5: 3-10

3 “Blessed are the poor in spirit, for theirs is the kingdom of heaven 4 Blessed are those who mourn, for they will be comforted. 5 Blessed are the meek, for they will inherit the earth. 6 Blessed are those who hunger and thirst for righteousness, for they will be filled. 7 Blessed are the merciful, for they will be shown mercy. 8 Blessed are the pure in heart, for they will see God. 9 Blessed are the peacemakers, for they will be called children of God. 10 Blessed are those who are persecuted because of righteousness, for theirs is the kingdom of heaven.”

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In particular, I dedicate this thesis to my son Barend Paul Gerber the fifth. May this be an inspiration to you to follow your dreams one day and to be successful in what you decide to take on.

Barry Gerber

SUMMARY

Longitudinal changes and interrelationships between anthropometric characteristics and motor and physical fitness abilities in adolescent girls

Success in sport is influenced by controllable factors, including coaching, facilities, nutrition and training programs. Less controllable factors during childhood and adolescence include influences of growth and maturation such as the onset of menarche. The timing and the magnitude of these processes affect each individual differently. Based on individual differences in development, menarche is reached earlier or later, resulting in the phenomenon of early, average and late maturing girls. This difference in maturity status affects the anthropometric growth and physical fitness and motor performance of girls in different ways.

This thesis is based on four objectives of which all were studied by means of two years of follow-up longitudinal data that included a period of three school years (Grade eight to Grade ten). The first aim was to determine growth differences in mass, sitting height, sitting height ratio, arm span, leg length and body mass index (BMI) of pre- and post-menarche adolescent girls over a three-year school period, and the implications of these differences on sport performance. The study aimed to determine secondly and thirdly, the differences between pre- and post-menarche girls' physical fitness capabilities (muscle strength, cardio respiratory endurance) and motor fitness capabilities (speed, agility, hand-eye coordination and power) over a period of three school years. The fourth aim was to investigate the classification agreement between self-reported age at menarche and calculated maturity off-set in adolescent girls.

The study made use of a convenience sample within the three school year longitudinal study titled *Growth and sport psychological characteristics of talented adolescent boys and girls (Growth study)*. This study included the high school's years (Grade eight to Grade ten) and

included participants from one Quintile five school within Potchefstroom, South Africa. The school had a boarding facility and all Grade 8 learners that enrolled in 2010 represented 46 different primary schools. Anthropometric measurements were taken at 9 time points (three times annually, 4 months apart) while motor- and physical capabilities were measured longitudinally at 3 time points (once annually in Feb 2010 until 2012). In 2010, 95 girls were enrolled in the study with a mean age of 13.73 ± 0.48 years at baseline. Of these, 37 (38%) were lost to follow-up, resulting in the final group consisting of 58 girls during the final measurements with a mean age of 16.26 ± 3.58 years in November 2012. The age of menarche was determined by the Status Quo method which was used to categorize the group at baseline into a pre- ($n=13$) and post-menarche group ($n=45$). The protocol of the International Standards for Anthropometric Assessment (ISAK) was used to measure stature, arm span, body mass, sitting height and leg length while sitting height ratio and BMI were calculated. Maturity offset was calculated by means of a set gender specific equation for girls that is based on chronological age, growth related measures, growth interactions and ratios. Physical- and motor fitness capabilities were tested using the Australian Sport Search Program. Physical fitness capabilities included muscle strength (cricket ball throw for distance) and aerobic capacity (beep test). Motor fitness capabilities included speed (0-10m and 0-40m speed), agility (10m agility test), hand-eye coordination (throw and catch) and power (vertical jump and basketball chest press).

Statistical analyses of objectives one to three were similar. For descriptive purposes, means, standard deviations (sd) and minimum and maximum values were calculated. To analyse the changes over time in each group, a repeated measures ANOVA with a Posthoc Bonferonni adjustment was used to determine statistical significance ($p < 0.05$) of differences between time point measurements. Independent *t*-testing was also done to investigate group differences with $p < 0.05$ set as the level of significance. Effect sizes were calculated to determine practical significance of differences with cut-off values of $d > 0.2$ indicating a small practical significance, $d > 0.5$ a medium practical significance and $d > 0.8$ a large practical significance. Statistical analysis for objective four included a Receiver Operating Characteristic (ROC curve) analysis to determine maturity offset cut-off points for early and late maturing girls. An asymptotic level of $p < 0.05$ was used as the set criterion for statistical significance where an area value of 1 indicated a strong/accurate prediction potential. Cross-tabulation and a Chi-square analysis was used to determine the association between the Status Quo and maturity offset results. Cut-off points for Chi-square (Cramer's *V*) were $V > 0.1$

indicating a small predictive effect, $V > 0.3$ a medium predictive effect and $V > 0.5$ a strong predictive effect.

The results with regards to objective one showed that post-menarche girls were taller and heavier, had a higher BMI and longer body segments at a younger age. These differences were significant at 13.51 years but declined to similar values ($p > 0.05$) at the end of the study at 16.25 years when most of the girls have reached menarche.

The results of objective two showed no statistical significant differences ($p > 0.05$) between the groups at the end of the study (15.51 years). However, post-menarche girls had practical significantly higher muscle strength with the pre-menarche girls showing a practical significant higher aerobic capacity and relative $\dot{V}O_{2\max}$ over the follow-up period, with differences between maturational groups ($p > 0.05$) becoming smaller with increased age. Post-menarche girls initially displayed better absolute $\dot{V}O_{2\max}$ ($p > 0.05$) values although performance of pre-menarche girls caught up and surpassed them at 15.51 years ($p > 0.05$). With regard to objective three, differences between maturity groups were only significant in the strength tests during baseline measurements (13.51 years). Explosive upper body strength differed significantly between the groups, favoring post-menarche girls during baseline measurements. Pre- and post-menarche girls also showed similar changes in motor fitness. Pre-menarche girls performed non-significantly ($p > 0.05$) better in agility and explosive leg strength and post-menarche girls significantly better in explosive upper body strength ($p < 0.05$), although non-significantly in hand-eye coordination and speed ($p > 0.05$) at 13.51 years. At 15.51 years no statistical significant group differences were found. Performance of pre-menarche girls surpassed post-menarche girls in hand-eye coordination and 0-40 m speed while post-menarche girls displayed higher leg strength scores after 2 years of follow-up.

The results regarding objective four showed that there was a level of classification agreement between the actual age of onset of menarche and the results derived from a maturity off-set equation. The results indicated an area value (AUC) of 0.757 where a score of 1 indicate accurate prediction, which shows that the prediction capability of the maturity offset equation is of relative high accuracy. Classification of girls as early or late developers at a younger age (13.51 years) nearer to their PHV were higher, while validity and accuracy of classification declined with increasing age possibly because most girls reached menarche and moved further away from PHV as was confirmed with cross-tabulation. It was concluded that the use of a set equation outside the population that it was developed for, should rather be limited to

categorizing girls in different maturity groups and not as a tool to predict maturity offset. The accuracy of the equations also declined with increasing maturity, therefore it should only be used a few years before and after reaching PHV.

Based on the above findings, it can be concluded that the timing of the onset of menarche contribute to significant differences between pre- and post-menarche girls' anthropometric growth during mid- to late adolescence. These include changes in body proportions and extremities and body composition including fat deposition and distribution. However, except for muscle strength differences ($p < 0.05$), no statistical significant differences in physical and motor fitness capabilities of girls of differing menarcheal status during mid- to late adolescence, were found. Some differences were however of small practical significance. It is still concluded that the time of reaching menarche is an unstable developmental period and girls will consequently, only be homogeneous in their physical and motor fitness abilities one to two years after all girls of the same chronological age have reached menarche. It is recommended that the knowledge that was generated by this thesis should be used to improve sports development and talent identification processes by incorporating the understanding of the temporary weaknesses but also the strengths associated with early or late development, and by applying this knowledge in appropriate short- and long-term motor performance goals.

Key terms: Anthropometric growth, Girls, Maturity, Menarche, Physical and motor fitness capabilities, Puberty

OPSOMMING

Longitudinale veranderinge en interverwantskappe tussen antropometriese eienskappe en motoriese- en fisieke fiksheid vermoëns in adolessente meisies

Sukses in sport word beïnvloed deur beheerbare faktore, insluitend afrigting, fasiliteite, voeding- en oefenprogramme. Minder beheerbare faktore tydens die kinderjare en adolessensie sluit die invloede van groei en ryping soos die bereiking van menarg in. Die tydsberekening en die omvang van hierdie prosesse beïnvloed elke individu verskillend. Gebaseer op individuele ontwikkelingsverskille word hierdie mylpale vroeër of later bereik wat lei tot die verskynsel van vroeë, gemiddelde en laat ontwikkelende meisies. Hierdie verskille in rypingstatus affekteer die antropometriese groei, fisieke fiksheid en motoriese prestasie van meisies op verskillende wyses.

Hierdie proefskrif is gebaseer op vier doelwitte waarvan alle doelwitte bestudeer is deur middel van twee jaar opvolg-longitudinale data wat 'n periode van drie skooljare insluit (Graad agt tot Graad tien). Die eerste doelwit was om groeiverskille in massa, sithoogte, sithoogte ratio, arm span, beenlengte en liggaamsmassa indeks (LMI) van pre- en post-menargale adolessente meisies oor 'n drie jaar skool tydperk te ontleed en die implikasies van hierdie verskille op sportprestasie te ondersoek. Die studie het tweedens en derdens ten doel gehad om die verskille tussen pre- en post-menargale meisies se fisieke fiksheidsvermoëns (spierkrag, kardio respiratoriese uithouvermoë) en motoriese fiksheidsvermoëns (spoed, ratsheid, hand-oog-koördinasie en krag) oor 'n drie jaar periode te bepaal. Die vierde doel was om die klassifikasie ooreenkoms tussen self-gerapporteerde aanvang van menarg en berekende rypingsafsnypunte by adolessente meisies te ondersoek.

Die studie het gebruik gemaak van 'n beskikbaarheidssteekproef binne die drie skool-jaar longitudinale studie getiteld *Growth and sport psychological characteristics of talented*

adolescent boys and girls (Growth study). Hierdie studie sluit die hoërskooljare in (Graad 8 tot Graad 10) en het deelnemers vanuit een kwintiel vyf skool in Potchefstroom, Suid-Afrika ingesluit. Die skool het koshuisfasiliteite, en alle Graad 8-leerders wat ingeskryf was in 2010 was verteenwoordigend van 46 verskillende laerskole. Antropometriese metings is geneem op 9 metingsgeleenthede (3 keer jaarliks, viermaandeliks uit mekaar) terwyl motoriese- en fisieke fiksheidsvermoëns longitudinaal oor 3 metingsgeleenthede gemeet was (een keer jaarliks in Februarie 2010 tot 2012). In 2010, was 95 meisies met 'n gemiddelde ouderdom van 13.73 ± 0.48 tydens die basislynmetings van die studie. Van dié groep is 37 (38%) meisies verloor tydens opvolgmetings, wat gelei het tot 'n finale groep van 58 meisies tydens die finale metings met 'n gemiddelde ouderdom van 16.26 ± 3.58 jaar in November 2012. Die aanvangsoudersdom van menarg is bepaal deur die Status Quo-metode, wat gebruik is om die groep te kategoriseer in 'n pre- ($n = 13$) en post-menargale groep ($n = 45$) tydens basislynmetings. Die protokol soos voorgeskryf deur die “International Society for the Advancement of Kinanthropometry (ISAK)” is gebruik om liggaamslengte, armspan, liggaamsmassa, sithoogte en beenlengte te bepaal terwyl sithoogte ratio en LMI bereken is. Rypingsafsnypunte is bereken deur middel van 'n bestaande geslagspesifieke formule wat gebaseer is op chronologiese ouderdom, groeiverwante metings, groei interaksies en verhoudings. Fisieke- en motoriese fiksheidsvermoëns is getoets deur gebruik te maak van die “Australian Sport Search Program”. Fisieke fiksheidsvermoëns het spierkrag (krieketbal gooi vir afstand) en aërobiese kapasiteit (Beep-toets) ingesluit. Motoriese fiksheidsvermoëns het spoed (0-10 m en 0-40 m spoed), ratsheid (10 m ratsheidstoets), hand-oog koördinasie (gooi en vang) en eksplosiewe krag (vertikale sprong en basketbal bors gooi) ingesluit.

Soortgelyke statistiese analyses is gebruik vir die ontleding van doelwitte een tot drie. Vir beskrywende doeleindes is gemiddeldes, standaardafwykings (sd) en minimum en maksimum waardes bereken. Om veranderinge oor tyd by elke groep te analiseer, is 'n herhaalde metings-ANOVA met 'n Posthoc Bonferonni-aanpassing gebruik om statistiese betekenisvolheid ($p < 0.05$) van verskille tussen meetgeleenthede te bepaal. 'n Onafhanklike t -toets is ook uitgevoer om groepsverskille te ondersoek met $p < 0.05$ wat gebruik is as die vlak van betekenisvolheid. Effekgroottes is bereken om die praktiese betekenisvolheid van verskille te bepaal waar afsnywaardes van $d > 0.2$ as aanduiding van klein praktiese betekenisvolheid, $d > 0.5$ as medium praktiese betekenisvolheid en $d > 0.8$ groot praktiese betekenisvolheid gebruik is. Statistiese analyses vir doelstelling vier het ook 'n “Receiver Operating Characteristic (ROC curve)” analise ingesluit om die rypingsafsnypunte vir vroeë

en laat ontwikkelende meisies te bepaal. 'n Asimptotiese vlak van $p < 0.05$ is gebruik as aanduiding van statistiese betekenisvolheid waar 'n oppervlakwaarde van 1 'n sterk/akkurate voorspellingspotensiaal aandui. Kruis-tabulering en 'n Chi-kwadraat ontleding is ook gebruik om die assosiasie tussen die resultate van die Status Quo en rypingsafsnypunte te bepaal. Afsnypunte vir die Chi-kwadraat (Cramer's V) is $V > 0.1$ wat 'n klein voorspellingseffek aandui, $V > 0.3$ 'n medium voorspellingseffek en $V > 0.5$ 'n sterk voorspellingseffek.

Die resultate met betrekking tot doelwit een toon dat post-menargale meisies langer en swaarder was, 'n hoër LMI en langer liggaamsegmente gehad het op 'n jonger ouderdom. Hierdie verskille was statisties betekenisvol op 13.51 jarige ouderdom maar het afgeneem tot soortgelyke waardes ($p > 0.05$) aan die einde van die studie op 16.25 jarige ouderdom waartydens meeste meisies reeds menarg bereik het.

Die resultate van doelwit 2 het geen statisties betekenisvolle verskille tussen groepe aan die einde van die studie uitgewys nie (15.51 jaar). Alhoewel post-menargale meisies praktiese betekenisvolle beter spierkrag en pre-menargale meisies beter aërobiese kapasiteit en relatiewe $\dot{V}O_{2maks}$ ($p > 0.05$) oor die opvolgperiode gehad het, het verskille tussen rypingsgroepe ($p > 0.05$) verklein met 'n verhoging in ouderdom. Post-menargale meisies het aanvanklik hoër absolute $\dot{V}O_{2maks}$ ($p > 0.05$) waardes getoon, alhoewel die $\dot{V}O_{2maks}$ waardes van pre-menargale meisies sodanig verbeter het dat hulle beter presteer het op 15.51-jarige ouderdom ($p > 0.05$). Met betrekking tot doelstelling drie, was verskille tussen rypingsgroepe slegs betekenisvol by die kragtoetse en tydens die basislynmetings. Eksplosiewe bolyfkrag het statisties betekenisvol verskil tussen rypingsgroepe tot voordeel van die post-menargale meisies tydens basislynmetings. Pre- en post-menargale meisies het ook soortgelyke veranderinge oor die opvolgtydperk in motoriese fiksheidstoetse getoon. Pre-menargale meisies het nie-betekenisvol beter presteer in ratsheid en eksplosiewe beenkrag en post-menargale meisies betekenisvol beter in eksplosiewe bolyfkrag ($p < 0.05$), alhoewel nie-betekenisvol ($p > 0.05$) in hand-oog koördinasie en spoed op 13.51-jarige ouderdom. Op 15.51-jarige ouderdom het geen statistiese betekenisvolle groepsverskille voorgekom nie. Die prestasie van die pre-menargale groep het die post-menargale groep in hand-oog-koördinasie en 0-40 m spoed ingehaal en later hoër waardes in dié vaardighede getoon terwyl post-menargale meisie hoër eksplosiewe beenkrag getoon het na die twee jaar opvolgtydperk.

Die resultate wat behaal is met betrekking tot doelwit vier het getoon dat daar wel klassifikasie ooreenstemming is tussen die werklike aanvangsouderdom van menarg en

resultate wat verkry is van berekende rypingsafsnypunte. Die resultate het 'n oppervlakwaarde (AUC) van 0.757 getoon wat 'n telling van 1 op 'n akkurate voorspelling toon, wat daarop dui dat die voorspellingsvermoë van die formule van relatiewe hoë akkuraatheid is. Klassifikasie van meisies as vroeë en laat ontwikkelaars op 'n jonger ouderdom (13.51 jaar) was egter beter, terwyl die geldigheid en akkuraatheid van die resultate afgeneem het met toenemende ouderdom, moontlik omrede meeste meisies reeds menarg bereik het en verder weg beweeg het vanaf piek lengte groei, soos bevestig deur die kruis-tabulering ontleding wat uitgevoer is. Daar is tot die gevolgtrekking gekom dat die gebruik van 'n standaard formule, buite die bevolking waarvoor dit ontwikkel is, eerder beperk moet word tot die kategorisering van meisies in verskillende rypingsgroepe en nie as instrument om rypingsafsnypunte as sodanig te probeer voorspel nie. Die akkuraatheid van die formule het ook afgeneem met verhoogde ryping, daarom moet die formule slegs 'n paar jaar voor en na die bereiking van piek lengte groei gebruik word.

Op grond van bogenoemde bevindings word die gevolgtrekking gemaak dat die tydsberekening van die aanvang van menarg betekenisvol bydra tot verskille in pre- en post-menargale meisies se antropometriese groei tydens mid- tot laat adolessensie. Dit sluit in veranderinge in liggaamsproporsies, -ledemate en liggaamsamestelling insluitend vetneerlegging en -verspreiding. Uitsluitend vir spierkragverskille ($p < 0.05$), het daar geen betekenisvolle verskille in fisieke- en motoriese fiksheidvermoëns van meisies van verskillende menargale-status gedurende mid- tot laat adolessensie, na vore gekom. Sommige verskille was egter wel van klein praktiese betekenisvolheid. Daar word egter steeds die gevolgtrekking gemaak dat die aanvangstydperk van menarg 'n onstabiele periode is in meisies se ontwikkeling en dat meisies eers homogeen sal wees in hul fisieke- en motoriese fiksheid een tot twee jaar nadat alle meisies van dieselfde chronologiese ouderdom, menarg bereik het. Daar word aanbeveel dat kennis wat vanuit hierdie proefskrif gegenereer is, gebruik moet word om sportontwikkeling- en talentidentifiseringsprosesse te verbeter deur begrip van die tydelike swakheid maar ook die sterkpunte wat met vroeë of laat ontwikkeling verband hou, te inkorporeer deur die toepassing van dié kennis tydens die ontwikkeling van toepaslike kort- en langtermyn motoriese prestasiedoelwitte.

Sluteltermes: Antropometriese groei, Fisieke en motoriese fiksheid, Meisies, Menarg, Ryping, Puberteit

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ABBREVIATIONS

PHV	Peak height velocity
BMI	Body mass index
TID	Talent identification
WHO	World Health Organization
GHRH	Growth hormone releasing hormone
EUBS	Explosive upper body strength
ELS	Explosive leg strength
HEC	Hand-eye coordination

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1.1 INTRODUCTION

The adolescent period, including puberty, refers to the transition period from childhood to adulthood. It is a unique period of growth and development that is characterised by multiple physical, physiological and psychological changes (Dahl, 2004:3; Gaudineau *et al.*, 2010:175, Sawyer *et al.*, 2018:844). According to the World Health Organisation (WHO), the adolescent period in girl's, stretches from eight to 19 years of age, which is characterised by three distinguishable phases, namely early, middle and late adolescence (WHO, 2015:1, Sawyer *et al.*, 2018:840).

Characteristics of the adolescence period in girls include the onset of puberty, peak height velocity (PHV) and menarche (Pantsiotou *et al.*, 2008:217). Puberty, which refers to a phase of development, is described as the developmental period that includes the emerging of sexual characteristics and the continuous maturation of these characteristics. Also, a period of maximum growth, referred to as PHV, occurs during this period (Malina *et al.*, 2004:293, Gabel *et al.*, 2017:253), while menarche, which is the first occurrence of menstruation, is also reached (Danubio *et al.*, 2004:470, Shadyab *et al.*, 2017:4). Maturation is described as the changes that occur due to growth in shape and complexity of body organs, which are genetically predetermined (Viru *et al.*, 1999:92; Pienaar, 2018:5). Growth, including structural growth (growth of the body in terms of height and mass) and sexual growth (development of primary and secondary sexual characteristics), refers to the magnification of the body as a whole, as well as in different parts of the body (Malina *et al.*, 2004:4).

From a medical point of view, the complex biological and physiological changes that occur from the onset of puberty have for a long time been considered as an important area of research among girls (Nicoletti, 1994:290). The largest variation in sexual maturity, among others reaching menarche, is found between the ages of 12 and 16 years. These changes show clear resemblances with anthropometric characteristics and motor- and physical fitness capabilities (Malina *et al.*, 2004:339). Menarche is one of several factors associated with other physical changes during puberty (Marshall & Tanner, 1969:291, Shadyab *et al.*, 2017:4) which can influence the development of motor and physical fitness capabilities of adolescent girls (Balyi & Way, 2010:4). The rate of biological development and maturation also plays an important role in the motor- and physical fitness capabilities of adolescent girls (Bronikowski & Bronikowska, 2008:30).

Research focusing on maturation, the rate and timing of progression to adulthood and its consequences, is essential in the study of growth in adolescents (Mirwald *et al.*, 2001:689). Studies that were published in the 1960s reported that the average age of onset of puberty in girls was between the ages of 8 and 13 years (Marshall & Tanner, 1969:294). Recent studies in the United States of America (USA) correspond with these statistics and report that pubertal milestones are reached at similar ages [puberty – 10 years, PHV – 11.2 years; and menarche – 12.4 years], especially among African American girls, although sometimes at a younger age among Mexican-American and white girls (Herman-Giddens *et al.*, 1997:509; Sun *et al.*, 2002:915; Bronkowski & Bronikowska, 2008:34; Pantiotou *et al.*, 2008:218, Shadyab *et al.*, 2017:4). A study among South African girls indicates that the average age of the onset of menarche is 12.4 years for black girls and 12.5 years for white girls (Jones *et al.*, 2009:131).

The age at which menarche occurs is not rigid and is influenced by a variety of factors, such as genetics, nutrition, health status (Kaprio *et al.*, 1995:749; Salces *et al.*, 2001:144; Ameade & Garti, 2016:6) and physical activity (Salces *et al.*, 2001:143; Ayatollahi *et al.*, 2002:355). The long-term consequences of differential timing of reaching puberty between girls in relation to sports participation have for some time been a subject of research (Apter *et al.*, 1989:783; Forman *et al.*, 1994:1393; Van Lenthe *et al.*, 1996:18; Okasha *et al.*, 2001:68). In this regard, literature indicates that it is important during research and classification of sporting talent among youths to take biological maturation into account, and not necessarily chronological age, to correct for developmental differences. Growth curves that can be developed through longitudinal research, can be used to identify unstable periods of growth that could affect girls' maturation and development. Such information can then be used to adjust exercise, competition and rehabilitation programmes according to biological age and not the chronological age of a group, region or population (Balyi & Way, 2010).

As considerable changes in height, weight, body mass index (BMI), and body fat percentage, are strongly associated with the onset of menarche (Plowman *et al.*, 1991:23; Ameade & Garti, 2016:5) that occurs during the last phase of PHV, it is clear from the literature that the adolescent period and more specific the time when menarche is reached in girls is a dynamic growth period. Growth and maturational changes during adolescence, especially the reaching of menarche, differs and results in temporary biological and physiological differences between girls during mid- to late adolescence. Simultaneous assessment of anthropometric

variables and motor and physical fitness capabilities will, however, result in more accurate information about these developmental processes among girls and will enable researchers to determine the possible interrelationship between these factors.

1.2 PROBLEM STATEMENT

Physical aging from the pre-pubertal age to adulthood represents a continuum that includes both early and late developers (Carel & Leger, 2008:2366; Wohlfahrt-Veje *et al.*, 2016:2669; Sawyer *et al.*, 2018:843). Some researchers agree that early, average or late occurring maturity is associated with differences in anthropometric development, which include more than just changes in longitudinal growth (Biro *et al.*, 2001:642). Early, average or late developers are classified in terms of the timing and deviation (a difference of 12 months) of reaching menarche compared to mean values within a certain population (Malina *et al.*, 2004:339).

Methods used in research to study to phenomena of menarche include monitoring studies based on prospective or longitudinal methods where girls are examined every 3-6 months, interviews with girls, and the retrospective and Status Quo methods (Malina *et al.*, 2004:292; Khadgawat *et al.*, 2016:384). Some of these methods are, however, costly and invade girls' privacy. Self-reporting of the onset of menarche by females is also not necessarily accurate because the date is not certainly well memorised (Gallahue *et al.*, 2012:297). Consequently, researchers have started to develop other methods, which include equations that can aid them in predicting maturity offset in order to correct for these limitations (Mirwald *et al.*, 2001:689; Sherar *et al.*, 2005:508). Prediction equations that were developed by Mirwald and co-workers (2001) are found to be reliable as an average difference of only 0.021 ± 0.489 years between the predicted age and the actual age of PHV and predicted PHV was found in girls.

The analysis of the onset period of puberty and reaching menarche is important in terms of anthropometric development (Danubio *et al.*, 2004:470; Sawyer *et al.*, 2018:843). Traditionally the assessment of growth primarily focused on linear growth. Armstrong and McManus (1996:19) indicate in this regard that during the growth spurt, which lasts three years, girls grow approximately 6-8-6 cm respectively over the three years of the growth spurt and reach PHV at approximately 11.9 years.

Changes in body proportions and body composition are also essential components of the growth process due to body composition that undergoes major changes as a result of fat deposition and distribution during the pubertal period (Rogol *et al.*, 2002:192; Papai *et al.*, 2012:41). Estrogen plays an important role in the lipogenic profile of girls during the puberty phase especially after menarche, approximately at or after 12.8 years (Rogol *et al.*, 2002:194; Ameade *et al.*, 2016:6), and is therefore interlinked with body fat and maturation status during adolescence (Kimm *et al.*, 2001:39; Boyne *et al.*, 2010:3195). Consequently, girls with a higher body mass index (BMI) and fat percentage tend to be in general more advanced in their maturation status compared to girls with a lower BMI and fat percentage (Kaplowitz *et al.*, 2001:349; Biro *et al.*, 2001:636; Shadyab *et al.*, 2017:38). In this regard, Deutsch and Mueller (1985:284) found that girls who reach menarche earlier, have a more central pattern of fat deposition compared to girls who reach menarche at a later age. Furthermore, Altintas and As Çi (2008:254) reported that when growth and development are studied, pubertal maturation is an important development process, resulting in an increased fat-to-muscle ratio and in fat deposition in the breast and hip areas in girls. In terms of muscle mass, Naughton *et al.* (2000:310) indicated that between 5 and 17 years, the muscle mass of girls only increase by about 5%. Variations in the accumulation and distribution of fat and muscles between generations are well documented, although the onset period when these differences first appeared is still unknown, because body composition is influenced by various factors, including biological heredity, sex hormones, growth hormones, nutritional status, and energy combustion (Naughton *et al.*, 2000:311).

Information about the phenomenon of puberty and the onset of menarche and its influences on girls' anthropometric development is important for the development of customized exercise and sports programmes as well as during talent identification procedures, where these factors must be taken into account. All maturation processes will influence adolescents' body composition and physical- and motor capabilities, which will consequently affect the performance of physical- and motor skills (Armstrong & McManus, 1996:23; Janz & Mahoney, 1997:1; Viru *et al.*, 1999:92; Baquet *et al.* 2006:53; Des te Croix, 2007:294; Bronikowski & Bronikowska, 2008:31; Pienaar, 2018:5; Ameade *et al.*, 2016:7). In this regard, it is reported that strength develops linear from birth until puberty (Milanese *et al.*, 2010:275) and reaches peak development parallel to PHV and approximately 0.6 years before peak mass velocity (Faust *et al.* as quoted by Malina *et al.*, 2004:328). Acceleration in the development of muscle strength and muscle endurance during adolescence, is also linked to

increased speed and agility (Malina *et al.*, 2004:329). These researchers also found that sub-maximum power output among girls occurs approximately one year after PHV.

Although several researchers have investigated the possible interrelationship between puberty and anthropometric growth before and after reaching menarche, the results are still contradicting (St George *et al.*, 1994; Frontini *et al.*, 2003; Tam *et al.*, 2006; Lee *et al.*, 2007). In this regard, Malina *et al.* (2004:331) found no correlation between peak motor development before, during and after menarche in relation to the onset of menarche. In addition, researchers report that the motor development of girls undergoes only minor changes that are largely the result of anthropometric growth differences from just before the onset of menarche, to about 3 years after menarche (Malina, 1994:390; Malina *et al.*, 2004:331). This is consistent with the findings of Van den Berg *et al.* (2006:286) who report no significant influence of growth and physical and motor fitness capabilities of early, average and late maturing girls, although these findings were based on a small number of subjects. Several researchers have already reported significant relationships between motor skills (Okely *et al.*, 2001:1902), visual motor coordination, gross motor development (Graf *et al.*, 2004:24), self-reported athletic coordination (Taylor *et al.*, 2002:429) and physical activity among young adults. There was however little focus on the interrelationship between anthropometric growth, physical- and motor fitness capabilities of adolescent girls and the influence of menarche on the development of these capabilities. Gerber *et al.* (2014:617) conducted a study on South African boys examining the interrelationship between anthropometric growth and physical- and motor fitness capabilities, where various correlations between variables were found. The majority of the interrelationships that were found between 13.75 and 15.75 years were of moderate to small significance and occurred largely between changes in height, arm span and sitting height, and changes in strength, speed, agility, and hand-eye coordination after correcting for maturation age. However, no studies were found that specifically focused on such interrelationships in adolescent girls. Furthermore, there is a lack of research on the rate of change in physical and motor fitness among adolescent girls that differ in maturity status. Repeated measurements of the same individual over a longitudinal period can, however, be used to analyse these changes over time (Wang *et al.*, 2013:330).

Studies that have been carried out globally have focused to a large extent on the effects of maturation, including menarche, on girls' physical- and motor development and

anthropometric growth separately and to a lesser extent in a combined manner (O'Dea & Abraham, 1999:69; Sampei *et al.*, 2003:1114; Biro *et al.*, 2003:643; Hands *et al.*, 2008:847). However, few similar studies, especially longitudinal studies in South Africa, primarily focused on the effect of the initial period of menarche on girls' current and future physical, motor and anthropometric growth (Henneberg & Louw, 1998; Van Gent, 2001; Monyeki *et al.*, 2006; Travill, 2007; Richter *et al.*, 2007). Studies that have been carried out in South Africa on the characteristics of girls during the puberty phase also mainly include cross-sectional studies, which mostly focused on specific populations and mainly in disadvantaged populations. Henneberg and Louw (1998) focused on the growth and physical fitness of 5 to 20-year-old coloured children in semi-urban areas while Naudé *et al.* (2009:678) focused on body composition, body proportions and the timing of puberty among black adolescent girls. Travill (2007:279) investigated the growth and physical fitness of underprivileged boys and girls aged 8 to 17 years of age, also from a cross-sectional study perspective. Although the *Birth to Twenty Study* is a longitudinal study, it is still in progress, and also focuses on a group of children (6 months to 15 years) growing up in semi-urban environments (Richter *et al.*, 2007:504). Results already reported from this study indicated differences in children of different cultures and races with respect to weight, height, skin fold thickness, and head-, hip- and waist circumference (Richter *et al.*, 2007:504). Although Van Gent (2001:1) investigated the anthropometric growth and the physical and motor fitness of 10 to 15-year-old girls, as well as other cross-sectional studies that were relevant to the study, the data were collected more than five-years ago. The effect of secular changes in growth that occurred over the past few decades must, however, be considered, as it could possibly have an effect on current growth and physical- and motor developmental trends of girls.

It is clear from the above literature that various longitudinal- (Prahl-Anderson *et al.*, 1994; Kemper *et al.*, 2004; Richter *et al.*, 2007, Lee *et al.*, 2005, Monyeki *et al.*, 2006; Volver *et al.*, 2007), cross-sectional- (Henneberg & Louw, 1998; Frederics *et al.*, 2005) and review studies (Malina *et al.*, 1988; Armstrong & McMunus, 2000) have already been completed focussing on girls' anthropometric growth during puberty. The results of these studies are, however, more than ten years old and therefore, the applicability to growth characteristics of current populations are questioned. With regard to physical (muscle strength, cardiovascular endurance)- and motor fitness capabilities (speed, agility, hand-eye coordination and power) only a few cross-sectional- (van Gent *et al.*, 2001; Armstrong *et al.*, 2011, Travill *et al.*, 2007; Van den Berg *et al.*, 2006) and review studies (Viru *et al.*, 1999; Armstrong & McManus,

2000), and only one longitudinal study (Volver *et al.*, 2007) were also found to be relevant to the objective of the current study. Most of these studies were again also older than ten years. It is therefore clear that a gap exists within the literature regarding current data on the anthropometric growth and physical- and motor fitness capabilities of adolescent girls of varying maturity status based on longitudinal data. More specific, limited research also exists in the simultaneous analysis of the anthropometric growth and physical- and motor fitness capabilities of girls during mid-adolescence over a longitudinal period. In addition, a gap also exists in the literature regarding the influence of variable time of onset of menarche on early, average and late developing girls' anthropometric growth and physical- (muscle strength, cardio respiratory endurance) and motor fitness capabilities such as speed, agility, hand-eye coordination, and power.

Therefore, the research questions to be answered in this study are fourfold. Firstly, will menarche status influence anthropometric growth characteristics such as height, mass, sitting height ratio, arm span, leg length, and BMI differently in adolescent girls differently over a two-year follow-up period? Secondly, how do differences in the timing of menarche lead to possible differences in physical fitness abilities (muscle strength, cardio respiratory endurance) in adolescent girls over a 2-year follow-up period? Thirdly it is asked how menarche status will contribute to developmental differences in motor fitness abilities (speed, agility, hand-eye coordination, power) in adolescent girls of differing menarcheal status over a 2-year follow up period. Finally, it is asked what the classification will be of a calculated maturity offset of PHV, an event that occurs early in the pubertal phase, when compared to actual self-reported age at menarche status. Answers to these questions will give Kinderkineticists, sport scientists, coaches and others involved in the physical development of girls, more insight into the magnitude of biological and physiological changes that occur in girls during puberty, and more specifically as a result of reaching menarche, and the impact of this event on other aspects of growth and development. More insight into the accuracy of using equations to predict maturity status will also enable coaches and people working with adolescent girls to adapt their programmes and goals well in advance of reaching menarche for such maturity differences. Such adjustments will contribute favourably to sports development and talent identification processes. This knowledge will also contribute to adolescent girls having more information of the influences of maturation and how differences in the onset of menarche will influence their growth and physical- and motor capabilities differently.

1.3. OBJECTIVES

The objectives of the study are:

1.3.1 To investigate to what extent menarche status will influence anthropometric growth characteristics such as height, mass, sitting height ratio, arm span, leg length, and BMI differently in adolescent girls over a two-year follow-up period.

1.3.2 To determine differences in muscle strength and cardio respiratory endurance as a result of the differing menarcheal status in adolescent girls over a 2-year follow-up period.

1.3.3 To determine differences in speed, agility, hand-eye coordination and power as a result of the differing menarcheal status in adolescent girls over a 2-year follow-up period.

1.3.4 To determine the accuracy of a calculated maturity offset equation to predict maturity status early in the pubertal phase.

1.4. HYPOTHESES

This study is based on the following hypotheses:

1.4.1 Adolescent girls of differing menarcheal status will significantly differ in height, mass, sitting height ratio, arm span, leg length, and BMI over a two-year follow-up period.

1.4.2 Adolescent girls of differing menarcheal status will significantly differ in muscle strength and cardiovascular endurance over a two-year period of follow-up, with post-menarche girls outperforming pre-menarche girls.

1.4.3 Adolescent girls of differing menarcheal status will significantly differ in speed, agility, hand-eye coordination and power over a two-year period of follow-up, with post-menarche girls outperforming pre-menarche girls.

1.4.4 The ability of a calculated maturity offset equation to classify maturity status early in the pubertal phase, will be accurate when compared to actual self-reported age of menarche status.

1.5 STRUCTURE OF THE THESIS

This thesis will be presented in article format. The structure of the thesis will be as follows:

1.5.1 Chapter 1 includes the introduction, problem statement, objectives, and hypotheses of the study. References will follow at the end of this chapter according to the adjusted Harvard method as prescribed by the North-West University.

1.5.2 Chapter 2, includes the literature review of the thesis titled “Relationships between menarche, anthropometric growth and physical- and motor fitness capabilities”. The literature review includes definitions of related terminology, menarcheal development, and methods to determine the onset of menarche, anthropometric development, physical- and motor development and the interrelationship between anthropometric growth and changes in physical- and motor fitness capabilities in girls. Furthermore, methods and results of growth studies that have already been conducted on adolescent girls will be discussed. References that were used in this chapter will follow at the end of this chapter according to the adjusted Harvard method as prescribed by the North-West University.

1.5.3 Chapter 3 is presented in the form of a scientific article. The article is titled: Two-year follow-up of differences in anthropometric growth between pre- and post-menarcheal girls: Implications for sport participation. The article is *submitted* for possible publication in the Journal of Cogent Social Sciences. Author guidelines for publication in this journal can be found in Appendix A. For technical purposes and uniformity of the thesis some changes were made to the guidelines of the journal. The article’s margins are similar to the rest of the thesis and the chapter was typed in one and a half line spacing. Furthermore, the tables and the figures were placed in the text and not at the end of the article and the headings were numbered. The above changes will aid in the easier reading of the thesis and fits into the rest of the thesis structure.

1.5.4 Chapter 4 is also presented in the form of a scientific article. The article is titled: Differences in strength and aerobic endurance between pre- and post-menarche girls during mid-adolescence: A two-year follow-up study. This article is *submitted* for possible publication in the American Journal of Human Biology. Author guidelines for publication in this journal can be found in Appendix B. For technical purposes and uniformity of the thesis some changes were made to the guidelines of the journal. The article’s margins are similar to

the rest of the thesis and the chapter was typed in one and a half line spacing. Furthermore, the tables and the figures were placed in the text and not at the end of the article, and the headings were numbered. The above changes will aid in easier reading of the thesis and fits into the rest of the thesis structure.

1.5.5 Chapter 5 is also presented in the form of a scientific article. The article is titled: Differences in motor fitness capabilities of pre- and post-menarche girls during mid-adolescence: A two-year follow-up study. The article is *submitted* for possible publication in the Annals of Human Biology. Author guidelines for publication in this journal can be found in Appendix D. For technical purposes and uniformity of the thesis some changes were made to the guidelines of the journal. The article's margins were set similar to the rest of the thesis and the chapter was typed in one and a half line spacing. Furthermore, the tables and the figures were placed in the text and not at the end of the article, and the headings were numbered. The above changes will aid in the easier reading of the thesis and fits into the rest of the thesis structure.

1.5.6 Chapter 6 is also presented in the form of a scientific article. The article is titled: Classification agreement when using self-reported age of menarche and calculated maturity off-set in adolescent girls: A two-year follow-up study. The article is prepared for possible publication in the Journal of Human Biology. Author guidelines for publication in this journal can be found in Appendix F. For technical purposes and uniformity of the thesis some changes were made to the guidelines of the journal. The article's margins were set similar to the rest of the thesis and the chapter was typed in one and a half line spacing. Furthermore, the tables and the figures were placed in the text and not at the end of the article, and the headings were numbered. The above changes will aid in the easier reading of the thesis and fits into the rest of the thesis structure.

1.5.7 Chapter 7 includes the summary, conclusions and recommendations of the study.

1.5.8 The Australian Sport Search protocol (Australian Sport Commission, 1996), Canadian Sports for Life (Balyi & Way, 2010) protocol and the International standards for anthropometric assessment that was part of the measuring protocol, are subject to copyright and could not be placed in the appendixes. Therefore, only a short description of the test involved were given in Appendix H.

1.6. APPENDIXES

- 1.6.1 Appendix A: Author Guidelines: Journal Cogent Social Science
- 1.6.2 Appendix B: Author Guidelines: American Journal of Human Biology
- 1.6.3 Appendix C: Author Guidelines: Annals of Human Biology
- 1.6.4 Appendix D: Author Guidelines: Journal of Human Biology
- 1.6.5 Appendix E: Ethical documentation and informed consent forms
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- 1.6.7 Appendix G: Proof of submission of paper for possible publication
- 1.6.8 Appendix H: Description of test items
- 1.6.9 Appendix I: Proof of language editing

1.7 REFERENCES

Altintas, A. & As Çi, F.H. 2008. Physical self-esteem of adolescents with regard to physical activity and pubertal status. *Pediatric exercise science*, 20(2):142–156.

Ameade, E.P.K. & Garti, H.A. 2016. Age at menarche and factors that influence it: A study among female university students in Tamale, Northern Ghana. *Plos one*, 11(5):1-10.

Apter, D., Reinila, M. & Vihko, R. 1989. Some endocrine characteristics of early menarche, a risk factor for breast cancer, are preserved into adulthood. *International journal of cancer*, 44(5):783-787.

Armstrong. N. & McManus, P. 1996. Growth, maturation and physical education. (In N. Armstrong, ed. *New directions in physical education: Change and innovation*. London: Cassell Education. p19-32.

Armstrong. N., & McManus, P. (2000). Growth, maturation and physical education. In N. Armstrong, (ed), *New directions in physical education: Change and innovation* (p19-32.). London: Cassell Education.

Armstrong, M.E.G., Lambert, E.V. & Lambert, M.I. 2011. Physical fitness of South African primary school children, 6 to 13 years of age: Discovery vitality health of the nation study. *Perceptual and motor skills*, 113(3):999-1016.

Australian Sport Commission. 1996. Sport search program. Canberra. Australia.

Ayatollahi, S.M., Dowlatabadi, E. & Ayatollahi, S.A. 2002. Age at menarche in Iran. *Annals of human biology*, 29(4):355-362.

Balyi, I. & Way, R. 2010. Canadian sports for life: The role of monitoring growth in long-term athlete development. Calgary: Canadian Sports Centre.

Baquet, C., Twisk, J.W.R., Kemper, E., van Praagh, E. & Berthoin, S. 2006. Longitudinal follow-up of fitness during childhood: interaction with physical activity. *American journal of human biology*, 18:51-58.

Biro, F.M., McMahon, R.P., Striegel-Moore, R., Crawford, P., Obarzanek, E. & Barton, B.A. 2001. Impact of timing of pubertal maturation on growth in black and white female adolescents: The NHLBI growth and health study. *Journal of pediatrics*, 138(5):636–643.

Biro, F.M., Lucky, A.W., Simbartl, L.A., Barton, B.A., Daniels, S.R., Striegel-Moore, R., Kronsberg, S.S. & Morrison, J.A. 2003. Pubertal maturation in girls and the relationship to anthropometric changes: Pathways through puberty, 142(6):643-646.

Boyne, M.S., Thame, M., Osmond, C., Fraser, R.S., Gabay, L., Reid, M. & Forrester, T.E. 2010. Growth, body composition, and the onset of puberty: longitudinal observations in Afro-Caribbean children. *Journal of clinical endocrinology and metabolism*, 95(7):3194-3200.

Bronikowski, M. & Bronikowska, M. 2008. Motor fitness in relation to the maturational process of pubertal boys and girls. *Papers on anthropology*, 17:28-37.

Carel, J.C. & Leger, J. 2008. Precocious puberty. *The new England journal of medicine*, 358(22):2366-2377.

Dahl, R.E. 2004. Adolescent brain development: a period of vulnerabilities and opportunities. *Annals New York academy of sciences*, 1021:1-22.

Danubio, M.E., DE Simone, M., Vecchi, F., Amicone, E., Altobelli, E. & Gruppioni, G. 2004. Age at menarche and age of onset of pubertal characteristics in 6–14-year-old girls From the Province of L’Aquila (Abruzzo, Italy). *American journal of human biology*, 16:470-478.

Des te Croix, M. 2007. Advances in paediatric strength assessment: changing our perspective on strength development. *Journal of sport science and medicine*, 6:292-304.

Deutsch, M.I. & Mueller, W.H. 1985. Androgyn in fat patterning is associated with obesity in adolescents and young adults. *Annals of human biology*, 12(3):275-286.

Forman, D., Pike, M.C., Davey, G., Dawson, S., Baker, K., Chilvers, C.E.D., Olive, R.T.D. & Coupland, C.A.C. 1994. Aetiology of testicular cancer: association with congenital abnormalities, age at puberty, infertility, and exercise. *British medical journal*, 308:1393-1399.

Frontini, M.G., Srinivasan, S.R. & Berenson, G.S. 2003. Longitudinal changes in risk variables underlying metabolic syndrome X from childhood to young adulthood in female subjects with a history of early menarche: the Bogalusa heart study. *International journal of obesity and related metabolic disorders*, 27:1398-404.

Fredriks, A.M., van Buuren, S., van Heel, W.J.M., Dijkman-Neerincx, R.H.M., Verloove-Vanhorick, S.P. & Wit, J.M. 2005. Nationwide age reference for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Archives of Disease in Childhood*, 90:807-812.

Gabel, L., Mcdonald, H.M. & Heatther, A.M. 2017. Sex Differences and Growth-Related Adaptations in Bone Microarchitecture, Geometry, Density, and Strength From Childhood to Early Adulthood: A Mixed Longitudinal HR-pQCT Study. *Journal of bone and mineral research*, 32(2): 250-263.

Gallahue, D.L., Ozmun, J.C. & Goodway, J.D. 2012. Understanding motor development. 7th ed. New York, NY: McGraw-Hill. 461p.

Gaudineau, A., Ehlinger, V., Vayssiere, C., Jouret, B., Arnaud, C. & Godeau, E. 2010. Factors associated with early menarche: results from the French health behaviour in school-aged children (HBSC) study. *Biomedical central public health*, 10:175-182.

Gerber, B.P., Pienaar, A.E., Kruger, A. & Ellis, S. 2014. Interrelations between anthropometric and fitness changes during mid-adolescence in boys: A 2-year longitudinal study. *American journal of human biology*, 26:617-626.

Graf, C., Koch, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., Lehmache, W., Bjarnason-Wehrens, B., Platen, P., Tokarski, W., Predel, HG. & Dordel, S. 2004. Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-project). *International journal of obesity and related metabolic disorders*, 28(1):22-26.

Hands, B.P., Larkin, D., Parker, H., Straker, L. & Perry, M. 2008. The relationship between physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scandinavian journal of medicine and science in sports*, 19(5):655–663.

Henneberg, M. & Louw, G.J. 1995. Average menarcheal age of higher socioeconomic status urban Cape coloured girls assessed by means of status quo and recall methods. *American journal of physical anthropology*, 96:1-5.

Henneberg, M. & Louw, G.J. 1998. Cross-sectional survey of growth of urban and rural “Cape-coloured” schoolchildren: anthropometry and functional tests. *American journal of human biology*, 10(1):73-85.

Herman-Giddens, M.E., Slora, E.J., Wasserman, R.C., Bourdony, C.J., Bhapkar, M.V., Koch, G.G. & Hasemeier, C.M. 1997. Secondary sexual characteristics and menses in young girls seen in office practice: a study from the Pediatric Research in Office Settings Network. *Pediatrics*, 99(4):505-12.

Janz, K.F. & Mahoney, L.T. 1997. Three-year follow-up of changes in aerobic fitness during puberty: the muscatine study. *American alliance for health, physical education, recreation and dance*, 68(1):1-9.

Jones, L.L., Griffiths, P.L., Norris, S.A., Pettifor, J.M. & Cameron, N. 2009. Age at menarche and the evidence for a positive secular trend in urban South Africa. *American journal of human biology*, 21(1):130-132.

Kaplowitz, P.B., Slora, E.J., Wasserman, R.C., Pedlow, S.E. & Herman-Giddens, M.E. 2001. Earlier onset of puberty in girls: relation to increased body mass index and race. *Pediatrics*, 108(2):347-53.

Kaprio, J., Rimpelä, A., Winter, T., Viken, R.J., Rimpelä, M. & Rose, M.J. 1995. Common genetic influences on BMI and age at menarche. *Human biology*, 67(5):739-753.

Kemper, H.C.G., Snel, J. & van Mechelen, W. 2004. Amsterdam growth and health longitudinal study. *Journal of science and medicine in sport*, 47:1-198.

Khadgawat, R., Marwaha, R.K, Mehan, S., Surana, V., Dabas, V., Sreenivas, V., Gaine, M.A. & Gupta, N. 2016. Age of onset of puberty in apparently healthy school girls from northern India. *Indian pediatrics*, 53(1):383-387.

Kimm, S.Y.S., Barton, B.A., Obarzanek, E., McMahon, R.P., Sabry, Z.I., Wacławski, M.A., Schreiber, G.B., Morrison, J.A., Similo, S. & Daniels, S.R. 2001. Racial divergence in adiposity during adolescence: The NHLBI growth and health study. *Pediatrics*, 107(3):e34-e42.

Lee, J.M., Appugliese, D., Kaciroti, N., Corwyn, R.F., Bradley, R.H. & Lumeng, J.C. 2005. Weight status in young girls and the onset of puberty. *Pediatrics*, 119:624-30.

Malina, R.M. 1994. Physical growth and biological maturation of young athletes. *Exercise and sport sciences review*, 22(1):389-433.

Malina, R.M., Bouchard, C. & Bar-Or, O. 2004. Growth, maturation and physical activity. Champaign, IL: Human Kinetics.

Marshall, W.A. & Tanner, J.M. 1969. Variations in pattern of pubertal changes in girls. *Archives of disease in childhood*, 44:291-303.

Melanese, C., Bortolami, O., Bertuccio, M., Verlato, G. & Zancanaro, C. 2010. Anthropometry and motor fitness in children aged 6-12 years. *Journal of human sport and exercise*, 5(2):265-279.

Mirwald, R.L., Baxter-Jones, A.D.G., Bailey, D.A. & Beunen, G.P. 2001. An assessment of maturity from anthropometric measurements. *Medicine and science in sports and exercise*, 34(4):689-694.

Monyeki, K.D., Koppes, L.L.J., Kemper, H.C.G., Monyeki, K.D., Toriola, A.L., Pienaar, A.E. & Twisk, J.W.R. 2006. Body composition and physical fitness of undernourished South African rural primary school children. *European journal of clinical nutrition*, 59:877-883.

Naudé, D., Kruger, H.S. & Pienaar, A.E. 2009. Differences in body composition, body proportions and timing of puberty between stunted and non-stunted adolescents. *African journal of physical, health education, recreation and dance*, 15(4):678-689.

Naughton, G., Farpour-Lambert, N.J., Carlson, J., Bradney, M. & Van Praagh, E. 2000. Physiological issues surrounding the performance of adolescent athletes. *Sports medicine*, 30(5):309-325.

Nicoletti, I. 1994. *Auxologia normale e patologica*. Florence: Centro Studi Auxologici. p 289-304.

O'Dea, J.A. & Abraham, S. 1999. Onset of disordered eating attitudes and behaviors in early adolescence: interplay of pubertal status, gender, weight, and age. *Adolescence*, 26(136):671-679.

Okasha, M., McCarron, P., McEwen, J. & Davey Smith, G. 2001. Age at menarche: secular trends and association with adult anthropometric measures. *Annals of human biology*; 28(1):68-78.

Okely, A., Booth, M. & Patterson, J. 2001. Relationship of physical activity to fundamental movement skill among adolescents. *Medicine and science in sports and exercise*, 33(11):1899-1904.

Pantsiotou, S., Papadimitriou, A., Douros, K., Priftis, K. & Fretzayas, A. 2008. Maturational tempo differences in relation to the timing of the onset of puberty in girls. *Acta paediatrica*, 97(2):217-220.

Papai, J., Troznai, Z., Szabo, T. & Szabo, A. 2012. Fat pattern of athlete and non-athlete girls during puberty. *Anthropological review*, 75(1)41-50.

Pienaar, A.E. 2018. Motor development, growth, motor backlogs, the assessment and intervention thereof: A manual for postgraduate students in Kinderkinetics. Potchefstroom: Ivyline Printers. 576p.

Plowman, S.A., Liu, N.Y. & Wells, C.L. 1991. Body composition and sexual maturation in premenarcheal and nonathletes. *Medicine and science in sports & exercise*, 23(1):23-29.

Prahl-Anderson, B., Kowalski, C.J. & Heydendael, P. 1994. A mix longitudinal interdisciplinary study of growth and development. New York, NY: Academic.

Richter, L., Norris, S. Yack, D. & Cameron, N. 2007. Cohort profile: Mandela's children. The 1990 birth to twenty study in South Africa. *International journal of epidemiology*, 36(3):504-511.

Rogol, A.D., Roemmich, J.N. & Clark, P.A. 2002. Growth at puberty. *Journal of adolescent health*, 31(6):192-200.

Salces, I., Rebato, E.M., Susanne, C., San Martin, L. & Rosique, J. 2001. Familial resemblance for the age at menarche in Basque population. *Annals of human biology*, 28(2):143-156.

Sampei, M.A., Novo, N.F., Juliano, Y., Colugnati, F.A.B. & Sigulem, D.M. 2003. Anthropometry and body composition in ethnic Japanese and Caucasian adolescent girls: considerations on ethnicity and menarche. *International journal of obesity*, 27(9):1114-1120.

Sawer, M.D., Azzopardi, P.A., Wickremarathne, M.D.S. & Patton, G.C. 2018. The age of adolescence. *The Lancet child and adolescent health*, 2(12):839-904.

Shadyab, A.H., Macera, C.A., Shaffer, R.A., Jain, S., Gallo, L.C., Gass, M.L.S., Waring, M.E., Stefanick, M.L. & LaCroix, A.Z. 2017. Ages at menarche and menopause and reproductive lifespan as predictors of exceptional longevity in women: The women's health initiative. *Menopause*, 24(1): 35-44.

Sherar, L.B., Mirwald, R.L., Baxter-Jones, A.D.G. & Thomis, M. 2005. Prediction of adult height using maturity-based cumulative height velocity curves. *Journal of pediatrics*, 147(4):508-514.

St George, I.M., Williams, S. & Silva, P.A. 1994. Body size and the menarche: the Dunedin study. *Journal of adolescent health*, 15(7):573-576.

Sun, S.S., Schubert, C.N., Chumlea, W.C., Roche, A.F., Kulin, H.E., Lee, P.A., Himes, J.H. & Ryan, A.S. 2002. National estimates of the timing of sexual maturation and racial differences among US children. *Pediatrics*, 110(5):911-919.

Tam, C.S., de Zegher, F., Garnett, S.P., Baur, L.A. & Cowell, C.T. 2006. Opposing influences of prenatal and postnatal growth on the timing of menarche. *Journal of clinical endocrinology and metabolism*, 91(11):4369-73.

Taylor, W., Sallis, J., Dowda, M., Freedson, P., Eason, K. & Pate, R. 2002. Activity patterns and correlates among youth: differences by weight status. *Pediatric exercise science*, 14(4):418-431.

Travill, A.L. 2007. Growth and physical fitness of socially disadvantage boys and girls aged 8-17 years living in the western cape, south Africa. *African journal for physical, health education, recreation and dance*, 13(3):279-293.

Van Den Berg, L., Coetzee, B. & Pienaar, A.E. 2006. The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *African journal for physical, health education, recreation & dance*, 18(3):273-290.

Van Gent, M.M. 2001. Anthropometrical, physical and motor fitness characteristics of 10- to 15-year old girls in the Northwest province. Potchefstroom: NWU. (Dissertation).

Van Lenthe, F.J., Kemper, C.G. & van Mechelen, W. 1996. Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam growth and health Study. *American journal of clinical nutrition*; 64(1):18-24.

Viru, A., Loko, J., Harro, M., Volver, A., Laaneots, L. & Viro, M. 1999. Critical periods in the development of performance capacity during childhood and adolescence. *Physical education and sport pedagogy*, 4(1):75-119.

Volver, A., Viru, A. & Viru, M. 2007. A two-year longitudinal study of sexual maturation effects on motor abilities in girls. *Medicine in sport*, 70:57-63.

Wang, C.K.J., Pyun, D.Y., Liu, W.C., Lim, B.S.C. & Li, F. 2013. Longitudinal changes in physical fitness performance in youth: a multilevel latent growth curve modeling approach. *European physical education review*, 19(3):329-346.

Wohlfahrt-Veje, C., Mouritsen, A., Hagen, C.P., Tinggaard, J., Mieritz, M.G., Boas, M., Petersen, J.H., Skakkebaek, N.E. & Main, K.M. 2016. Pubertal onset in boys and girls is influenced by pubertal timing of both parents. *Journal of clinical endocrinology and metabolism*, 101(7):2667–6674.

World health organization (WHO). 2015. Adolescent health. http://www.who.int/topics/adolescent_health/en/. Page visited 9 April 2015.

CHAPTER 2

LITERATURE REVIEW: RELATIONSHIPS BETWEEN MENARCHE, ANTHROPOMETRIC GROWTH AND PHYSICAL- AND MOTOR FITNESS CAPABILITIES

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2.1 INTRODUCTION

The overarching focus of this thesis is differences in various characteristics that are associated with growth in females that are in different stages of their development during the adolescent period. Within this focus, the objectives of the study are fourfold. First, the study aims to investigate to what extent menarche status will influence anthropometric growth characteristics such as height, mass, sitting height ratio, arm span, leg length and BMI differently in adolescent girls over a two-year follow-up period. Secondly and thirdly, the study aims to determine the possible differences in the physical- (speed, agility, hand-eye coordination, explosive strength) and motor fitness capabilities (strength, aerobic capacity) as a result of differing menarcheal statuses in adolescent girls over a two-year period. Lastly, the study aims to determine the accuracy of a calculated maturity offset equation to predict maturity status early in the pubertal phase.

The period wherein all of the abovementioned changes take place is known as adolescence. Important biological and physiological milestones are reached during this adolescent period including the reaching of peak height velocity (PHV) and menarche. The reaching of both these milestones has a significant influence on girls' anthropometric growth and physical and motor fitness capabilities. In this regard, it is important to have accurate information regarding the onset of PHV and menarche status. Such information can make it possible to draw valid conclusions about the immediate and future effects of reaching these milestones during earlier or later stages in adolescence on a girl's anthropometric growth and physical and motor fitness capabilities. In this regard, it will be important to discuss the usefulness and limitations of existing methods and procedures that were used in the past to collect data on maturation, while new and improved methods to determine and predict girls' maturity status will also be discussed.

Growth and development are two processes that play a continuous role in human maturation from birth, and consequently lead to increased growth of the body as a whole as well as the growth of different parts of the body throughout the life cycle (Malina *et al.*, 2004:4). Knowledge about growth and maturation, especially during adolescence, is therefore important as it is used for various purposes, including monitoring growth longitudinally in order to be able to determine differences in growth curves between individuals of differing maturity status although of the same chronological age. Furthermore, knowledge of growth can also be used during the development of health promotion programs as well as during

talent identification (TID) in sport (Stang & Story, 2005: 1). As the adolescent period is considered to be one of the most complex transitional stages involving morphological, physiological and psychological aspects, (Deborah & Russel, 2005:301; Garnier *et al.*, 2005:718), it also affects individuals' levels of physical activity during this phase of development (Eisenmann & Wickel, 2009:260). In this regard, biological maturity (levels of differentiation of cells, tissue, skeleton or organs, see 2.2.4 for a full definition) during adolescence plays a fundamental role in the development of physical and motor capabilities (Beunen *et al.*, 2006:s2451; Bronikowski & Bronikowska, 2008:34), especially during the pubertal phase. Therefore, as most sporting codes select teams according to chronological age to manage participation in sport (Davids & Baker, 2007:7) and not biological age that takes maturation of girls of the same chronological age in consideration, the current literature review will investigate the possible differences in growth between early and late developing girls as well as possible differences in physical- and motor fitness capabilities.

This literature review will, therefore, focus on studies of differences in the anthropometric growth and the physical- and motor fitness capabilities of early- and late developing girls, especially during the adolescence period. Literature that focuses on the timing of the onset of menarche and ways to determine the date of onset of menarche and maturity status will firstly be investigated. Thereafter anthropometric growth followed by the developmental tendencies of girls' physical- and motor fitness capabilities will be investigated followed by investigations into the possible interrelationships between girls' anthropometric characteristics and physical- and motor fitness capabilities. Lastly, the methods and results of cross-sectional, longitudinal and review growth studies that have already been complete, will be investigated. The terms associated with the present study will be defined and explained as a starting point. This literature review will only focus on the growth and development of girls as females are the focus of this thesis.

2.2 TERMINOLOGY

Terms relevant to the aims of the study form the background of the literature review. These include adolescence, puberty, maturation, menarche, the difference between chronological and biological age, TID, growth, and growth assessment.

2.2.1 Adolescence

The age bracket ascribed to adolescence, although a well-researched topic, still differs among reliable sources in the current literature. According to the “*Verklarende Woordeboek van die Afrikaanse Taal*”, adolescence is described as the period that extends from puberty into adulthood – between 14 and 21 in boys and 12 and 21 years in girls (Schoonees *et al.*, 1981:18). The World Health Organization (WHO) categorizes adolescence as the period between the age of 10 and 19 years in both boys and girls (WHO, 2015a:1), whereas the United Nations describes adolescence as the period between the ages of 15 and 24 years in both boys and girls (UNESCO, 2014:1). Rodriguez *et al.* (2004:54) define adolescence as a critical period in the human’s life because of a variety of changes that take place between childhood and adulthood, characterized by a global acceleration in growth and maturation of the body. In this regard, Deborah and Russel (2005:301) add that adolescence is part of puberty, during which secondary sexual characteristics develop.

According to Deborah and Russel (2005:301), adolescence can be divided into three sub-phases, namely early-, mid- and late adolescence, based on differential influences on various physical, biological and sexual characteristics:

- In girls, early adolescence refers to the period between 10 to 12 years. This period is characterized by early puberty and includes the development of breasts and pubic hair. This period also includes the start of a growth spurt that represents a period of accelerated growth over a three-year period due to significant hormonal changes that take place as a result of puberty in girls. Girls develop concrete thought processes and early moral concepts during this period. Lastly, girls develop a stronger identity and gain acceptance of their sexual development.
- Mid-adolescence refers to the period between 12 and 17 years. This is the period during which the growth spurt ends. Girls also reach menarche during this period. They develop a mature female body shape with fat deposits changing certain areas of the body to prepare the body for reproduction.
- Late adolescence refers to the period between 17 and 20 years, when girls reach a mature status in most aspects of development.

2.2.2 Puberty

According to researchers (Schoonees *et al.*, 1981:867, Demirkale *et al.*, 2019:3), puberty is a period during which specific characteristics of gender maturity start to develop. It starts during early adolescence when gender glands become functional and secondary sex characteristics start to develop (Anderson, 2009:1). Puberty starts at approximately 14 years in boys and 12 years in girls.

The first signs of puberty in girls are the onset of breast development (breast buds), which occurs at an average age of approximately 11 years (Demirkale *et al.*, 2019:3). Puberty status is mainly determined by means of the Sexual Adulthood Scale or Tanner phases. Tanner divides pubertal development into five phases from pre-puberty to adulthood (see 2.5 – maturation for a complete discussion of the phases). Girls who have not reached the outcomes of Phase 2 (no elevation of the papilla and no pubic hair) are referred to as pre-pubertal girls (Pantsiotou *et al.*, 2008:217). When menarche or the first onset of menses occur in girls, they are at the end of puberty and are then classified as post-pubertal (O'Donnell, 2012:1).

2.2.3 Maturation

Maturation describes the changes that occur in the body due to growth, which in turn leads to changes in the form and complexity of the body (Balyi & Way, 2010:6). This results in two forms of maturation, namely structural maturation, and functional maturation. Structural maturation refers to accumulating growth in stature and the size of certain body parts and begins with the start of the growth spurt. It ends when the mature body stature has been reached in late adolescence. Functional maturation refers to the ability to achieve functional or sexual re-productivity (Pienaar, 2018:5). The first signs of maturation in girls occur during the onset of puberty (Gluckman & Handson, 2006:10).

2.2.4 Menarche

Menarche refers to the start of the menstrual cycle in girls; in other words, when a girl starts ovulating for the first time (Towne *et al.*, 2005:210). It starts on average at the end of puberty (10 to 13 years) and approximately six months to one year after peak height velocity (PHV) (Gluckman & Handson, 2006:10; Karapanou & Papadimitriou, 2010:118). When a girl

reaches menarche, it leads to various somatic, endocrine and psychiatric changes (Marshall & Tanner, 1986:172). Data from the United States of America indicates that menarche starts on average at 12.6 ± 1.5 years of age, with 12.0 years as the mean age (Chen *et al.*, 2016:470). Chinese girls reach menarche on average from the age of 12.5 ± 1.4 years, although nearly one quarter (23.9 %) reach menarche earlier (<11 years) (Xie & Ho, 2016:133). Malina *et al.* (2004:339) state that menarche approximately starts at 12.8 ± 1.0 years in girls, and this cut-off point is used globally to indicate early- (11.8 years), average- (11.8 - 13.8 years) and late developing (> 13.8 years) girls.

A variety of methods are used to determine the onset of menarche, including monitoring studies based on longitudinal methods, interviews with girls, recall methods and the Status Quo method (Mirwald *et al.*, 2001:689). These methods will be discussed in more detail later in the literature review. Information from the latter methods can be used to classify girls as pre- and post-menarche on the basis that pre-menarche girls have not yet had their first menstruation, while post-menarche girls have already reached menarche.

2.2.5 Chronological versus biological age

Chronological and biological age are important terminology that needs to be understood when growth is studied. Chronological age is universally used to group children, adolescents, and adults and is defined as an individual's age in months and years from the date of birth (Gallahue *et al.*, 2012:9). Biological maturation, also known as relative age, is defined as the tempo of development of various aspects of the body until it reaches maturity (Wilmore & Costill, 1999:518). Guedes (2011:130) defines biological maturation as the concept of biological aging, which is used as a reliable estimate of the level of maturation of an individual.

2.2.6 Talent identification (TID)

TID is a process used to identify individuals who have the potential to perform well in sport (Vaeyens *et al.*, 2008:703). Talent in sport is identified by looking for characteristics that are partly genetic and which are influenced by a variety of environmental conditions that are difficult to measure (Elliot *et al.*, 1989:15). Furthermore, talent during adolescents is influenced by the interaction between natural abilities, the ability to perform mature game

patterns at a young age, and the ability to perform advanced sport-specific skills (Howe *et al.*, 1998:399).

Furthermore, it is difficult to identify future sporting potential by predicting future development of a player rather by evaluating and using their current growth and performance as indicators of future growth and development (Mitchell, 2013:1). Growth and maturity have a direct influence on the abilities of a player at a specific time, and it should be taken into account during sport TID and development programmes. Girls chosen for sports teams before the onset of puberty are therefore chosen on favourable physical characteristics. This is not optimal, as it can lead to late developing girls not being given a chance to be included in TID programs or to compete as a result of insufficient physical characteristics (Williams & Reilly, 2000:600). Individuals who initially have the desired characteristics, such as ideal body size or speed, are usually not able to keep this advantage throughout the process of maturation (Vaeyens *et al.*, 2008:705).

2.2.7 Growth

On a cellular level, growth is the result of an increased number of body cells in the human growth plates, leading to increases in body stature and the length of body segments. As a result of these increases, there is an increase in body mass (Dimeglio, 2001:549). This definition concurs with that of Pienaar (2018:5), who defines growth as the structural and physiological changes that occur as a result of an increase in cells and the intracellular connective changes that take place during the maturation phase. Malina *et al.* (2004:4) suggest that growth signifies the enlargement of the body as a whole, as well as in various body segments. This contributes to a person becoming taller and heavier as the growth process progresses. As from birth, growth can be divided into three main periods, namely:

- The first year of life, called the baby year.
- The period from one year of age up to adolescence. The second phase can further be divided into the early childhood years (preschool, one to six years) and the mid-childhood years (primary school period, 7 to 13 years).
- The third period is referred to as adolescence (12 to 21 years). This period is difficult to define in terms of chronological age as a result of variation in the onset of this period. Girls enter puberty on average at age 12, which includes three years of rapid growth (growth spurt) and the milestone of reaching maximum growth

in one of these years (PHV). The growth spurt, including PHV, are both associated with significant changes in the girls' growth and maturation during puberty. This contributes to various growth changes in anthropometric characteristics, while also influencing changes in girls' physical and motor fitness capabilities (Van den Berg *et al.*, 2006:287).

Human growth entails significant changes in body size, proportion, and appearance from birth up to maturity (Malina *et al.*, 2004:4). The process of growth is not continuous. There are periods of accelerated growth during certain periods of human life, with gradual growth or temporary plateaus at other times (Malina *et al.*, 2004:4). Individual patterns of growth also vary as a result of differences in genetics and the environment in which we live (Pienaar, 2018:9). Children are inclined to bear similar or even the same growth patterns as their parents or ancestors, although influences such as the environment, life circumstances, nutrition, and hygiene also have significant influences on the growth process (Pienaar, 2018:139). Balyi and Way (2010:4) state that growth occurs mainly in three areas, namely neural (growth of the brain and the nervous system), structural (growth in terms of stature and body mass) and genital growth (development of primary and secondary sexual characteristics).

2.2.8 Assessment of growth

The assessment of growth provides a reference for the determination of normal development in a population or nation (Dimeglio, 2001:549). Decades ago, Tanner (1992:106) speculated that growth reveals nutritional and health status of an entire society, reflecting secular changes and the varying health and welfare of populations over time. Nicoletti (1994) (as cited by Danubio *et al.*, 2004:470) states that the study of puberty plays an important role in medical research because of the complex physiological changes that occur during this period. Measures of body stature are therefore important to evaluate children's growth, to calculate their nutritional index, and to calculate and standardize the physiological characteristics of lung volumes, muscle strength and basal metabolic rate (WHO, 2006:10). Moreover, growth assessment is vital during the process of TID, because in the world of sport, specific body types, including body build and body proportions, are required (Balyi & Way, 2010:5).

In view of the above basic terms, following a discussion on the biological process of menarche, its differential timing and the various methods to identify the onset of menarche.

2.3 TIMING OF THE ONSET OF MENARCHE

The most reliable indicator of the secular pubertal changes that take place during the adolescent period in girls, is the onset of menarche, especially when it is reached at an early age (Parent *et al.*, 2003:668; De Sanctis *et al.*, 2019:2). During the last few decades, the medical profession has had a curious interest in girls reaching menarche at earlier ages (Parent *et al.*, 2003:668; De Sanctis *et al.*, 2019:3). This interest reflects an accumulated awareness among various interest groups as a result of the inequality that emerges from the earlier biological reproductive ability. Young girls are not psychologically ready for these changes or do not have the social maturity until at least in their late teens, a few years after they reached biological maturity (Gluckman & Handson, 2006:7).

Parent *et al.* (2003:671) performed a review study that showed that the onset age of menarche has lowered from 1983 to 2006. It is estimated that during the most part of the 20th century, the onset age of menarche has lowered with three months per decade (Tanner, 1989 as cited by Karapanou & Papadimitriou, 2010:115), indicating that girls reach puberty three months earlier every 10 years.

The onset age of menarche varies between individuals and possibly among populations. This leads to individual differences in reaching developmental milestones such as adult growth characteristics and the maturation of the physiological and biological systems of girls at different ages although the sequence of changes is identical. These differential maturational aspects are important for coaches, school teachers, and persons who work with female children and adolescents because of the influence that reaching menarche has on various aspects of development. Consequently, accurate information on the onset of menarche is vital to ensure that maturational differences between girls are taken into consideration during team selection and TID. The methods to determine the onset of menarche are subsequently discussed.

2.4 METHODS TO DETERMINE THE AGE OF MENARCHE

Various methods are utilized to determine the time at which menarche is reached, each with its individual strengths and challenges. These methods include longitudinal monitoring

studies where girls' sexual maturation is examined every three to six months, interviews, retrospective methods, recall, and the Status Quo method (Malina *et al.*, 2004:292).

Improved methodology to assess the pubertal process and maturation has led to more research on pubertal development, especially in girls (Steinberg & Morris, 2001:89). The accuracy of the retrospective method that requires girls to recall the exact onset date of first menstruation (a method that was quite sufficient in the 1900s), is now questioned based on doubt about the ability of girls to accurately recall the date of onset of menarche after a number of years (Towne *et al.*, 2005:210).

The recall method obtains information pertaining to the date of onset of menarche from post-menarcheal girls (or their mothers) by asking if they can remember and recall the age at their first menstruation (Henneberg & Louw, 1998:2). Many studies have examined the correlation between the recalled and actual age of menarche. Livson and MacNeil (1962:218) longitudinally studied 43 girls in the late 1920s with regard to various aspects of growth and development from early childhood to adolescence. During the time of the study, these girls reported their onset of menarche and were asked 17 years later to recall the date. The researchers found a correlation between actual and recalled age of $r=0.75$. Damon and Bejema (1974:383) performed a study on women whose menstrual history was known and a correlation of 0.60 was found after they had to recall the onset of menarche approximately 39 years later. Koo and Rohan (1997:61) found after a two-year recall that only 59.1% of women could recall the correct month and year, while the recalled date of 77% of women deviated within one month in relation to the actual date of onset.

These results show that the recall method becomes less valid and less accurate with a bigger time lapse between menarche and the time of recall. Furthermore, only girls who have already reached menarche can be evaluated by means of this method because it is a recall of the past and not a method that investigates the current state of menstruation (Karapanou & Papadimitriou, 2010:117).

The results obtained from monitoring studies are considered to be more accurate. However, these studies are difficult to perform because of the longitudinal nature of the method. Pre-menarcheal girls have to be monitored every three months in these studies, to accurately determine whether their menstrual cycle has started (Karapanou & Papadimitriou, 2010:117).

The Status Quo method gathers information about the current state or the onset age of menarche by asking a girl (or her mother) to indicate whether menstruation has started before or after the time of assessment (Furu, 2009:588). The girl or parent should answer the question with a Yes or a No. When the answer is Yes, she should indicate the year and month when the first menstruation occurred. When using the Status Quo method, the study sample should be large and representative of a population. This method should also be used among girls 8 to 16 years of age, as this age period includes the minimum and maximum ages that menarche is usually reached (Karapanou & Papadimitriou, 2010:119).

All of the methods as described above have various challenges, including validity and accuracy of the information obtained, methods being time consuming and personally invasive, and the fact that menarche is a late event in the pubertal phase. More non-invasive methods than physical assessments and age of menarche are necessary to classify girls into early, average and late developing girls, according to Malina *et al.* (2016:245). Consequently, a once-off and non-invasive method is needed to determine girls' maturational statuses earlier in the pubertal phase. Such a non-invasive method that can be used earlier in the pubertal phase to classify girls as early or late maturing girls will now be discussed.

2.5 METHODS TO DETERMINE MATURITY STATUS

One of the most effective methods to determine gender maturation is the use of the Tanner scale, which portrays physical and sexual maturation (Marshall & Tanner, 1969:291). This scale is a 5-point evaluation scale that is used to determine stages of genital and pubic hair development. The average general stages of puberty and stages of genital and pubic hair development of girls as described by Marshall and Tanner (1969:291) are:

General stages

- Level 1: Pre-puberty stage (approximately 8 to 11 years)
- Level 2: First development of gender sexual characteristics (approximately 8 to 14 years)
- Level 3 + 4: Continual development (approximately 9 to 15 years)
- Level 5: Adult development (approximately 12 to 19 years)

Stages of breast development

- Stage 1: Pre-adolescence with an elevation of the papilla.
- Stage 2: Characterized by the development of the breast bud, the elevation of the breast and papilla to a small mound and the enlargement of the areola.
- Stage 3: Continuous enlargement of the breast and areola with no separation visible of the contours.
- Stage 4: Areola and papilla are projected and forms a secondary mound above breast level.
- Stage 5: Mature stage where only the papilla is projected due to the recession of the areola.

Stages of pubic hair development

- Stage 1: Pre-adolescent, no pubic hair.
- Stage 2: Sparse growth of long, slightly pigmented, downy hair, straight or only slightly curled, appearing chiefly along the labia.
- Stage 3: Considerably darker, coarser, and more curled. The hair spreads sparsely over the junction of the pubes.
- Stage 4: Hair is now adult in type. The area covered by hair is still smaller than for adults, with no spread to the medial surface of the thighs.
- Stage 5: Adult in quantity and type. Hair is distributed as an inverse triangle of the classically feminine pattern.

The need to assess maturation, especially the time and tempo of progressing to a mature state is important when studying growth in children and adolescents (Mirwald *et al.*, 2001:689). It is known that maturational changes do show interrelationships with changes in physical characteristics, with definite differences in anthropometric growth characteristics and physical fitness capabilities between early and late developers in comparison to average developing girls (Gay *et al.*, 2004:76). Different procedures are used that include skeletal age, dental age, assessment of secondary sexual characteristics and determining of PHV.

The assessment of skeletal age, which is considered the single best maturational index, is costly, requires specialized equipment and interpretation, and incurs radiation safety issues (Mirwald *et al.*, 2001:689). Although the methodology covers the entire period of growth

from birth to adult maturity, it does not lend itself to fieldwork. Dental age and morphological age are broader measurement techniques that are also used, but they have limited applicability (Mirwald *et al.*, 2001:689). The assessment of secondary sex characteristics is another method but is limited to the adolescent period. In a nonclinical situation, it is considered by parents to be personally invasive to children and adolescents (Mirwald *et al.*, 2001:689). In addition to the limited application period, as explained, secondary sex characteristics do not reflect the timing of growth. Somatic methods, including age of peak height velocity (PHV) or the differential growth associated with segmental growth (arm span, sitting height, leg length), require continuous measurements for a number of years before and after PHV and are not suitable for a once-off measurement in time (Mirwald *et al.*, 2001:689). It is therefore important to be able to determine when PHV will occur in order to plan training and developmental programmes accordingly. Various methods are available to determine PHV, although each method has its advantages and disadvantages.

Based on the various challenges that are outlined in the previous paragraph, there is a valid, less invasive once-off assessment of biological growth and maturation of girls that can be used in schools and field-settings (Malina *et al.*, 2016:440). Mirwald and co-workers (2001:691) developed maturity offset equations to calculate the maturity offset of boys and girls. Maturity offset is a cross-sectional measure that estimates age at PHV and is expressed in years around PHV where negative values indicate pre-PHV and positive values post-PHV. Mirwald *et al.* (2001:691) suggest that calculated maturity offset equations are accurate up to four years pre-PHV and no more than two years post-PHV, with utility between 8 to 16 years of age. Variables that are used in these equations include:

- Independent variables: chronological age, stature, sitting height, leg length, and mass.
- Interaction variables: variables that are calculated that reflect the interaction between specific anthropometric variables and age, which include age and height, age and sitting height, age and leg length, age and mass, and the interaction between leg length and sitting height.
- Five ratio variables: mass divided by height, body mass index (BMI) (mass divided by height squared), sitting height divided by height, leg length divided by height, and leg length divided by sitting height (Mirwald *et al.*, 2001:691).

After many equations were tested, a final equation was developed for girls that look as follows:

Maturity offset = $-9.376 + 0.0001882 \times (\text{leg length and sitting height interaction}) + 0.0022 \times (\text{age and leg length interaction}) + 0.005841 \times (\text{age and sitting height interaction}) - 0.002658 \times (\text{age and mass interaction}) + 0.07693 \times (\text{mass by height ratio})$

*Interactions: A x B

*Ratio: A/B x 100

R = 0.94, R² = 0.890; Standard error of estimate (SEE) = 0.569.

With the above literature as background to methods for determining girls' maturation, including methods to determine the onset date of menarche and calculating maturity offset, the focus of this literature study will now turn to literature findings regarding the influence of menarche on the development of anthropometric characteristics and body composition.

2.6 ANTHROPOMETRIC GROWTH AND BODY COMPOSITION OF GIRLS

Growth and development are both standard processes that all individuals undergo which proceed in a definite pattern, although the onset and duration of these processes differ between individuals. This is the reason why Balyi and Way (2010:3) state the importance of establishing growth patterns for individuals, groups, and populations through a longitudinal time frame to enable the monitoring and analysing of growth status and growth tendencies meaningfully.

Growth and body composition are globally measured by using anthropometric measurements to monitor physical dimensions, body composition and related gender growth characteristics of individuals, groups, and populations (Wells, 2007:416). Anthropometry, derived from the words *anthropos* (man) and *metry* (measure), is a set of standard techniques that are used to take measures of the body and body segments (Malina *et al.*, 2004:42). A variety of measurements or a combination of measurements are commonly used for clinical purposes in the evaluation of growth and growth abnormalities, for example, an unusually short stature (Mumtaz *et al.*, 2009:308). The golden standard protocol that is used globally to take

measurements is prescribed by the International Society for the Advancement and Kinanthropometry, also known as ISAK (Stewart *et al.*, 2011).

Maturation and the onset of menarche play an important role in the growth process of girls (Mirwald *et al.*, 2001:689). Growth measurements can be used to determine an individual's maturation and the possible influence of maturation, including the onset of menarche, on a girl's growth. Furthermore, growth information can put an individual in objective focus in comparison with other individuals of the same race, gender, and age (Balyi & Way, 2010:3). Lastly, information about girls' growth, development and maturation status can be used to identify sporting talent more accurately. In this regard, growth relative to menarche will next be discussed.

2.6.1 Growth relative to menarche

Body size factors, including stature, body mass, body mass index (BMI) and body fat percentage, have long been found to be strongly associated with the onset of menarche (Plowman *et al.*, 1991:2326; St George *et al.*, 1994:575). The relationship between the growth spurts in stature and body mass and menarche has long been studied (Tanner, 1962:1). Early maturing girls tend to have more mass-for-height as reflected in a stocky build, where late maturing girls tend to have less body-mass-for-height and are leaner in build. Proportional differences are also reflected in the shoulders and hips and in the legs and trunk as differences in the leg and trunk length are related to the duration of growth (Malina *et al.*, 2004:342). Early maturation is associated with earlier closure of the growth plates, which results in relatively shorter limbs compared with the torso, whereas late maturation is associated with later closure of the growth plates, which results in longer limbs due to an extended period of limb growth (Malina *et al.*, 2004:342).

The following section focuses on the influence of differential timing of onset of menarche, on selected anthropometric growth variables used during this study, including stature, body mass, sitting height, sitting height ratio, and BMI.

2.6.1.1 Stature

Stature is defined as the perpendicular distance between the transverse level of the vertex and the inferior aspects of the feet (Malina *et al.*, 2004:42; Stewart *et al.*, 2011:57). The first two years from birth are described as a growth acceleration phase because children grow approximately 10cm during the first year after birth and 12 to 13cm during the second year, where after their growth levels out at approximately four years of age (Rogol *et al.*, 2000:523s). From around the age of four years, children start growing approximately five to six centimetres annually until the onset of puberty, where after a final phase of accelerated growth, called the adolescent growth spurt, occurs. This phase includes peak height velocity (PHV) (Rogol *et al.*, 2000:523s).

PHV is a period during which adolescents experience their maximal growth in stature, i.e. the time of maximal growth per annum. Females (11.3-12.2 years) experience PHV earlier than males (13.3-14.1 years), though males appear to grow more during this period (Malina *et al.*, 2004:308). The onset of the adolescent growth spurt coincides with the onset of puberty. During this period, many of the body's hormones, such as the growth hormone thyroxine, insulin, and corticosteroids (all of which influence growth), leptin (which alters body composition), and parathyroid hormone, 1,25-dihydroxy-vitamin D, and calcitonin (all of which affect skeletal mineralization) change, and in turn influence growth (Cole *et al.*, 2015:867). However, the key hormone in growth is the growth hormone, which is mediated by growth hormone releasing hormone (GHRH) and somatostatin (SS) (Cole *et al.*, 2015:867).

Longitudinal results from a study done by AberbergaAugskalne and Kemper (2007:7) on seven- to 16-year-old girls (N=45) from the Netherlands over a ten-year period, showed a well-defined adolescent growth spurt in stature. Results from this study show that PHV occurred in 73% of the girls (early developers) at 10.5 ± 0.4 years and in 2.2% girls (late developers) at 13.9 ± 0.6 years (AberbergaAugskalne & Kemper, 2007:7) with a median age of 12.2 ± 1.2 years. The results further indicated an average PHV of 8.2 ± 1.9 cm in average developers, 9.4 ± 1.7 cm in early developers and 7.2 ± 2.2 cm in late developers during the first year of the growth spurt in girls. Final statures of these Dutch girls at 16 years of age were 165.0 ± 4.1 cm (average developers), 165.2 ± 3.4 cm (early developers) and 168.5 ± 1.7 cm (late developers) (AberbergaAugskalne & Kemper, 2007:9). From these findings, it becomes clear that although the late developing girls grew less at a younger age and during

the first year of their growth spurt, they were ultimately taller compared to average and early developing girls.

Regarding a girl's stature, data from Australia, as tabulated in Table 2.1, indicates that the average stature of 16-year-old girls is 164.5cm (Van Gent, 2001:53). Furthermore, results from Van Gent (2001:53) indicate that girls from the Northwest Province in South Africa are generally shorter than the average South African girl of the same age. Results similar to Van Gent's is reported by Travill (2007:283). Travill's study was performed on South African girls from the Western Cape and showed that the height-for-age of these girls from underprivileged areas was lower in comparison with the average South African girl. This was attributed to socio-economic circumstances that may have influenced puberty, PHV and the onset of menarche. None of these studies took into consideration or describe the influences of maturation and more specific the influence of differential timing of onset of menarche. Therefore, only broad conclusions can be drawn from the results of these studies.

Bronikowski and Bronikowska (2008:30) performed a study on 13-year-old boys and girls from Poznań, Poland. They found that early developing 13-year-old girls were taller than the average developing girls, with an average difference of 5 cm in stature between the maturity groups. The average stature of girls in the various maturity groups at 13 years of age were as follows: early developers (160.7cm) and late developers (159.9cm). In accordance with Bronikowski and Bronikowska's comparative study of early and late developers, results from Cumming *et al.* (2012:751) of 252 girls between 11 and 14 years in England also show variances in stature between early and late developing girls with minimum (late developers) and maximum (early developers) values of 143.2cm and 158.5cm (11-12 years), 150cm and 166.0cm (12-13 years) and 153.2cm and 166.6cm (13-14 years). Maturity status in this study was determined by calculating the percentage of adult stature using the Khamis-Roche method and not the onset of menarche. The Khamis-Roche method predicts adult stature in the absence of skeletal age with only a slight decline in accuracy and reliability. The applicability of the Khamis-Roche method is, however, limited to white American children without pathologies (Khamis & Roche, 1995:504).

Stature is not an isolated growth process but is influenced by growth in the different body parts or segments that jointly contribute to a person growing taller and heavier. Body segments studied in this thesis include arm span, sitting height and the ratio between sitting height and total stature. This makes a discussion of growth in these body segments relevant.

2.6.1.2 Arm span

Arm span refers to the perpendicular distance between the tip of the middle fingers of both hands when the arms are stretched out horizontally at shoulder height (Simmons, 2000:1).

Growth in the upper extremity (arms and hands) follows a similar developmental pattern as that of the lower extremities, where the first five years after birth is characterized by accelerated growth up to where after a plateau is reached. A further acceleration is found at the beginning of puberty (Pritchett, 1988:523; Dimeglio, 2001:554). The hand shows a relatively small growth acceleration approximately 6 months before the forearm, with peak growth more or less 6 months before the upper arm. The ulna is approximately 80% of the length of the humerus after five years of age (Dimeglio, 2001:554). According to a study done by Van Gent (2001:53), girls from the Northwest Province of South Africa and the average girl in South Africa generally displays similar arm spans (Table 2.1), varying from 149.03cm at 12 years to 161.83cm at 15 years. It is clear from the results presented in table 2.1 that the arm spans of South African girls are generally shorter than that of Australian girls between 12 and 14 years, which varies from 155.6 cm to 164.02 cm.

Results from a study done by Lee *et al.* (2005:18) on girls aged eight to 18 years from Taipei, showed longer arm span values at 13 years (157.0cm) compared to the average South African girl and girls from the Northwest Province in South Africa. However, these arm span values are still less than that of Australian girls at a younger age. South African girls did (Table 2.1). Information specific to differences between the arm spans of maturity groups (early and late onset of menarche) have not yet been reported resulting in insufficient literature in this regard.

Arm span can also be used as an alternative to determine an individual's stature when it is not possible to determine stature in itself, since these two body segments differ minimally in length. This last-mentioned assumption was tested in a study by Golshan *et al.* (2007:364) where minor differences between arm span and stature (approximately two centimetres) were found in boys and girls. Zverev and Chisi (2005:469) also investigated this relation among healthy children between six and 15 years from the St Pius Primary School in Blantyre, Malawi. An average correlation of 0.98 was found between arm span and stature among boys. Arm span is also useful in determining body proportion, especially among children, and can be a useful indicator of growth abnormalities in the case of a disproportion between the

arm span and stature of the child (Dimeglio, 2001:549). This relation between arm span and stature is expressed in terms of a ratio, where a ratio of 1:1 indicates a correlation of 1.0. Quanjer *et al.* (2014:909) investigated arm span and stature among individuals from different countries from birth to 80 years of age. From these results, the ratio of girls' arm span and stature was reported to be approximately 0.97 (European), 1.00 (Asian) and 1.1 (Iranian). The ratios increased from birth until 18 years to a ratio of approximately 1.1 to 1.4 among the different countries, after which a plateau was reached. None of the studies analysed arm span differences between early and late developing girls.

2.6.1.3 Sitting height and sitting height ratio

Sitting height refers to the perpendicular distance between the transverse surface of the vertex (upper part of the head) and the inferior aspect of the gluteus maximus when in a sitting position (Malina *et al.*, 2004:42; Stewart *et al.*, 2011:60). A sitting height ratio is calculated when putting sitting height in relation to an individual's total stature (Malina *et al.*, 2004:48). In this regard, sitting height is then calculated as a percentage of the total stature in order to determine the length of the upper body and lower limbs separately (Malina *et al.*, 2004:48). According to Martorell *et al.* (as quoted by Malina *et al.*, 2004:68), sitting height, among girls, show a linear increase from birth until approximately 10 years, where after upper-body growth slightly increases and evens out at approximately 14 years of age. Final increases in sitting height occur after PHV has taken place.

One of the general methods to investigate and compare body proportions among children is to determine the ratio between sitting height and stature or sitting height and leg length and to compare the results with age-specific reference data. Sitting height can also be used as an estimation of stature when stature measures are not possible, for example when there are deformities of the lower limbs (Fredriks *et al.*, 2005:807). In special cases where certain limbs are missing (for example both lower limbs), sitting height can be used to determine an estimated total stature (Fredriks *et al.*, 2005:807). This ratio can be compared with age-specific reference data to determine cases of extreme short or long stature. According to Fredriks *et al.* (2005:807), sitting height or sitting height ratio can also be used to gain information on individuals with extraordinary short or long stature. In such cases, total stature and leg length are compared to sitting height to determine the relation between the different body segments. Furthermore, growth curves can be determined by taking sitting height

measures into account, normally expressed as a percentage of the total stature (Lee *et al.*, 2005:16).

Apart from using sitting height as a body segment in growth analyses, sitting height ratio measures can be used for various other purposes such as predicting the onset of puberty. According to Dimeglio (2005:550), PHV is reached around 11 to 13 years of age among girls when they reach the so-called bone age. Once girls reach bone age, few if any further growth takes place in the lower limbs, with growth only taking place in the upper limbs (sitting height) until final stature is reached (Tanner *et al.*, 1966:460; Tanner & Whitehouse, 1976:174; Tanner & Davies, 1985:320). Generally, girls' sitting height is approximately 75cm at the onset of puberty (Dimeglio, 2001:550). According to these researcher, approximately 80% of girls reach menarche when their sitting height reaches 84cm. These ratios and tempos are only a reflection of the growth phenomenon and therefore precise measurements of the Tanner phases and the onset of puberty are needed to develop more accurate data in this regard.

Van Gent (2001:53) reports results regarding the sitting height of girls aged 12 to 15 years in the Northwest Province of South Africa, the greater population of South Africa, as well as data of Australian girls of the same age. Because of variances in stature (Australian girls are taller), Australian girls also have taller sitting heights compared to South African girls (Table 2.1). Van Gent (2001:53) also found that girls from the Northwest Province of South Africa display similar sitting heights to the greater population of South Africa.

When comparing stature and sitting height of different countries, it must be kept in mind that maturity levels at a certain age and gene-pools differ among countries, and probably also between the northern and southern hemispheres. Fredriks *et al.* (2005:810) developed national reference data for sitting height among boys and girls in the Netherlands. These researchers reported sitting height values for girls from the Netherlands to be 83.13cm to 88.71cm between 13 and 18 years. When compared to reported South African and Australian values, Dutch girls have taller sitting height measurements (Table 2.1). According to Smith (2016:1), the Netherlands is classified as the tallest nation in the world, with an average stature (men and women combined) of 1.83m. Similar to the results of Frederiks *et al.* (2005:810), results from a study done by Lee *et al.* (2005:18), who studied growth in girls from eight to 18 years in the Shih-Pai district in Taipei, also found taller sitting height measurements in Taipei girls in comparison with South African and Australian girls. In this

regard, Dimeglio (2001:550) found that, it appears that children, teenagers, and adolescents from countries in the northern hemisphere have a taller upper body and shorter lower body compared to those from the southern hemisphere and are generally taller than girls from countries in the southern hemisphere. One must, however, keep in mind that growth curves for the populations in the different countries could differ because of varying secular growth tendencies among different nations.

It is clear that each nation displays unique growth patterns. It is therefore important that growth research be done on each separate nation to develop a unique frame of reference. Even though longitudinal research has been done on segmental lengths, most studies did not take maturation (for example the onset of menarche) into account. This leaves a void in the literature and it is important to study the influence of maturation on segmental growth to better understand changes in this area of growth.

Bone growth is considered to be the major reason for segmental and total body length (Bogin & Varela-Silva, 2010:1060). Together with bone growth and length of body segments, the body develops greater muscle mass, tendons, and skin surfaces. All the above-mentioned variables, continuously develop and contribute to greater body mass as the body grows taller.

The next section subsequently examines literature findings on the body mass and body composition of girls and the influence of maturation on these factors.

2.6.1.4 Body mass

Body mass is the quantity of the mass-carrying aspects (matter) in the body (Chemicool Dictionary, 2017:1) and is the composition of independent varying tissue. Body mass includes body composition, including water, fat, muscles and organs.

Body mass follows a similar development curve as stature. However, mass keeps on increasing and does not reach a plateau at approximately 12 to 13 years like stature, among girls (Malina *et al.*, 2004:49). Armstrong and McManus (2000:22) found in this regard that body mass constantly and linearly increases until 8 years where after an acceleration in body mass increases were found. Similar to Armstrong and McManus, Myburgh *et al.* (2016:1959) found that British elite female tennis players' body mass increased significantly between 8 and 17 years. Results from this study showed an average mass of $33.17\text{kg} \pm 5.53$ (O/10),

44.54kg±5.61 (O/12), 57.00kg±6.54 (O/14) and 61.26kg±7.73 (O/16). Thereafter girls' body mass increases drastically as a result of increased fat deposits until their early twenties. At that time stature had already reached a plateau. As a result of hormonal changes during adolescence, a peak increase in body mass among girls takes place after PHV (Aberberga-Augskalne & Kemper, 2007:7). It is clear from these results that the biggest increase in body mass takes place between 12 and 14 years, which is in line with the average age of onset of menarche (see 2.3 for menarcheal development). In terms of differences between maturity groups, minor differences were found at ages younger than 10 years. From 12 to 15 years, there are significant differences in the body mass of differing maturity groups. In this regard, Myburgh *et al.* (2016:1960) found differences of up to 14.9kg between early and late developers' body mass at 12 years and 12.8kg between average and late developers at 14 years of age. Nwankwo *et al.* (2016:5) studied the differences in body mass among pre- (younger than 13.54 years) and post-menarcheal girls (older than 13.54 years) between 11 and 18 years from 800 primary school children in Nigeria. Nwankwo *et al.* (2016:5) found statistically significant ($p < 0.05$) differences in body mass among pre-menarcheal ($38.38\text{kg} \pm 2.60$) and post-menarcheal ($49.02\text{kg} \pm 3.85$) girls.

Results of Van Gent (2001:53), on South African girls from the Northwest Province of South Africa, show that they weigh less than the average South African girl at 13 years but is heavier by the age of 15 years. The study furthermore showed that 12- to 15-year-old South African girls' mass is on average lower in comparison to Australian girls of the same age. Travill's (2007:283) study showed similar results to that of Van Gent, with body mass of girls in South Africa varying between 46.65kg to 65kg from 13 to 17 years (Table 2.1).

As most changes in girls' mass during adolescence are mostly due to increased fat deposits, it is important to investigate the changes in the fat mass of girls. McCarthy *et al* (2006:600) developed a frame of reference for the percentage of fat in girls of different ages. These researchers report that the average percentage of fat for age in girls is 22.5% (10 years), 23.3% (11 years), 23.5% (12 years), 23.8% (15 years), 24% (14 years), 24.1% (15 years) and 24.3% (16 years).

Other than percentage fat, another method available to determine girls' body composition and health is by calculating their Body Mass Index (BMI) (WHO, 2015b:1). This calculation includes measures of body mass and stature and changes in either one of these variables will have an effect on girls' BMI scores.

TABLE 2.1: ANTHROPOMETRIC GROWTH OF GIRLS FROM VARIOUS PARTS OF THE WORLD, 10-18 YEARS

Age	10	11	12	13	14	15	16	17	18
Population									
Stature (cm)									
Van Gent (2001:53)									
Northwest Province, SA	-	-	<i>N</i> =70	<i>N</i> =85	<i>N</i> =94	<i>N</i> =94	-	-	-
			147.42	151.59	156.39	158.23			
Whole of SA	-	-	<i>N</i> =71	<i>N</i> =69	<i>N</i> =195	<i>N</i> =195	-	-	-
			151.80	152.34	157.39	157.52			
Australia	-	-	<i>N</i> =341	<i>N</i> =517	<i>N</i> =305	<i>N</i> =305	-	-	-
			155.40	159.40	161.00	164.52			
Travill (2007:283)									
Western Cape, SA	-	-	<i>N</i> =36	<i>N</i> =36	<i>N</i> =36	<i>N</i> =36	<i>N</i> =36	-	-
			152.20	154.00	155.00	158.20	160.20		
Mass (kg)									
Van Gent (2001:53)									
Northwest Province, SA	-	-	37.5	42.29	48.95	51.51	-	-	
Whole of SA	-	-	42.13	44.28	49.24	50.34	-	-	
Australia	-	-	46.30	50.50	53.00	56.40	-	-	
Travill (2007:283)									
Western Cape, SA	-	-	-	46.60	47.30	52.80	59.70	65.00	-
Arm span (cm)									
Van Gent (2001:53)									
Northwest Province, SA	-	-	149.03	154.91	160.25	161.83	-	-	
Whole of SA	-	-	154.15	154.27	159.76	160.08	-	-	
Australia	-	-	155.60	159.40	161.80	164.02	-	-	
Lee <i>et al.</i> (2005:18)	140.2	146.6	154.1	157.0	158.8	158.90	159.60	160.50	160.60
Shih-Pai, Taipei									

Table 2.1 continue

Sitting Height (cm)									
Van Gent (2001:53)									
Northwest Province, SA	-	-	49.83	50.77	50.73	51.10	-	-	
Whole of SA	-	-	51.36	51.06	50.92	50.94	-	-	
Australia	-	-	61.80	62.30	63.40	62.40	-	-	
Lee <i>et al.</i>, (2005:18)									
Shih-Pai, Taipei	-	-	-	82.70	85.30	85.50	86.80	87.20	87.70
Fredriks <i>et al.</i> (2005:810)									
Netherlands	-	-	-	83.13	85.50	87.10	88.11	88.54	88.71

2.6.1.5 Body mass index (BMI)

Body mass index (BMI) is important for calculating an individual's body mass in relation to stature. BMI is an individual's body mass in kilogram (kg) divided by height in square meter (kg / m^2) (WHO, 2015b:1). As stature and body mass change over time, it has an influence on a person's BMI score, as these are two variables used in the BMI formula (WHO, 2015b:1). Changes in BMI decrease from birth until early childhood with the lowest levels reached at approximately 5 to 6 years, where after a linear increase is seen until adolescence (Malina *et al.*, 2004:64). According to the Centre of Disease Control and Prevention (CDC) Growth Charts of the United States, girls' BMI values should vary between 18 and 22 years, representing the 50th percentile between 12 and 20 years of age (Malina *et al.*, 2004:66).

BMI values are age dependent and values are similarly calculated for boys and girls, although the interpretation of the cut-off values for below normal, normal, overweight and obesity, differ between the sexes. BMI does not correlate with the general classification of obesity by making use of fat percentage, the reason being vast differences in body type, composition and body proportions of different nations (WHO, 2015b:1). It is therefore advisable to use the two methods jointly to obtain a more accurate classification of an individual's health status.

TABLE 2.2: SUMMARY OF LITERATURE WITH REFERENCE TO THE BODY MASS INDEX OF GIRLS

	10-11 Years	11-12 Years	12-13 Years	13-14 Years	14-15 Years	15-16 Years	16-17 Years	17-18 Years
Cumming <i>et al.</i> (2012) Early developers	-	22.4	25.3	25	-	-	-	-
Cumming <i>et al.</i> (2012) late developers	-	16.8	17.6	17.9	-	-	-	-
Travill (2007)	-	-	18.9	20.1	19.9	22	23.9	25.3
Hands <i>et al.</i> (2008)	-	-	-	-	21.2	-	-	-
Bitar <i>et al.</i> (2000)	16.2	-	18.5	-	-	-	-	-

BMI scores=kg/m²

During adolescence, more specifically during puberty, adolescent girls undergo various changes in body composition, especially regarding body fat and muscle mass. This could possibly be attributed to sex-specific hormonal changes. This indicates that reaching menarche influences these factors, and therefore also directly influences the BMI among girls. The above relationship makes it important to investigate research findings on the development of adolescent girls' BMI.

Cumming *et al.* (2012:751) conducted research on 11- to 14-year-old English girls (N=252) with a mean age of 12.9 years and found vast differences in BMI between early (N=50) and late developers (N=51). The difference in BMI between 13 and 14 years were as high as 7.1kg/m², with the early developers having the highest average BMI (Table 2.2). Bitar *et al.* (2000:159) studied French girls at age 10.4 years (before they reached puberty) and 12.8 (after they have reached puberty) and found corresponding BMI values to that of the pre-pubertal girls of Cumming and co-workers (2012:751) (Table 2.2). The major difference between early and late developing girls might be attributed to hormonal changes taking place during the onset of puberty, which have a major influence on fat deposits in girls (Malina *et al.*, 2004:421). These differences in BMI among early and late developing girls confirm that the pubertal phase plays a significant role in changing girls' body composition. It must be kept in mind that BMI depends directly on changes in body mass and stature, and that the timing when these two factors reach peak velocity and plateau directly influence BMI values.

One would expect that BMI values among pre- and post-menarcheal girls would differ because of maturity differences, although there is a void in the literature when it comes to focused research in this regard.

2.6.2 Summary: Anthropometry

It is clear from the above-literature findings that various changes in anthropometric and body composition factors occur as a result of natural growth with increased age. It furthermore seems that puberty and the onset of menarche contributes to a variation in girls' stature and body mass, and to major biological changes such as the development of secondary sex characteristics, wider hips, and higher fat percentages. Girls undergo notable hormonal changes during the onset of puberty and the onset of menarche, which plays a significant role in fat deposits in girls to prepare them for sexual reproduction. Each of these changes has a further influence on the physical and motor fitness capabilities of girls (Bronnikowski & Bronnikowska, 2008:33), which is another focus of this study.

The next section of this literature review will be a discussion on the development of physical and motor fitness capabilities in girls. This discussion will be followed by an analyses of literature findings on the interrelations between anthropometric variables and physical and motor fitness capabilities.

2.7 DEVELOPMENT OF PHYSICAL AND MOTOR FITNESS CAPABILITIES

The processes of growth and biological maturation are interrelated, and both processes influence the functional capabilities of an individual. They also influence an individual's body composition and fitness capabilities, which in turn influence the execution of motor and fitness capabilities (Viru *et al.*, 1999:107).

Physical growth represents a biological process that is influenced by the environment, social and genetic factors (Aberberga-Augskalne & Kemper, 2007:5) while physical development is influenced by the composition and maturation of the growing human being (Turley & Wilmore, 1997:830). The most noticeable anthropometric, physical and motor changes mainly take place during adolescence when the so-called domino effect (changes in one aspect causing changes in other aspects) occurs among different biological, physiological and

psychological aspects (Suslov & Nikitushkin, 1991:30). In turn, this has an influence on sporting abilities and sporting talent.

Following a discussion on physical and motor fitness capabilities with a focus on development during puberty.

2.7.1 Physical fitness capabilities

Physical fitness is viewed as the capacity to execute daily activities without any unnecessary exhaustion (Gallahue *et al.*, 2012:80). Physical fitness is also defined as the ability to participate in physical activities without limitation of physiological and psychological qualities (Ortega *et al.*, 2008:49). Performance- (which is the focus of the chapter) and health-related physical fitness involve the development of control over the body, especially the muscles and coordination (Basterra, 2008:4) and include muscle power, muscle endurance, flexibility and body composition (Pienaar, 2018:40). Physical fitness combined with the mechanical demands of activities, influence the human's ability to move in a controlled manner and with confidence (Gallahue *et al.*, 2012:80). Performance-related physical fitness is seen as the building blocks for the development of a talented player and for success in sport. The development of physical fitness capabilities, including muscle strength and cardio-respiratory endurance, are defined and discussed next.

2.7.1.1 Muscle strength

Muscle strength refers to the ability of a muscle or muscle group to generate power against resistance (Pienaar, 2018:39; Gallahue *et al.*, 2012:449). Muscle strength, comprising the ability of the body to produce power output, is divided into isometric- (producing strength against a static object where the muscles contracts, but no change in muscle length takes place), isotonic- (the ability of the muscle to go through the full range of motion, where the muscle contracts and lengthens) and isokinetic strength (where the muscles contract and holds the position for the full motion) (Gallahue *et al.*, 2012:253).

In the developing child, linear growth, body mass, and muscle size are important factors influencing their muscle development (Melanese *et al.*, 2010:275). Strength develops linear from birth to puberty (Melanese *et al.*, 2010:275) and reaches peak development when PHV occurs, and approximately 0.6 years before peak mass velocity is reached (Faust *et al.*, as

quoted by Malina *et al.*, 2004:328). In this regard, Gallahue *et al.* (2012:333) found that peak muscle development among girls takes place after they reach PHV and peak mass velocity, although variation is found among girls during this time in terms of strength development. Muscle strength is influenced by a combination of factors, including anthropometric characteristics, neurological characteristics, hormones and age (Des Ste Croix, 2007:292). Bronkowski and Bronikowska (2008:32) found that muscle strength development is also related to maturity status (as determined by the biological maturity rate, S. Pavilonis's method) in 13-year-old adolescent girls from Poland. From Bronkowski and Bronikowska's (2008:32) study, results showed that early developing girls could press 25.1kg during the hand grip test, average developers 21.8kg and late developers, 18.7kg. These differences can be attributed to body size and composition and hormonal differences between the maturity groups (Bronkowski & Bronikowska, 2008:35).

2.7.1.2 Cardio-respiratory endurance

Gallahue *et al.* (2012:442) define cardio-respiratory endurance as the ability to execute repetitive high intensity activities that demand the use of the circulatory and respiratory systems. Cardio-respiratory endurance (aerobic fitness) involves the ability to execute large muscle activities at a moderate to high intensity over long periods, according to Pienaar (2018:39).

$\dot{V}O_2$ or $\dot{V}O_{2max}$ refers to the maximum oxygen intake or maximum volume of oxygen used per minute by the body or heart during maximum or exhausting exercise and is measured in millilitre oxygen used per minute per kilogram body mass (Baechle & Earle, 2008:123).

$\dot{V}O_{2max}$ or maximum oxygen intake determines an athlete's ability to execute ongoing exercise and tests the athlete's aerobic endurance. Aerobic endurance is dependent on pulmonary, cardiovascular and haematological components of oxygen delivery (Malina *et al.*, 2004:235). Few studies exist on longitudinal cardiovascular parameters in children and adolescents relative to growth patterns (AberbergaAugskalne & Kemper, 2007:5). A review study by Mirwald and Bailey 1986 (as quoted by Malina *et al.*, 2004:243) found that absolute $\dot{V}O_{2max}$ among girls (oxygen L/min) develops linear until 13 years of age, where after a plateau is reached that persists throughout adolescence. With reference to relative $\dot{V}O_{2max}$ (L/kg/min), a considerable decrease can be seen among girls from the ages of 12 to 13 years (Malina *et al.*, 2004:243). This tendency can be linked to hormonal changes in girls, which

contribute to an increase in fat deposits and a decrease in muscle mass among girls after the onset of puberty (Bitar *et al.*, 2000:160).

Although results from Armstrong *et al.* (1990:357) show that maturation among 12-year-old girls does not influence the $\dot{V}O_2$ response during maximum exercise, Aberberga-Augskalne and Kemper (2007:10) found that cardiovascular functioning among late developing girls (as determined by one-year differences in average age from PHV) shows more effective patterns in terms of cardiovascular response to exercise. Last-mentioned researchers also found that the greatest increase in the pace volume of the heart takes place approximately one year before PHV among girls with an average increase of 19 ml/min annually. The cross-sectional study of Van den Berg *et al.* (2006:282) that focused on differences in early, average and late developing 14-year-old girl's tennis players (as determined by the Biological Maturation Identification Questionnaire, Faulkner, 1996:135), found that average developing girls performed better in the 20m beep endurance test (level 7.35), followed by late developing girls (level 7.15). The early developers who were already in an advanced stage of puberty, performed the poorest (level 6.80). Bronikowski and Bronikowska (2008:32) focused on 13-year-old girls of differing maturity statuses, and their results were found to be contradictory to literature where early developers (level 4.3) performed better than late developing girls (level 3.7), with averaged developing girls reaching level 4.7. These results are contradictory to most literature, including results from a study by Aberberga-Augskalne and Kemper (2007:8), who found that late developing girls had more effective patterns of cardiovascular response to exercise because of more effective contraction of the myocardium and effectiveness of cardiovascular control, with maturation.

Because of differences in body and organ sizes between boys and girls, girls only have approximately 70 to 75% of the aerobic capacity in comparison to boys, and this percentage lowers over time after the onset of puberty (Gallahue *et al.*, 2012:251).

Results from a study by Van Gent (2001:53) shows that the aerobic performance (as tested by the beep test) of girls in the Northwest Province of South Africa declined from 35 shuttles (pacer level 5.2) to 32 shuttles (pacer level 4.9) among 12- to 15-year-olds, and girls from Australia dropped from 37 shuttles (pacer level 5.5) to 35 shuttles (pacer level 5.3) also from 13- to 15-year-olds, as tested by the 20m beep test (Table 3). These findings indicate that maturation does have an influence in girls' cardio-respiratory endurance, especially after the onset of puberty.

TABLE 2.3: PHYSICAL FITNESS CAPABILITIES OF GIRLS

Van Gent (2001)			Hands <i>et al.</i> (2008)
	Northwest Province, SA	SA population	Australia
Muscle strength (Throwing a basketball from the chest for distance in metres)			
12 years	3.90	4.41	5.03
13 years	4.15	4.33	5.24
14 years	4.44	4.89	5.55
15 years	4.77	5.00	5.79
Cardio-respiratory endurance (according to 20m Beep)			
12 years	35	37	30
13 years	34	36	37
14 years	33	39	36
15 years	32	40	35

Keeping in mind this background knowledge of girls' physical fitness development, literature findings on motor fitness capabilities will now be discussed, as well as the role that maturation plays in the development of these capabilities.

2.7.2 Motor fitness capabilities

Motor fitness is one aspect of the multi-dimensional framework of physical fitness that is defined as a set of characteristics people have or achieve. It is linked to the ability to execute physical activity (DeVault, 2010:1; Pienaar, 2018:39). Motor fitness, also referred to as performance or skills-related fitness, describes an individual's ability to perform effectively during sport or similar activities (Basterra, 2008:4; Ortega *et al.*, 2008:49; Melanese *et al.*, 2010:266). Furthermore, motor fitness refers to an athlete's ability to use a combination of agility, coordination, balance, anaerobic strength (explosive strength) and reaction time during successful participation in all sport activities (DeVault, 2010:1).

The following motor fitness capabilities, including coordination, speed, agility and anaerobic muscle strength that are part of the focus of this study, will now be defined and discussed.

2.7.2.1 Coordination

Coordination is based on a global system consisting of various synergistic elements that are combined and therefore does not represent independent abilities (Wheeler, 1991:11; Paus *et al.*, 1999:1908; Grasso, 2006:1). Skills and capabilities such as balance, rhythm, spatial orientation and the ability to react to both visual and auditory stimuli, are among the factors influencing coordination (Grasso, 2006:1). Coordination is described as the activation of different motor units and the accurate timing of various muscles fibres to reach the optimal end product (Van Rooyen, 1993:36). A more recent definition is that coordination refers to the ability to use different body segments in a fluent and voluntary manner without using any unnecessary extra movements (Pienaar, 2018:45). Advanced coordinated movements contribute to better developed motor fitness capabilities and learning new skills (Pienaar, 2018:45).

The development of basic coordination through movement is of utmost importance, especially before the onset of puberty. The end goal is to develop sport-specific coordination between 7 and 14 years, and more specifically between 10 and 13 years, which is identified as a critical development period for coordination (Grasso, 2006:1).

Results from the literature show a decrease in hand-eye-coordination among girls from the Northwest Province of South Africa from 12 to 15 years as tested with the throw and catch test (Van Gent, 2001:53). Furthermore, these results show a small increase from 12 to 14 years among girls from the greater South African population, with a decrease from 14 to 15 years (Table 2.4). However, data from Australian girls show conflicting results where a constant increase was found from 12 to 15 years (Van Gent, 2001:53). This contradicting result between South-African and Australian data can possibly be ascribed to exposure to, or a lack of exposure, to Physical Education classes in the different countries' school curricula, that might have contributed to a training effect and leading to constant improvement.

Freitas *et al.* (2016:1129) studied the influence of skeletal maturation on coordination among 613 learners (284 boys and 329 girls) between 11 and 14 years of age from the Madeira and Porto Santo Islands in Portugal. Results showed that the percentage variation in motor coordination as tested by the Body Coordination Test for Children test battery, which includes dynamic balance backwards, jumping on one leg, side jumps and lateral moves, could only be attributed to a limited extend to maturation, although a difference in results

were found between the sexes. Factors such as neuro-muscular maturation, specific orders during training and training itself and sport participation also influence motor coordination between 11 and 14 years of age (Freitas *et al.*, 2016:1129). Furthermore, these researchers also indicate that skeletal maturity (skeletal age according to chronological age) explains 8.1% of the variance in motor coordination among boys and only 2.8% of the variance among girls after correcting for stature and mass (Freitas *et al.*, 2016:1129).

2.7.2.2 Speed and agility

Speed refers to one's ability to make quick, explosive movements by moving the body, or parts of it, at a fast pace against gravitation (Pienaar, 2018:174). Furthermore, Gallahue *et al.* (2012:452) indicate that speed is a combination of reaction and movement time.

Agility refers to the ability to change the body's position without the loss of speed, strength, balance and body control (Pienaar, 2018:174). Gallahue *et al.* (2012:442) likewise define agility as the ability to quickly and accurately change the direction of the whole body while moving from point A to B.

The adolescent acceleration in muscle strength and muscle endurance, which is directly linked to speed and agility, take an onset approximately 0.5 to one year after reaching PHV (Malina *et al.*, 2004:329). This link between the last-mentioned factors is the result of similar accelerations in morphological and biochemical determinants (the proportion of various muscle fibre types) (Little & Williams, 2005:76). Pauole *et al.* (2000:446) found considerable correlations of $r=0.73$ between the T-test (agility) and 40-m speed test. Furthermore, results from the Motor Performance Study of Michigan State University (as quoted by Malina *et al.*, 2004:222) show identical development of speed and agility from 5 to 18 years. More specifically, the results of the study show that both speed and agility improve significantly between 5 and 8 years of age, where after a further, more linear increase is seen between 13 and 14 years among girls, after which a plateau is reached. Van Gent (2001:53) investigated the differences in agility among 12- and 15-year-old girls from South Africa, compared to data from Australia in terms of speed and agility. These results reveal similar developmental curves for speed and agility among girls from South Africa and Australia (Table 2.4). More specifically, a decline in agility is found from 12 to 13 years. Furthermore, results from Van Gent (2001:53) show similar development curves of girls' speed and agility in both South African and Australian girls.

Van den Berg *et al.* (2006:282) investigated the developmental differences of early (n=4), average (n=11) and late (n=11) developing 14-year-old South African female tennis players (as determined by the Biological Maturation Identification Questionnaire), and found that girls' speed (10m speed test) varies non-significantly among maturity groups with late developers showing better performances (2.21sec), followed by the early developers (2.25 sec) and the average developers (2.32 sec). These researchers mentioned that one should consider that the maturation groups were small and that the study group was homogenic as it consisted only of tennis players and that this could have been the reason for the minor differences.

From the above discussed results, it can be concluded that maturation, including anthropometric, biological and physiological changes, play a role in the development of speed and agility among girls, although other factors, such as training and genetics, might also have an influence.

2.7.2.3 Anaerobic muscle strength

Anaerobic muscle strength refers to energy stored in the muscles, in order to use the muscles without using oxygen. Anaerobic muscle strength is mainly linked to the phosphagen and lactic acid systems, which are used for brief actions and cannot be executed for longer than two minutes (Aertssen *et al.*, 2016:118). This description correlates with Baechle and Earle (2008:250), who defines anaerobic muscle strength as the ability of muscle tissue to maintain a high strength output while contracting at a high speed for a short period of time.

Anaerobic muscle strength shows similar development among boys and girls where linear increases take place from 5 to 14 years of age, where after a plateau is reached among girls at 14 years of age (Gallahue *et al.*, 2012:343). In this regard, Malina *et al.* (2004:330) indicate that peak development in sub-maximal power output among girls occurs approximately one year after PHV.

Results from Van Gent's (2001:53) cross-sectional study (as measured by the vertical jump) in terms of South African data showed no visible developmental pattern in anaerobic muscle strength. In terms of Australian results, a clear increase in anaerobic muscle strength was reported from 12 to 15 years, with the greatest increase between 12 and 13 years, which is the same period when girls on average reach menarche. Australian girls also performed better

compared to girls from the Northwest Province of South Africa but performed slightly lower compared to the greater population of South Africa.

In terms of the differences in the vertical jump performances of early, average and late developing 14-year-old girls, Van den Berg *et al.* (2006:282) found significant differences where the average developers performed best with a jump of 27.86cm, followed by early developers (26.75cm) and late developers (23.25cm). These results correlate with literature indicating that anaerobic development takes place after puberty (Malina *et al.*, 2004:330).

TABLE 2.4: MOTOR FITNESS ABILITIES OF GIRLS (Van Gent, 2001)

	Northwest Province, SA	Greater SA population	Australia
Coordination (Throw and catch test “total of 10 trials”)			
12 years	12.34	7.73	8.90
13 years	7.09	7.81	9.70
14 years	5.51	7.82	10.00
15 years	5.52	7.74	12.70
Speed (40m sprint in seconds)			
12 years	8.10	7.18	7.58
13 years	8.14	7.37	7.44
14 years	8.20	7.22	7.30
15 years	8.29	7.20	7.15
Agility (in seconds)			
12 years	22.99	21.18	22.17
13 years	23.03	22.35	21.31
14 years	22.71	21.92	21.00
15 years	23.27	21.50	20.75
Anaerobic strength /Explosive strength (vertical jump in centimetre)			
12 years	23.61	30.77	27.70
13 years	22.90	29.68	29.20
14 years	24.20	31.23	29.30
15 years	24.78	30.18	30.70

During the standing long jump test, which also tests anaerobic muscle strength in the legs, Bronikowski and Bronikowska (2008:32) indicated that 13-year-old girls from Poland jumped on average 153.8cm (early developers), 153.4cm (average developers) and 140.7cm (late developers). These results confirm the findings from Australian data, which reported

that girls' anaerobic muscle strength still develops until approximately 14 to 15 years (Van Gent, 2001:53). In conclusion, it seems from the literature that early developing girls perform better than late developing girls in terms of anaerobic muscle strength.

The above results show that anthropometric growth and maturation play an important role in the development of various physical- and motor fitness capabilities. These influence of anthropometric growth on physical- and motor fitness capabilities will in turn influence sport-specific skills (Butcher & Eaton, as quoted by Melanese *et al.*, 2010:274). Butcher and Eaton (as quoted by Melanese *et al.*, 2010:274) explain that there is a link between somatic characteristics (any cell of a living organism excluding reproductive cells) and fundamental skills, for example where body size and mass indicates a negative relationship with skills where the body needs to work against gravitation.

Knowledge of the effect of anthropometric changes on the development of physical- and motor fitness capabilities of adolescent girls is therefore important. Given the knowledge of the development of anthropometric characteristics and physical and motor fitness capabilities separately, the focus of this literature review now turns to literature investigating the interrelationship between these factors.

2.8 INTERRELATIONSHIPS BETWEEN ANTHROPOMETRIC CHARACTERISTICS AND PHYSICAL AND MOTOR FITNESS CAPABILITIES

Individual and team sport participants require a combination of health- and motor (performance-related) fitness factors. According to Hill (2011:1), structural characteristics such as stature, body mass, and segmental length, directly relate to the choice of a specific sport and the ability to perform well during participation in sport and physical activity. The speed at which an action is executed is influenced by the total stature and body mass, as well as the length of the specific limbs used for the action (Hill, 2011:1).

Abbott and Collins (2002:174) indicate that various correlations exist between anthropometric growth and physical fitness capabilities among Scottish girls, as indicated in Table 2.5. These researchers found that the basketball chest press from a sitting position correlates with stature, body mass, sitting height and arm span, while the shuttle run (cardio-respiratory endurance) only correlates with stature and body mass. Gerber *et al.* (2014:622) also found interrelationships between physical fitness capabilities and anthropometric

characteristics among boys with an average age of 13.73 years. Results from the study indicate that the development of muscle strength, as tested by the cricket ball throw, showed interrelationships with stature ($r=0.28$ to $r=0.44$), sitting height ($r=0.30$ to $r=0.37$) and arm span ($r=0.29$ to $r=0.36$). Furthermore, cardio-respiratory endurance only showed interrelationships with body mass ($r=0.32$ to $r=0.41$) (Gerber *et al.*, 2014:622).

Aberberga-Augskalne and Kemper (2007:10) completed a study on 41 boys and 45 girls from Riga between the ages of seven and 16 years. They found that late developing girls (as determined by PHV) show more effective cardiovascular adjustments at each level of peak growth during exercise in comparison to early and average developing girls.

TABLE 2.5: CORRELATIONS BETWEEN PHYSICAL FITNESS ABILITIES AND ANTHROPOMETRIC ASPECTS AS FOUND BY ABBOTT AND COLLINS (2000)

Performance task	Anthropometric variable			
	Stature	Mass	Sitting height	Arm span
Basketball throw	0.55*	0.46**	-0.47**	0.28**
Shuttle run	0.07**	-0.22**	-0.33	-0.02

*=Significant at $p<0.05$; **=Significant at $p<0.01$

To date, no similar studies as the one by Gerber *et al.* (2014:622) on boys have been done in South Africa on girls. However, it is important that these factors should be assessed simultaneously and in relation to each other. It is important because research that analyse anthropometric characteristics and motor- and physical fitness capabilities separately can only provide a one-dimensional picture of growth, maturation, and potential for sport in children and adolescents. Melanese *et al.* (2010:266) are of the opinion that changes in motor skills are the integrated outcome of most body functions used during physical activity. Therefore, simultaneous assessment of anthropometric characteristics and motor- and physical capabilities will give more accurate information on the interrelated nature of these variables in children and adolescents, although links between these variables are currently unclear due to a lack of studies in this research area (Melanese *et al.*, 2010:266).

Results from a study done by Hands *et al.* (2008:659) on 14-year-old adolescent girls from Western Australia shows that BMI have small, but negative correlations ($p=-0.13$) with motor dexterity and muscle endurance, and positive correlations with aerobic fitness ($p=0.27$) and muscle strength ($p=0.15$). An explanation for the positive correlation can be attributed to the

fact that high muscle mass, which contributes to a higher BMI, often leads to better performance in muscle strength activities (Hands *et al.*, 2008:672). On the other hand, a lower BMI is beneficial for activities where the body should be able to move fluently and with ease. Abbott and Collins (2002:174) investigated this phenomenon in 1 217 girls with a mean age of 12.68 years from Scotland and found various correlations (Table 2.6). The results showed that throwing skills only correlate with stature, *vertical jump* with stature, mass and sitting height, *agility* with mass and sitting height and *speed* with mass and stature (Table 2.6).

TABLE 2.6: CORRELATIONS BETWEEN MOTOR FITNESS ABILITIES AND ANTHROPOMETRIC CHARACTERISTICS AS FOUND BY ABBOTT AND COLLINS (2002)

Performance task	Anthropometric variables			
	Stature	Mass	Sitting height	Arm span
Catch	0.18**	0.020	0.01	0.09
Vertical jump	0.21**	-0.04*	-0.12**	0.03
Agility run	-0.00	-0.19	-0.96*	0.00
40m sprint	-0.15**	0.09**	0.02	-0.06

*=Significant at $p<0.05$; **=Significant at $p<0.01$

D'Hondt *et al.* (2011:558) found in their study that girls between the ages of 8 and 12 years, with an average/normal BMI, performed better in balance ($p<0.001$) and jumping skills ($p<0.001$) than girls whose BMI indicates overweight and obesity. These researchers concluded that body mass (overweight or obesity), even when corrected for maturity differences, has a negative influence on gross motor skills among children and adolescents. Gerber *et al.* (2014:622) longitudinally investigated the interrelationship between anthropometric characteristics and physical- and motor fitness capabilities among 13- to 15-year-old boys from the Northwest Province in South Africa. Results from this study showed that stature ($r=0.74$), sitting height ($r=0.70$) and arm span ($r=0.70$) have the most significant correlations with the development of motor- and physical fitness capabilities (Gerber *et al.*, 2014:622). Furthermore, they found that the basketball chest press which test explosive upper body strength of the body had the most significant correlations with anthropometric characteristics (stature, mass, sitting height, arm span) compared to speed, agility, explosive

strength and coordination. No similar studies could be found in the literature that was done on adolescent girls, which indicates a gap in the literature.

With this background on the development of anthropometric characteristics and motor- and physical fitness capabilities, this literature review will be concluded by an investigation of the methods and results of completed growth studies. These include cross-sectional studies, longitudinal and review studies that have relevance to the objectives of this study. These studies mainly focused on the growth and the interrelated nature of physical and motor fitness capabilities among adolescent girls.

2.9 INFLUENCES OF DIFFERENTIAL TIMING OF MATURATIONAL PROCESSES ON GIRL'S SPORT PARTICIPATION

Going through puberty can have a significant impact on athletic performance in both positive and negative ways (de Sousa, 2017:1). While increases in body size, hormones, and muscle strength can improve athletic performance, there may be a temporary decline in balance skills and body control during the growth spurt (de Sousa, 2017:1). Rapid increases in height and weight affect the body's centre of gravity. Sometimes the brain has to adjust to this higher point of gravity and a teen may seem a bit "clumsy" for instance (de Sousa, 2017:1).

Furthermore, individual variations in the timing of puberty may influence the adoption of unhealthy behaviours (Lee *et al*, 2016:267). Specifically, a comparison between those who mature on time and those who mature late shows that adolescents who mature early are at a higher risk of exposure to several psychological, social, and health disadvantages (Lee *et al*, 2016:267). For example, girls who experience puberty earlier than their counterparts are more susceptible to adverse health behaviours such as earlier alcohol use, cigarette smoking, and eating disorder (Magnusson *et al.*, 1986:150; Kaplowitz *et al.*, 2001:350). In turn, this contributes to a decline in physical activity among girls (Baker *et al.*, 2007:491), and an increased time spent in sedentary behaviour.

Mid-adolescence, and more specifically the time period just before and after reaching menarche, is described as a vulnerable period in the development of physical- and motor skills due to the significant changes that occur in body segments and body dimensions during this period (Gaudineau *et al.*, 2010:5). Maturational status is an individual restriction which can affect behavioural variables such as the self (O'dea & Abraham, 1999:75) and their perceived athletic performance (Craft *et al.*, 2003:436; Niven *et al.*, 2007:476; Cumming. *et*

al., 2010:285). Maturational status seems to be particularly negative for girls because they are subject to most remarkable bodily alterations starting with puberty (e.g. deposition of body fat, enlargement of the breasts and menarche) (Oliveira, 2019:3022). In this regard, adolescents with a higher maturational level may have lower levels of perceived athletic performance, as the bodily changes seems to affect their perceptions of competence negatively (O’dea & Abraham., 1999:75; Craft *et al.*, 2003:436, Cumming *et al.*, 2010:285).

Changes during maturation, being earlier or later than normal, also have implications for sport selection. Williams and Reilly (2000:564) state in this regard that players chosen for individual or team sports are initially chosen (before the onset of puberty and menarche) based on physical characteristics. This results in, inadequate opportunities for late developing girls to develop and excel in sport due to their current insufficient physical characteristics. In agreement, Van den Berg *et al.* (2012:514) also concluded that the physiological development of late developers, which had not yet fully developed, can lead to the elimination of talented players at a young age during the talent identification process.

2.10 GROWTH STUDIES

Research has been conducted since the early 1900s on adolescents’ structural and biological growth and the remarkable changes that occur during adolescence. Such research findings have been characterized by various trends (Lerner & Steinberg, 2004 as quoted by Nichols, 2009:1) such as biologists describing physical development and the changes that accompany puberty; psychologists studying cognitive development; sociologists examining how various social arenas influenced adolescents; and educational psychologists studying how adolescents’ motivation differed across school and classroom settings. More recently researchers increasingly examine how different areas of life interact and affect one another. Another trend consists of changing assumptions about adolescence. The discussion below focuses on studies that reported on anthropometric growth among adolescent girls and will include aspects regarding the nature of the design, the population size, the variables tested and research findings.

2.10.1 Cross-sectional studies

Cross-sectional growth studies, also known as cross-sectional analyses or transversal studies, are observational studies that consist of the analyses of the data of a study group, collected within a specific timeframe. One characteristic of cross-sectional studies is that different groups can be compared with each other at one single moment in time. South African studies, namely that of Henneberg and Louw (1998), the Thusa Bana Study (Van Gent's, 2001), Van den Berg *et al.* (2006), Fredriks *et al.* (2005), Armstrong *et al.* (2011) and an international comparative study with South African studies from Travill (2007) will be discussed in this regard.

2.10.1.1 Henneberg and Louw (1998)

The focus of the study was to analyse different physical growth patterns (stature, body mass, length of body segments, circumferences and widths) and functions (grip strength, reflexes, and pulse rate) of school-aged coloured children from different socio-economic backgrounds (SES) from the Cape Province of South Africa. Data from 906 boys and 1068 girls from a high SES area between the ages of 5 and 20 years, and 834 boys and 940 girls from a low SES area between the ages of 5 and 19 years were collected between 1986 and 1988. It was found that the stature and body mass of pre-pubertal children aged five to nine years from high socio-economic areas compared well to data on American children, although stature and body mass decreased after puberty compared to American children, which showed increases (Henneberg & Louw, 1998:81). These differences in stature and body mass that were observed in the study of Henneberg and Louw are difficult to interpret because of differences in the nutritional status between the countries. Furthermore, results indicated that girls from high socio-economic areas were taller and heavier compared to girls from low socio-economic areas (Henneberg & Louw, 1998:87), although these differences decreased with increasing age. In summary, it was found that differences in the lower limb lengths contribute to differences in stature between girls from different socio-economic areas. The body mass results showed that age and SES influence children's development. This was evident in the comparison of SA girls with a higher SES and the American girls who represented a first world country with whom they compared relatively well. Girls with a lower SES also had notably less favourable body composition scores. SES in general had a negative impact on children's growth and development. Although this study took pubertal development into consideration, the applicability of the results to modern populations is questioned as the study

was conducted in the 1990s. Furthermore, the focus was on a homogeneous population, and therefore, the results cannot be generalized.

2.10.1.2 Thusa Bana Study (Van Gent, 2001)

The cross-sectional study of Van Gent, (2001) on the 1220 children, of which 556 were girls and 664 boys, between the ages of 10 to 15 years formed part of a multidisciplinary research project of the Faculty of Health Sciences at the North-West University of South Africa, known as the Thusa Bana Study that were done between 2001 and 2002. Four anthropometric measurements (stature, body mass, arm span and relative sitting height) were taken. Furthermore, physical fitness- (modified sit and reach, 20m beep test, grip strength, flexed arm hang, seven-level abdominal muscle strength test) and motor fitness capabilities (5m agility, basketball throw, vertical jump, target throwing for accuracy and 40m speed test) were also evaluated. Apart from relative sitting height, it was found that all anthropometric variables increased with age. It was clear from the results that the biggest anthropometric changes in girls took place around 13 years of age, which is after the average onset of puberty and menarche (12.78 years). In terms of the physical fitness capabilities of girls, it was found that only the throw and catch test and the basketball throw showed meaningful improvements over time. From the results it seems that physical and motor capabilities among South African girls decrease from 13 years (coordination and speed), or reach a plateau (agility, explosive strength). It also seems that puberty has a minor or no negative impact on girls' motor and physical fitness capabilities. Lastly, significant differences were found for most variables between racial groups. Again, because the study was conducted more than 10 years ago, its validity to more recent growth tendencies is questionable. Although menarche age (12.78 years) was calculated during the study, the influence of the possible onset of menarche on anthropometric and physical fitness capabilities was not investigated while the interrelations between anthropometric characteristics and physical- and motor fitness capabilities were also not investigated.

2.10.1.3 Fredriks *et al.* (2005)

The study of Fredriks *et al.* (2005) was conducted between 1996 and 1997 during the Fourth Dutch Growth Study. A total of 14 500 children (7 482 boys and 7 018 girls) from the Netherlands between birth and 21 years formed part of this cross-sectional study. Sitting height was only tested for 6 877 boys and 6 202 girls. Children with known growth disorders

or who took medicine that influenced normal growth were excluded from the study. Results showed positive relationships between stature, sitting height and leg length for all ages. Results furthermore showed a linear increase in girls' sitting height from 72.28cm to 88.1cm between 9 and 16 years, where after a plateau is reached. The results should, however, be generalized with care, because the Dutch population is among the tallest nations in the world. Also, the data are outdated and their relevance on modern populations may have decreased over the past two decades.

2.10.1.4 Van den Berg *et al.* (2006)

This study was conducted on 25 female tennis players between 12 and 14 years of age from Northern Gauteng and the Northwest Province of South Africa. Their average chronological age was 13.22 years. The participants completed 21 physical- and motor tests, including internal and external shoulder flexibility, right leg hamstring flexibility, vertical jump, grip strength, abdominal strength, lower back strength, muscle endurance, overhead and inverted overhead medicine ball throw, overhand throwing test, 10m speed test, 40m speed test and the shuttle run. Furthermore, the girls completed a biological maturity questionnaire (BMIQ), where after they were placed into three categories, namely early- (n=4), average- (n=11) and late developers (n=11). Results from the study showed that biological maturation can be used during talent identification as maturation has an influence on the development of female tennis players. They also found that physiological development among late developers who are not yet fully developed, may lead to the elimination of talented players at an early age during talent identification. This may be because early developing girls perform better in tennis in their various age groups during the pre-adolescent phase compared to average and late developing groups. On the other hand, results indicated that this tendency changes after the onset of puberty, when the more ideal body types of the average and late maturing tennis players put them at an advantage to perform better at tennis than their early developing adolescent peers (Van den Berg *et al.*, 2012:522). Although the results were notable for this study, it did not focus on the age of onset of menarche and its impact on girls' fitness capabilities. Furthermore, the possible interrelated nature of growth and fitness capabilities were not investigated or put into perspective, and the number of participants in the study was small.

2.10.1.5 Discovery Vitality Health of the Nation Study (Armstrong *et al.*, 2011)

Physical fitness capabilities and anthropometric characteristics were measured from 2001 to 2004 by using 8 different tests on 10 295 South African children (5611 boys, 4684 girls) between 6 and 13 years of age in the Discovery Vitality Health of the Nation Study (Armstrong *et al.*, 2011). The aim was to determine the present degree of physical fitness among South African children from various ethnic groups. The group of girls comprised of 2 427 black, 881 coloured, and 1 248 white girls, with the remaining total being of other ethnic groups. The measurements included stature, body mass, body mass index (BMI), standing long jump, beep test, sit-and-reach, push-ups (EUROFIT test battery) and throwing a cricket ball. In terms of anthropometric growth, a growth spurt was found in the stature and body mass of the girls between 10 and 12 years of age among all ethnic groups, although this result is based on cross-sectional information (Armstrong *et al.*, 2011:1007). Regarding the physical and motor fitness capabilities of girls, explosive leg strength (standing long jump) and abdominal muscle strength (sit-ups) improved the most between 9 and 11 years, and aerobic endurance (20m beep test) improved most between 9 and 10 years, where after a plateau is reached. Their upper body and shoulder muscle strength (cricket ball throw) showed a linear improvement from 9 to 10 years (Armstrong *et al.*, 2011:1010).

2.10.1.6 Travill (2007)

This study was completed by Travill in 2007 on eight to 17-year-old boys and girls in the Khayelitsha Township in the Western Cape of South Africa. The aim was to provide a general reflection of the growth and physical activity status of boys and girls from rural areas. Six schools were randomly selected from a total of 21 schools in the research area. Six children per age (ages 8.0 to 17.99 years) and gender were randomly selected from each of the schools that represented a total of 720 participants. Twelve anthropometric measurements were taken, namely stature, body mass, upper and lower limb lengths, arm circumference, calve circumference, skinfolds of the triceps, biceps, sub-scapular, supra-iliac and medial calve, and breadths of the humerus and femur. Physical fitness tests included flexibility (sit and reach), grip strength, standing long jump, speed (50 m) and cardiovascular endurance (three minute-walk test). Results from the study showed that boys and girls from this underprivileged group showed growth delays compared to standard norms of the National Centre for Health Statistics (NCHS). Children of these areas also presented with inadequate fitness levels. This may be attributed to noticeably higher levels of fat in girls of all ages

compared to boys, which may be attributed to lower levels of endurance. The higher average body mass was mainly because of higher fat deposits after the growth spurt, which was noted between 12 and 13 years (Travill, 2007:286). It was also found that girls were more flexible compared to boys of all ages, although these differences were only meaningful between 12 and 15 years. Average speed showed considerable increases between 8 and 9 years among boys, and 8 and 10 years among girls. The researchers claim that because biological capacity is influenced by physical characteristics and body composition, physical fitness levels of boys and girls in this study were poor because of growth retardation. It should, however, be noted that puberty and the age of menarche were not taken into consideration during the analyses of the results.

It is important to note that only limited conclusions can be made from cross-sectional studies, as data of such studies are collected at a single moment in time or by means of once-off measurements. Longitudinal data are therefore important to accurately study growth tendencies. Following, the methods and findings of national and international growth studies will therefore be discussed.

2.10.2 National and international longitudinal studies

During a longitudinal study, participants are continuously monitored with regard to growth, risk factors and health outcomes, or both. Such studies vastly vary in size and complexity with duration of up to ten years or longer. A few longitudinal studies have been done globally (Prahl-Anderson *et al.*, 1994, Kemper *et al.*, 2004; Lee *et al.*, 2005; Volver *et al.*, 2007), as well as in South Africa (Monyeki *et al.*, 2006; Richter *et al.*, 2007) on adolescent girls to analyse growth patterns, and the findings of these studies will now be discussed.

2.10.2.1 Amsterdam Growth and Health longitudinal study (Kemper *et al.*, 2004)

Kemper and co-workers started this 23-year-long study in 1974 in the Netherlands (Kemper *et al.*, 2004). This study group comprised of 600 healthy 13-year-old boys and girls from two primary schools, one in Amsterdam and the other in Permerend, a suburb of Amsterdam. Four-yearly measurements were taken from 1974 from 13- to 16-year of age, with a further four follow-up measurements at 21-, 27-, 29- and 32 years of age. The study had four aims,

namely (1) to determine how boys and girls grow and develop regarding their physical and socio-psychological well-being between 13- to 18 years of age, (2) how lifestyles change, especially regarding aspects of importance to health, (3) how healthy teenagers are, and how healthy their lifestyles are when considering their diet, physical activity, smoking habits and alcohol consumption, and (4) what relations could be found between lifestyle and health. Tests and measurements included anthropometric measurements (stature, body mass, skin folds), aerobic fitness, neuro-motor fitness (pull-ups, bent arm hang, leg pull-ups, five metre agility test, sit and reach, vertical jump). The results relevant to the objectives of this thesis showed that although the physical fitness of boys and girls did not decline during this period, their time spent on physical activity did decline. With regard to physical fitness and its relation to the individual's health, the results indicated that physical fitness (measured by maximal oxygen uptake per kg bodyweight and by maximal slope reached on a treadmill test) during adolescence was related to a healthy Cardio Vascular Disease (CVD) risk profiles at the age of 32 years (inversely to the sum of four skinfolds, waist circumference and to total serum cholesterol). Physical activity during adolescence was also not related to a healthy CVD risk profile at the age of 32 years. Daily physical activity was positively related to HDL ($p < 0.01$), and inversely to the TC:HDL ratio ($p < 0.05$) and to the sum of four skinfolds ($p < 0.01$). $\dot{V}O_{2max}$ was also inversely related to the TC:HDL ratio ($p < 0.01$) and to the sum of four skinfolds ($P < 0.01$). In addition, $\dot{V}O_{2max}$ was also inversely related to TC ($p < 0.01$). Neuro-motor fitness was inversely related to the sum of four skinfolds ($p < 0.01$), and positively to systolic blood pressure (< 0.01). No specific data regarding girls could be found.

2.10.2.2 Nijmegen Growth Study

Kemper and co-workers referred to the Nijmegen Growth Study (Prahl-Anderson *et al.*, 1994), which was used in the discussion of the Amsterdam Growth and Health Longitudinal Study. This study also focused on the growth of adolescents and therefore the results of this study is of importance to the objectives of this thesis and will therefore be discussed.

The study, which was conducted on children from birth to 14 years of age from the Nijmegen area is based on a mixed longitudinal design, which is one of the most effective ways to study growth and maturation. The study comprised of three groups (0-4 years, 5-9 years, and 9-14 years), who were all studied individually for five years. After completion of the study the three groups' growth curves (stature and body mass) were plotted together to develop one single curve, portraying the whole period from 4- to 14 years.

Although the study was conducted longitudinally, the focus was on growth and physical fitness. No interrelations between last-mentioned variables were investigated. The influence of maturation and menarche on girls' growth and development were also not studied. Lastly, data from this study are also considered to be outdated and therefore the applicability of the results on modern populations is being questioned. Detailed results of the study are also difficult to obtain without buying the original published publications.

2.10.2.3 A Longitudinal Study of Growth Patterns in School children in One Taipei District II (Lee *et al.*, 2005)

This study investigated growth patterns in children from the Shih-Pai district in Taipei and was conducted on 1 076 children (507 boys and 569 girls) between 8 and 18 years over a period of four years (1994-1997). Stature, body mass, sitting height, arm span, skin folds, BMI and the relationship between sitting height, arm span and stature were investigated. It was found that peak sitting height increased to 6.3cm/year among girls at an average age of eight-and-a-half years. The second acceleration in sitting height appeared at an average age of 11.5 years among girls. The increase in sitting height over the total period of the second acceleration period was 3.7cm in girls. Sitting height increased over time from 75.1cm at 10 years to 87.7cm at 18 years. An increase in peak arm span took place at 8.5 years among girls, while peak arm span increase was 8.1cm/year among girls at 8.5 years and 7.5 cm/year at 12 years of age. The average sitting height to leg length ratio was fairly consistent at 1.06:1 to 1.21:1 among girls over the four-year follow-up period. The average arm span to stature ratio varied between 0.99:1 to 1.03:1 among girls, and the average sitting height to stature ratio was relatively consistent among girls (0.51:1 to 0.55:1). In summary, this study only focused on the development of growth curves for the mentioned variables. Hence, the focus was only on the development of a few anthropometric variables, including sitting height, arm span and BMI. The influence of puberty and menarche was therefore not taken into account during the analyses of these growth patterns.

2.10.2.4 Volver *et al.* (2007)

This longitudinal study was conducted by Volver *et al.* (2007) on 36 Estonian girls between the ages of 11 and 13 years over a period of two years. The aim was to investigate the significance of influences on the development of physical fitness during the transition from one level of sexual maturation to the following. Girls' biological maturation was determined

by examining the girls' breast development according to the five Tanner stages. The question whether the girls already started menstruating was also asked. At the onset of the study only two girls had reached menarche, with post-menarcheal girls comprising 50% of the total group at the conclusion of the study. The test protocol included analyses of the growth and development of girls and included stature, body mass and breast development among the girls. Also included were eight physical fitness tests, namely 20m speed, agility (4x9m), standing long jump, squats in 30s, trunk forward flexion and the Cooper 12-minute running test. The most important findings of the study were the improvements in the standing long jump, the 20m speed test, and sit-ups when girls reached their level three sexual maturation. The researchers claimed that level three of sexual maturation (as determined by the Tanner levels of development) relates to an increase in the secretion of androgenic hormones in fast contracting muscle tissue influencing various skills requiring high strength output.

The results of the 20m speed test for girls between the age 11 to 12 years and the number of sit-ups per 30 seconds for girls between 12 and 13 years were inconsistent. More mature girls (as identified by the girls themselves using the Tanner stages) were taller and heavier, but only showed better results in the standing long jump and flexibility tests than the late developing girls (Volver *et al.*, 2007:60). Although menarche status was known, this milestone was not taken into consideration during the study. Only the results of breast development were used to place girls into different stages of biological development and to investigate the influence of the transition to the next stage on physical fitness among girls.

2.10.2.5 Pantiotou *et al.* (2008)

This study was conducted in Greece over a period of 7.5 years from 1990 to 1997 on 307 healthy girls from mid- to high socio-economic environments. The average age of the girls was between 6.8 and 8.5 years during the first measurements, and 14.6 to 16.1 years during the final measurements. During each measurement (six monthly), stature and body mass were measured, and each girl's pubertal status was determined during a physical examination of their sexual development and palpitation of their breasts. BMI was calculated based on individual measurements. Results from the study showed that the average age of the girls' pubertal phase started at 8.7 years (early developers, N=31), 10.0 years (average developers, N=125), and 11.0 years (late developers, N=28). Furthermore, the onset date of menarche was known for 182 girls as determined by the Status Quo method. The results indicated that some girls reached menarche on average at 11.1 years (early developers), some at 12.1 years

(average developers), and some at 13.0 years (late developers). The study furthermore showed that during PHV (the year in which they grew the most), girls' stature increased by 10cm (early developers), 9.6cm (average developers) and 9.4cm (late developers) in one year.

2.10.2.6 Leuven Longitudinal Study on Lifestyle, Fitness and Health (Beunen *et al.*, 1997)

Although the Leuven growth study only investigated boys between 12 and 19 years, it was still considered to be important to investigate the research focus and methods of the study. A longitudinal component analyses were used during the study to investigate growth patterns among various somatic and motor characteristics of 173 boys between 13 and 18 years of age, and again when they were adults at 30 years of age. Within the larger study, a smaller population of Flemish boys was annually studied to determine possible relations between somatic characteristics, physical performance and the age of PHV. The results showed negative relations between the speed at which limbs move and explosive and static strength, and the age of PHV during adolescence. Also, early developers initially performed better than late developers, but from adolescence to adulthood (30 years), the late developers not only caught up with the early developers, but significant differences could be observed with respect to explosive strength and functional strength to the advantage of late developers. Differences in body mass, stature and body breadths, circumferences and skinfolds were also reported throughout the study among boys of different maturity levels.

2.10.3 South African longitudinal studies

A few longitudinal studies have been performed in South Africa that investigated growth, namely the Birth to Twenty Study (Richter *et al.*, 2007) and the Ellisras longitudinal study (Monyeki *et al.*, 2006). Following a brief discussion on these South African longitudinal studies.

2.10.3.1 Birth to Twenty Study (Richter *et al.*, 2007)

This study was performed by Richter and co-workers from 1990 to 2010. A total of 3 273 new-born babies (78% black, 6% white, 12% coloured and 4% Indian) from Johannesburg (Soweto) were investigated.

The study was meant to be multi-disciplinary in nature, with the aim of investigating growth, health, well-being and the academic progress of children from rural areas from birth to 10 years. In 2000 the study was extended by another 10 years, leading to the 20-year longitudinal follow-up study, which is still ongoing. Follow-up measurements were taken at six months and one-year intervals, where after measurements varied from annually to triennially. The focus of the study is on a variety of themes, including (1) demographic, socio-economic and household information, (2) community, suburb and school environments, (3) health and nutrition, (4) cognitive development and school performance, (5) social and psychological adjustments, (6) risk behaviour, (7) the extent of physiological measurements, and (8) growth and physical activity. Of the findings that have already been published, increased growth within the current population compared to children born in the 1970s were found. Furthermore, it was found that white children are heavier and taller compared to black children (Richter *et al.*, 2007:507). Age of menarche was determined by using the Status Quo method for 287 (188 black, 99 white) urban South African girls born in Soweto, Johannesburg, in 1990. The average age of onset of menarche was 12.4 years for black girls and 12.5 for caucasian girls (Jones *et al.*, 2009:2). The overall aim of the study was to investigate secular development patterns among South African girls regarding the onset of menarche. To date, no results could be found where the impact of menarche age on girls' growth and development was studied.

2.10.3.2 Ellisras longitudinal study (Monyeki *et al.*, 2006)

This study was performed by Monyeki and Kemper from 1996 to 2003. During baseline measurements, the study comprised of 2 225 children between the ages of three and 14 years, of which 550 were pre-school children with an average age of 4.4 years, and 1 675 were primary school children with an average age of 8 years. The participants were from a rural area in Ellisras in the Limpopo Province of South Africa. The study mainly focused on the variable fat patterns among children of the Ellisras area, from pre-school age up to early adolescence. Results from the study showed that the average fat percentage varied from 16.8% and 18.7% between 7 and 14 years of age. The fat percentage for girls frequently changed from 9 years with an average fat percentage of 16.7%, 15.6% (10 years), 17.5% (11 years), 15.4% (12 years), 15.7% (13 years), and 18.6% (14 years). Results from a sub-study of the longitudinal study investigated correlations between anthropometric variables and

physical fitness. Significant correlations were found between these variables among malnourished children.

2.10.4 Review studies

A review paper is an attempt to summarize the position of present research findings on a specific subject in one encompassing scientific article (Free Dictionary, 2017:1). This type of studies reviews already executed study results, rather than producing new results. Next, a few review studies will be discussed [(Malina *et al.* (1988); Viru *et al.* (1999); Armstrong and McManus (2000)] focusing on the growth and development of girls during the adolescent period.

2.10.4.1 Malina *et al.* (1988)

This review paper was published by Malina and co-workers in 1988 and the results were mainly based on North-American (Thissen *et al.*, 1976) and European studies (Wafelbakker, 1970; Taranger & Hagg, 1980; Cameron *et al.*, 1982; Prader *et al.*, 1989) conducted during the early 1950s until late 1980s. The review focused on three areas of growth in healthy children, namely (1) the timing and duration of the adolescent growth spurt from the results of studies that were conducted over a 10-year period on North-American and European children, (2) changes in body composition during the toddler and adolescent period, which was investigated with consideration of biological immaturity of children (level when concentrations of water, proteins, and minerals are relatively consistent in fat free cells), (3) an investigation of the change and distribution of subcutaneous fat. Findings regarding these aims confirm that girls reach puberty approximately two years before boys. Further, the results showed that the distribution of subcutaneous fat deposits showed strong correlations to the onset of the growth spurt and sexual maturation. Data from the study shows that the average age when Swiss girls reach their growth spurt is between 8.6 and 12.9 years. PHV is reached at 9.3 to 15 years while they grow 5 to 10.1cm per year during PHV (Largo *et al.*, 1978:29).

2.10.4.2 Viru *et al.* (1999)

Viru and co-workers published a review paper in 1999. The results of various studies from different countries were analysed for the purpose of the study. The following questions were investigated during the review study: (1) Are there any age-specific differences in the physiological foundation during the development of performance capabilities? (2) At what age does peak development in motor capabilities take place? (3) Are the periods of accelerated development in motor capabilities related to accelerated physiological functions? (4) Is the trainability of a person connected to these periods? Results from the study showed an association between the tempo of growth and development and improvements in motor capabilities. These researchers found that growth and development cause various physiological and biological changes within a person, and this, in turn, influences the development of motor functions and capabilities. They also found that the aging of the neurological system improves coordination mechanisms and that this is the main factor that influences opportunities for motor development and improvement during the early childhood years. During sexual maturation, new opportunities arise for motor development, mainly due to hormonal changes. Results regarding motor functioning showed that the first critical period in children's development is during the early childhood years (birth to 12 months), the second critical period around 7 to 9 years of age while the third period is during puberty (11-13 years).

2.10.4.3 Growth, Maturation and Physical Education (Armstrong & McManus, 2000)

The literature chapter written by Armstrong and McManus forms part of a book titled *New directions in physical education: Change and innovation*, published in 1996. The information in the chapter is based on 14 published articles on a wide variety of issues related to physical education. This chapter in question is titled *Growth, maturation and physical education*. The authors claim that children are not "little adults" and therefore focused on the growth and development of younger children. Regarding growth, the researchers indicate that the growth spurt in girls can occur as early as 7.7 years of age, and late development as late as 10 years of age, with an average onset of 9 years. They also indicated that girls grow 6-8-6cm on average during the three-years of the growth spurt. The results pertaining to body mass show that increases in body mass takes place during the same time period as stature increases, although it takes longer for body mass to reach adult body mass. The results also show that girls' body mass increases by approximately 33.5kg from 7 to 18 years of age. Armstrong

and McManus also investigated the development of physical fitness factors, including aerobic fitness, anaerobic fitness, muscle strength, and flexibility. Results from these studies show that girls' aerobic fitness increase with age, body size, and maturation, although development takes place inconsistently among girls. Results also show that anaerobic fitness develops faster than aerobic fitness. Regarding speed and agility, girls display only a small acceleration between 12 and 17 years of age. In summary, the researchers claimed that girls' physical- and motor fitness capabilities vary from a young age due to growth and maturation processes within a certain age group. The researchers concluded that ontogenetic development is responsible for changes in humans, promoting motor functioning and abilities. The tempo of improvements in motor capabilities reflects the appearance and extension of these changes.

2.11 SUMMARY

The aim of this literature review was to discuss literature findings on the differences in the development among pre- and post-menarcheal girls' anthropometric characteristics and physical and motor fitness capabilities, as well as the possible interrelationship between these variables. The literature review focused on the effect of maturation on anthropometric, physical- and motor variables among girls. Different terms and periods relating to the study were highlighted and discussed, namely adolescence, puberty, menarche, maturation, growth, relative and chronological age, and talent identification. The review brought the following information to the fore.

The adolescent phase in girls mainly occurs between 10 and 20 years of age, which can be further divided into early (9-12 years), mid- (12-17 years) and late (18-20 years) adolescence, each spanning periods over 3 to 4 years. During adolescence the most remarkable growth and maturation changes take place, including the pubertal phase and the onset of menarche among girls. Girls on average reach their pubertal phase between 12 and 14 years, and the onset of menarche between 12 and 13 years of age. These periods can vary with as much as 3 to 4 years among girls from the same chronological age, as well as between girls from different race and socio-economic status.

Puberty and menarche, according to the literature, are two important biological milestones during a girl's development, leading to various changes in the body. The literature study

revealed that only a few studies exist that focused on differences between pre- and post-menarche girls, largely due to the challenges of longitudinal research and the sensitivity surrounding the collection of this type of data.

Various methods were developed to determine the date of the onset of menarche, including questionnaires, recalling methods, retrospective and the Status Quo method. All these methods have limitations, including being time consuming, expensive and not always producing accurate data. Alternative methods were identified from the literature to calculate maturity offset by using growth measurements, age, and ratios of body parts. These formulae have been discussed.

The literature review further highlights the fact that adolescence is a period of accelerated growth and pubertal changes. Variations in the onset and tempo of changes among girls' growth and development occur during adolescence and consequently leads to early, average and late development in girls. The differences between these groups regarding anthropometric characteristics and physical- and motor fitness capabilities were investigated and highlighted where possible. Growth and maturation are two processes related to each other and which continuously lead to changes in body size and composition. This literature review revealed that the greatest changes in growth and maturation among girls take place around puberty including the reaching of peak height velocity and the onset of menarche, mainly due to significant hormonal changes. The influence of menarche on growth and development among girls was investigated and the findings show that anthropometric characteristics as well as physical- and motor fitness capabilities among girls undergo major changes in different ways due to the onset of menarche, which involves remarkable hormonal changes.

Regarding muscle strength development, the literature study revealed that muscle strength develops optimally around the time of peak mass increase around 12 years of age. Cardiovascular endurance seems to develop linear up to 13 years of age, where after it reaches a plateau. Regarding motor fitness capabilities, it seems that the period between 13 and 14 years of age is the turning point in the upward positive development of these capabilities. In this regard, speed reaches a period of acceleration between 13 and 14 years of age, where after it evens out. Coordination significantly develops between 10 and 13 years of age and explosive power up to 14 years of age, where after it evens out and reaches a plateau.

Furthermore, the results of the studies reviewed, indicated that physical- and motor fitness capabilities among girls are influenced in different ways by structural growth and biological maturation during puberty, the growth spurt and the onset of menarche. Consequentially, the skill levels and sport participation among girls are influenced in various ways (positively and negatively). It, therefore, seems important to consider structural growth and biological maturation and also how these two processes influence girls' physical- and motor fitness during talent identification and should also be considered when developing fitness, training and sport programmes.

Lastly, the findings from existing cross-sectional, longitudinal and review studies investigating growth and physical- and motor development were investigated. The majority of these studies focused only on anthropometric growth or physical- and motor fitness capabilities of adolescent girls separately. Only a few studies focused on the possible interrelationship between these variables. Most of these studies are older than 10 years and the validity of the applicability of their results on modern populations is thus debateable. As the aim of the literature review was mainly to investigate the effect of menarche/maturation on the development of girls' anthropometric characteristics, and physical- and motor fitness capabilities, it came to the fore that only a few studies have investigated the relationship between menarcheal age and growth, as well as menarcheal age and physical- and motor fitness capabilities. When keeping in mind that the onset of menarche influences anthropometric characteristics, physical- and motor fitness capabilities, there are differences between early and late developing girls. It seems from the studies that early developing girls are at an advantage at a younger age, as they are physically more advanced. These girls perform better in physical activities and sport, but they lose their initial advantage as they grow older. Late developing girls close this gap during adolescence and perform better than early developing girls in physical- and motor fitness capabilities from approximately 10- to 12 years of age. All changes taking place during puberty are strongly influenced by maturation changes, especially menarche, which plays an important role in girls' sport skills.

Most of the studies are out dated and the relevance of the information for modern populations are questioned. Further, the studies mostly focused on one aim, for example, the relationship between menarche and anthropometry, and did not investigate all three above-mentioned characteristics in relation to the impact of menarche. Lastly, few studies were found that are longitudinal in nature.

Therefore, simultaneous assessment of anthropometric characteristics and motor- and physical fitness capabilities seem to be of importance. This will aid in the collection of more accurate information on the development of adolescent girls and to investigate the effect of early and late development, and the relations between the development of these aspects. There are limited to no studies analysing these events longitudinally. This highlights a limitation with regard to knowledge concerning the interrelatedness of human systems, especially regarding girls. Knowledge in this regard will assist with talent identification, which must take place at approximately 14 years. More accurate identifications will be possible if we better understand these developmental processes in girls. The current study therefore attempts to address these challenges to gain more knowledge and insight about the influence of early and late onset of menarche on girls' anthropometric growth and physical- and motor fitness capabilities.

With this literature review as a background, the results of the study will now be discussed in chapters three to six.

2.12 REFERENCES

Abbott, A. & Collins, D. 2002. A theoretical and empirical analysis of a “state of the art” talent identification model. *High ability studies*, 13(2):157-178.

Aberberga-Augskalne, L. & Kemper, H.C.G. 2007. Longitudinal relationship between cardiovascular functioning and peak height velocity during exercise in 7 to 16 year old boys and girls. *Human movement science*, 8(1):5-11.

Aertssen, W.F.M., Ferguson, G.D. & Smits-Engelsman, B.C.M. 2016. Performance on functional strength measurement and muscle power sprint test confirm poor anaerobic capacity in children with developmental coordination disorder. *Research in developmental disabilities*, 59(1):115-126.

Anderson, S. 2009. Collins English dictionary: Complete & unabridged. 10th ed. London: Harper Collins.

Armstrong, N., Balding, J., Gentle, P., Williams, P. & Kirby, B. 1990. Peak oxygen uptake and physical activity in 11 to 16 year-olds. *Pediatric exercise science*, 2:349-358.

Armstrong, N. & McManus, P. 2000. Growth, maturation and physical education. (In N. Armstrong, ed. *New directions in physical education: Change and innovation*. London: Cassell Education. p19-32.

Armstrong, M.E.G., Lambert, E.V. & Lambert, M.I. 2011. Physical fitness of South African primary school children, 6 to 13 years of age: Discovery vitality health of the nation study. *Perceptual and motor skills*, 113(3):999-1016.

Baechle, T.R. & Earle, R.W. 2008. *Essentials of strength training and conditioning*. 3rd ed. Champaign, Ill: Human Kinetics.

Baker, B.L., Birch, L.L., Trost, S.G. & Davison, K.K. 2007. Advanced pubertal status at age 11 and lower physical activity in adolescent girls, *Journal of Pediatrics*, 151(5):488-493.

Balyi, I. & Way, R. 2010. Canadian Sports For Life: The role of monitoring growth in long-term athlete development. Calgary: Canadian Sports Centre.

Basterra, M. 2008. Understanding and supporting your child's development age 0–6months. Developed by informed parents—successful children (IPSC).
http://www.marylandpublicschools.org/NR/rdonlyres/676DD433-449C-4A26-B364-0936353CBE4E/24408/IPSC_eng_35.pdf. Date of access: 10 Aug. 2012.

Beunen, G., Ostyn, M., Simons, J., Renson, R., Claessens, A.L., Vanden Eynde, B., Lefevre, J., Vanreusel, B., Malina, R.M. & van't Hof, M.A. 1997. Development and tracking in fitness components: Leuven longitudinal study on lifestyle, fitness and health. *International journal of sport medicine*, 18(3):s171-s178.

Beunen, G.P., Rogol, A.D. & Malina, R.M. 2006. Indicators of biological maturation and secular changes in biological maturation, *Food and nutrition bulletin*, 27(4):s244-s256.

Bitar, A., Vernet, J., Coudert, M. & Vermorel, M. 2000. Longitudinal changes in body composition, physical capacities and energy expenditure in boys and girls during the onset of puberty. *European journal of nutrition*, 39:157-163.

Bogin, B. & Varela-Silva, M.I. 2010. Leg stature, body proportion, and health: A review with a note on beauty. *International journal on environmental research and public health*, 7(3):1047-1075.

Bronikowski, M. & Bronikowska, M. 2008. Motor fitness in relation to the maturational process of pubertal boys and girls. *Papers on anthropology*, 17:28-37.

Chen, L., Li, S., He, C., Zhu, Y., Buck Louis, G.M., Yeung, E., Hu, F.B. & Zhang, C. 2016. Age at Menarche and Risk of Gestational Diabetes Mellitus: A Prospective Cohort Study Among 27,482 Women. *Diabetes care*, 39(3):469-471.

Chemicool dictionary. 2017. Definition of mass.

<https://www.chemicool.com/definition/mass.html>. Last visited:31 March 2019.

Cole, T.J., Ahmed, M.L., Preece, M.A., Hindmarsh, P. & Dunger, D.B. 2015. The relationship between Insulin-like Growth Factor 1, sex steroids and timing of the pubertal growth spurt. *Clinical endocrinology*, 82:862-869.

Craft, L.L., Pfeiffer, K.A. & Pivarnik, J.M. 2003. Predictors of physical competence in adolescent girls. *Journal of youth and adolescence*, 32(6):431-438.

Cumming, S.P., Sherar, L.B., Smart, J.E.H., Rodrigues, A.M.M., Standage, M., Gillison, F.B. & Malina, R.M. 2010. Physical activity, physical self-concept, and health-related quality of life of extreme early and late maturing adolescent girls. *Journal of early adolescence*, 32(2):269-292.

Cumming, S.P., Sherar, L.B., Gammon, C., Standage, M. & Malina, R.M. 2012. Physical activity and physical self-concept in adolescence: A comparison of girls at the extremes of the biological maturation continuum. *Journal of research on adolescence*, 22(4):746-757.

Damon, A. & Bajema, C.J. 1974. Age at menarche: accuracy of recall after thirty-nine years. *Human biology*, 46(3): 381-384.

Danubio, M.E., DE Simone, M., Vecchi, F., Amicone, E., Altobelli, E. & Gruppioni, G. 2004. Age at menarche and age of onset of pubertal characteristics in 6-14-year-old girls from the Province of L'Aquila (Abruzzo, Italy). *American journal of human biology*, 16:470-478.

Davids, K. & Baker, J. 2007. Genes, environment and sport performance: Why the nature-nurture dualism is no longer relevant. *Journal of sports medicine*, 37(11):1-20.

Davis, B., Bull, R., Roscoe, J. & Roscoe, D. 1997. Physical education and the study of sport. 3rd ed. London: Mosby.

Deborah, C. & Russel, V. 2005. ABC of adolescence: Adolescent development. *British medical journal*, 330:301-304.

Demirkale, Z.H., Abali, Z.Y., Bas, F., Poyrazoglu, S., Bundak, R. & Darendeliler, F. 2019. Comparison of the clinical and anthropometric features of treated and untreated girls with borderline early puberty. *Journal of pediatric and adolescent gynecology*, 19(1):1-27.

Des te Croix, M. 2007. Advances in paediatric strength assessment: changing our perspective on strength development. *Journal of sport science and medicine*, 6:292-304.

De Sanctis, V., Rigon, F., Bernasconi S., Bianchin, L., Bona, G., Bozzola, M., Buzi, F., De Sanctis, C., Tonini, G., Radetti, G. & Perissinotto, E. 2019. Age at Menarche and Menstrual Abnormalities in Adolescence: Does it Matter? The Evidence from a Large Survey among Italian Secondary Schoolgirls. *The indian journal of pediatrics*. 1:1-8.

D'Hondt, E., Deforche, B., Vaeyens, R., Vandorpe, B., Vandendriessche, J., Pion, J., Philippaerts, R., de Bourdeaudhuij, I. & Lenoir, M. 2011. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: A cross-sectional study. *International journal of pediatric obesity*, 6:556-564.

De Sousa, A. 2017. Physical Changes During Puberty and the Effects on Sports Performance. <https://www.nordangliaeducation.com/our-schools/singapore/article/2017/3/31/physical-changes-during-puberty-and-the-effects-on-sports-performance>. Last visited 8 July 2019.

DeVault, N. 2010. Definition of Motor Skills in Children. <http://www.livestrong.com/article/168392-definition-of-motor-skills-in-children>. Date of access: 7 Jul. 2010.

Dimeglio, A. 2001. Growth in pediatric orthopaedic. *Journal of pediatric orthopaedics*, 21:549-555.

Eisenmann, J.C. & Wickel, E.E. 2009. Biology of physical activity in children: Revisited. *Pediatric exercise science*, 21:257-272.

Elliott, B.C., Ackland, T.R., Blanksby, B.A., Hood, K.P. & Bloomfield, J. 1989. Profiling junior tennis players part 1: morphological, physiological and psychological normative data. *Australian journal of science and medicine in sport*, 21(3):14-21.

Faulkner, R.A. 1996. Maturation. In D. Docherty (Ed), *Measurement in pediatric Exercise science* (pp. 129-158). Champaign, IL: Human Kinetics Publishers.

Freitas, D.L., Lausen, B., Maia, J.A., Lefevre, J., Gouveia, E.R., Thomis, M. & Malina, R.M. 2016. Skeletal maturation, fundamental motor skills and motor coordination in children 7-10 years. *Journal of sports sciences*, 33(9):924-934.

Free dictionary. 2017. Review. <https://www.thefreedictionary.com/review>. Last visted, November 2017.

Fredriks, A.M., van Buuren, S., van Heel, W.J.M., Dijkman-Neerinx, R.H.M., Verloove-Vanhorick, S.P. & Wit, J.M. 2005. Nationwide age reference for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Archives of disease in childhood*, 90:807-812.

Frisch, R.E., & McArthur, J.W. 1974. Menstrual cycles: fatness as a determinant of minimum weight for height necessary for their maintenance and onset. *Science*, 185:949-951.

Furu, M. 2009. Menarcheal age in Stockholm girls, 1967. *Annals of human biology*, 3(6):587-590.

Gallahue, D.L., Ozmun, J.C. & Goodway, J.D. 2012. Understanding motor development. 7th ed. New York, NY: McGraw-Hill.

Garnier, D., Simondon, K.B. & Benefice, E. 2005. Longitudinal estimates of pubertal timing in sengalese adolescent girls. *American journal of human biology*, 17:718-730.

Gaudineau, A., Ehlinger, V., Vayssiere, C., Jouret, B., Arnaud, C. & Godeau, E. 2010. Factors associated with early menarche: results from the French Health Behaviour in School-aged Children (HBSC) study. *Bio Med Central Public Health*. 10:175:1-7.

Gay, J.L., Monsma, E.V., Smith, A.L., DeFreese, J.D. & Torres-McGehee, T. 2004. Assessment of growth and maturation in female athletes at a single point in time. *Women in sport and physical activity*, 22:76-82.

Gerber, B.P., Pienaar, A.E., Kruger, A. & Ellis, S. 2014. Interrelations between anthropometric and fitness changes during mid-adolescence in boys: A 2-year longitudinal study. *American journal of human biology*, 26:617-626.

Gluckman, P.D. Handson, M.A. 2006. Evolution, development and timing of puberty. *Trends in endocrinology and metabolism*, 17(1):7-12.

Golshan, M., Crapo, R.O., Jensen, R.L. & Golshan, R. 2007. Armspan as an independent predictor of pulmonary function parameters: validation and reference values. *Respiratory*, 12:361-366.

Grasso, B. 2006. Coordination & Movement Skill Development - The key to long-term Athletic Success. <http://www.performbetter.com/webapp/wcs/stores/servlet/PBOnePieceView?storeId=10151&catalogId=10751&languageId=-&pagename=209>. Date of access: 18 Nov. 2015.

Groos, A.D. & Smith, T.A. 1992. Age at menarche and associated nutritional status variables in Karimuri and Daribi census divisions of Simbu Province. *Papua New Guinea medical journal*, 35:84- 94

Guedes, D.P. 2011. Growth and development applied to physical education and sport. *Brazilian journal of physical education and sport*, 25:127-140.

Hands, B.P., Larkin, D., Parker, H., Straker, L. & Perry, M. 2008. The relationship between physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scandinavian journal of medicine and science in sports*, 19(5):655-663.

Henneberg, M. & Louw, G.J. 1998. Cross-sectional survey of growth of urban and rural “Cape-coloured” schoolchildren: anthropometry and functional tests. *American journal of human biology*, 10(1):73-85.

Hill, D. 2011. The Advantages of a Long Arm Span.
<http://www.livestrong.com/article/552216-the-advantages-of-a-long-arm-span>. Date of access: 16 Dec. 2011.

Howe, M.J.A., Davidson, J.W. & Sloboda, J.A. 1998. Innate talents: reality or myth? *Behavioral and brain sciences*, 21:399-442.

Kaplowitz, P.B., Slora, E.J., Wasserman, R.C., Pedlow, S.E. & Herman-Giddens, M.E. 2001. Earlier onset of puberty in girls: relation to increased body mass index and race. *Pediatrics*, 108(2):347-53.

Karapanou, O. & Papadimitriou, A. 2010. Determinants of menarche. *Reproductive biology and endocrinology*, 8:115-122.

Kemper, H.C.G., Snel, J. & van Mechelen, W. 2004. Amsterdam growth and health longitudinal study. *Journal of science and medicine in sport*, 47:1-198.

Khamis, H.J. & Roche, A.F. 1995. Predicting adult stature without using skeletal age: the Khamis-Roche method. *Pediatrics*, 95(3):504-507.

Koo, M.M. & Rohan, T.E. 1997. Accuracy of short-term recall of age at menarche. *Annals of human biology*, 24(1):61-64.

Largo, R.H., Gasser, T.H., Prader, A., Stuetzle, W. & Huber, P.J. 1978. Analysis of the adolescent growth spurt using smoothing spline functions. *Annals of human biology*, 5:421-434.

Lee, T.S., Chao, T., Tang, R.B., Hsieh, C.C., Chen, S.J. & Ho, L.T. 2005. A longitudinal study of growth in schoolchildren in one Taipei district II: sitting height, arm span, body mass index and skinfold thickness. *Chinese medical association*, 68(1):16-20.

Lerner, R. M., & Steinberg, L. (Eds.). (2004). *Handbook of adolescent psychology* (2nd ed.). Hoboken, NJ: Wiley.

Lindgren, G.W., Degertors, I.L., Fredrikson, A., Loukili, A., Mannerfeld, R., Nordin, M., Palm, K., Petterson, M., Sundstrand, G. & Sylvan, E. 1991. Menarche 1990 in Stockholm schoolgirls. *Acta paediatrica scandinavica*, 80:953-955.

Little, T. & Williams, A.G. 2005. Specificity of acceleration, maximum speed, and agility in professional soccer player. *Journal of strength and conditioning research*, 19(1), 76-78.

Livson, N. & McNeill. 1962. The accuracy of recalled age at menarche. *Human biology*, 34(3):218-221.

Magnusson, D., Stattin, H. & Allen, V.L. 1986. Differential maturation, among girls and its relation to social adjustment – a longitudinal perspective. *Life span development behaviour*, 7:135-173.

Malina, R.M., Bouchard, C. & Beunen, B. 1988. Human growth: selected aspects of current research on well-nourished children. *Annual review of anthropology*, 17:187-219.

Malina, R.M., Bouchard, C. & Bar-Or, O. 2004. Growth, maturation and physical activity. Champaign, IL: Human Kinetics.

Malina, R.M., Choh, A.C., Czerwinski, S.A. & Chumlea, W.C. 2016. Validation of maturity offset in the Fels longitudinal study. *Pediatric exercise science*, 28:439-455.

Marshall, W.A. & Tanner, J.M. 1986. Puberty. In: Falkner, F. & Tanner, J.M (Eds). Human growth: A comprehensive treatise. (vol 2). *Postnatal growth; Neurobiology*. New York: Plenum. p171-209.

Marshall, W.A. & Tanner, J.M. 1969. Variations in pattern of pubertal changes in girls. *Archives of disease in childhood*, 44:291-303.

McCarthy, H.D., Cole, T.J., Jebb, S.A. & Prentice, A.M. 2006. Body fat reference curves for children. *International journal of obesity*, 30(4):598-602.

Melanese, C., Bortolami, O., Bertuccio, M., Verlato, G. & Zancanaro, C. 2010. Anthropometry and motor fitness in children aged 6-12 years. *Journal of human sport and exercise*, 5(2):265-279.

Mirwald, R.L., Baxter-Jones, A.D.G., Bailey, D.A. & Beunen, G.P. 2001. An assessment of maturity from anthropometric measurements. *Medicine and science in sports and exercise*, 34(4):689-694.

Mitchell, J. 2013. Talent identification.

<https://coachgrowth.wordpress.com/2013/10/05/talent-identification>. Date of access: April 2018.

Monyeki, K.D., Koppes, L.L.J., Kemper, H.C.G., Monyeki, K.D., Toriola, A.L., Pienaar, A.E. & Twisk, J.W.R. 2006. Body composition and physical fitness of undernourished South African rural primary school children. *European journal of clinical nutrition*, 59:877-883.

Myburgh, G.K., Cumming, S.P., Silva, M.C.E., Cooke, K. & Malina, R.M. 2016. Growth and maturity status of elite British junior tennis players. *Journal of sports sciences*, 34(20):1957-1964.

Mumtaz, M.M., Nihal, H., Ahmed, O., Iskender, G., Hasan, B.U. & Selim, K. 2009. Age reference for arm span and stature of turkish children and adolescence. *Annals of human biology*, 36(3):308-319.

Nichols, S. 2009. Adolescence. <http://www.education.com/reference/article/adolescence1>. Updated on Dec 23, 2009.

Nicoletti, I. 1994. *Auxologia normale e patologica*. Florence: Centro Studi Auxologici. p 289-304

Niven, A.G., Fawkner, S.G., Knowles, A. & Stephenson, C. 2007. Maturational differences in physical self- perceptions and the relationship with physical activity in early adolescent girls. *Paediatric exercise science*, (4):472-480.

Nwankwo, M., Danborn, B. & Hamman, W.O. 2016. Relationship between age at menarche and anthropometric profiles, demography, and ethnicity among adolescent girls in Nigeria. *Annals of bioanthropolog*, 4(1):1-7.

O'dea, J.A. & Abraham, S. 1999. Association between self-concept and body weight, gender, and pubertal development among male and female adolescents. *Adolescence*, 34(133):69-79.

O'Donnell, J. 2012. Parenting through Puberty.

<http://tweenparenting.about.com/od/physicalemotionalgrowth/u/TweensandPuberty.htm>. Last accessed 6 Aug 2013.

Oliveira, D., de Oliveira, I.S., Basso, L. & Cattuzzo, M.T. 2019. Relationship between perceived athletic competence, maturational status and physical activity in boys and girls. *J. Phys. Educ.* v. 30, 3016-3025.

Ortega, F.B., Artero, E.G., Ruiz, J.R., Vincente-Rodriguez, G., Bergman, P., Hagstro, M. Ottevaere, C., Nagy, E., Konsta, O., Rey-Lopez, J.P., Polito, A., Dietrich, S., Plada, M., Beghin, L., Monios, Y., Sjo Srom, M. & Castillo, M.J. 2008. Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *International journal of obesity*, 32:s49-s57.

Pantsiotou, K. 2008. Data on pubertal development in Greek boys: a longitudinal study. *Hormones*, 6(2):148-151.

Pantsiotou, S., Papadimitriou, A., Douros, K., Priftis, K., Nicolaidou. & Fretzayas. 2008. Maturational tempo differences in relation to the timing of the onset of puberty in girls. *Acta paediatrica*, 97:217-220.

Paus, T., Zijdenbos, A., Evans, A., Worsley, A., Cillins, D.L., Blumenthal, J., Giedd, J.N. & Rapoport, J.L. 1999. Structural maturation of neural pathways in children and adolescents: In Vivo study. *Science*, 283(5409):1908.

Pauole, K., Madole, K., Garhammer, J., Lacourse, M. & Rozone, R. 2000. Reliability and validity of the t-test as a measure of agility, leg power, and leg speed in college-aged men and women. *Journal of strength and conditioning research*, 14(4), 443-450.

Parent, A.S., Teilmann, G., Juul, A., Skakkebaek, N.E., Toppari, J. & Bourguignon, J.P. 2003. The timing of normal puberty and the age limits of sexual precocity: Variations around the world, Secular trends, and changes after migration. *Endocrine reviews*, 24(5):668-693.

Pienaar, A.E. 2018. Motoriese ontwikkeling, groei, motoriese agterstande, die assesering en die intervensie daarvan: 'n Handleiding vir nagraadse studente in kinderkinetika. Potchefstroom: Xerox

Plowman, S.A., Liu, N.Y. & Wells, C.L. 1991. Body composition and sexual maturation in pre-menarcheal and non-athletes. *Medicine and science in sports & exercise*, 23(1):23-29.

Prahl-Anderson, B., Kowalski, C.J. & Heydendael, P. 1994. A mix longitudinal interdisciplinary study of growth and development. New York, NY: Academic.

Pritchett, J.W. 1988. Growth and prediction of growth in the upper extremity. *Journal of bone and joint surgery*, 70A:520-525.

Quanjer, P.H., Capderou, A., Mazicioglu, M.M., Aggarwal, A.M., Banik, S.D., Popovic, S., Tayie, F.A.K., Golshan, M., Ip, M.S.M. & Zelter, M. 2014. All-age relationship between arm span and height in different ethnic groups. *European respiratory journal*, 44:905-912.

Richter, L., Norris, S., Yack, D. & Cameron, N. 2007. Cohort profile: Mandela's children. The 1990 birth to twenty study in South Africa. *International journal of epidemiology*, 36:504-511.

Rodriguez, G., Moreno, L.A., Blay, M.G., Blay, V.A., Garagorri1, J.M., Sarria, A. & Bueno, M. 2004. Body composition in adolescents: measurements and metabolic aspects. *International journal of obesity*, 28:s54-s58.

Rogol, A.D., Clark, P.A. & Roemmich, J.N. 2000. Growth and pubertal development in children and adolescents: effects of diet and physical activity. *American journal of clinical nutrition*, 72:521s-528s.

Sawer, M.D., Azzopardi, P.A., Wickremarathne, M.D.S. & Patton, G.C. 2018. The age of adolescence. *The Lancet child and adolescent health*, 2(12):839-904.

Schoonees, P.C.; Odendal, F.F.; Swanepoel, C.J.; Du Toit, C.J. & Booysen, C.M. 1981. HAT: Verklarende handwoordeboek van die Afrikaanse taal (Afrikaans Edition). South Africa. Perskor publishers. 1378p.

Simmons, K. & Greulich, W. 1943. Menarcheal age and the height, mass and skeletal age of girls aged 7 to 17 years. *Journal of pediatrics*, 22:518-548.

Simmons, D. 2000. Talent identification of British diving. Physiological and anthropometrical Test. [CD Rom]. British diving.

Smith, O. 2016. Mapped: The world's tallest (and shortest) countries.
<http://www.telegraph.co.uk/travel/maps-and-graphics/the-tallest-and-shortest-countries-in-the-world>. Update 6 June 2016).

Stang, J., & Story, M. 2005. Adolescent growth and development. In. J. Stang & M. Story (Eds.), *Guidelines for adolescent nutrition services* (pp. 1–8). School of Public Health, University of Minnesota.

Steinberg, L. & Morris, A.S. 2001. Adolescent development. *Annual review of psychology*, 52:83-110.

St George, I.M., Williams, S. & Silva, P.A. 1994. Body size and the menarche: The Dunedin study. *Journal of adolescent health*, 15(7):573-576.

Stanton, W.R., Kelley, J.L., Bunyan, D.A. & Silva, P.A. 1992. Expected gain in body mass and onset of the menarche. *The Australian & New Zealand journal of obstetrics and gynecology*, 32:338-340.

Steinberg, L. & Morris, A.S. 2001. Adolescent development. *Annual review of psychology*, 52:83-110.

Stewart, A.D., Marfell-Jones, M., Olds, T., & de Ridder, H. 2011. International standards for anthropometric assessment. Potchefstroom: International Society for Advancement of Kinanthropometry (ISAK).

Suslov, F. & Nikitushkin, V. 1991. To train a runner: The preparation of young runners in sport schools and what a coach should take into account. *Soviet sports review*, 26(1):30-34.

Tanner, J.M. 1962. *Growth at Adolescence*, 2nd ed. Oxford, England Blackwell Scientific Publications.

Tanner, J.M. & Davies, P.S.W. 1985. Clinical longitudinal standards for height and height velocity for North American children. *Journal of pediatrics*, 107:317-329.

Tanner, J.M., Whitehouse, R.H. & Takaishi, M. 1966. Standards from birth to maturity for height, mass, height velocity and mass velocity: British children 1965, part I and II. *Archives of disease in childhood*, 41:454-471.

Tanner, J.M. & Whitehouse, R.H. 1976. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. *Archives of diseases in childhood*, 51:170-179.

Tanner, J.M. 1992. Growth as a measure of the nutritional and hygienic status of a population. *Hormone research*, 38(1):s106-s115.

Taranger, J. & Hagg, U. 1980. The timing and duration of adolescent growth. *Acta odontol scand*, 38(1):57-67.

Thissen, D., Bock, R.D., Wainer, H. & Roche, A.F. 1976. Individual growth in stature: a comparison of four growth studies in the USA. *Annals of human biology*, 3(1):529-542.

Towne, B., Czerwinski, S.A., Demarath, E.W., Blangero, J. & Siervogel, R.M. 2005. Heritability of age at menarche in girls from the Fels longitudinal study. *American journal of physical anthropology*, 123:210-219.

Travill, A.L. 2007. Growth and physical fitness of socially disadvantage boys and girls aged 8-17 years living in the western cape, south Africa. *African journal for physical, health education, recreation and dance*, 13(3):279-293.

Turley, K.R. & Wilmore, J.H. 1997. Cardiovascular responses to submaximal exercise in 7- to 9-yr old boys and girls. *Medicine and science in sports and exercise*, 29(6):824-832.

United nations educational, scientific and cultural organization (UNESCO). 2014. What do we mean by youth. <http://www.unesco.org/new/en/social-and-human-sciences/themes/youth/youth-definition/>. Page visited 9 April 2015.

Van Den Berg, L., Coetzee, B. & Pienaar, A.E. 2006. The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *African journal for physical, health education, recreation & dance*, 18(3):510-15.

Van Gent, M.M. 2001. Anthropometrical, physical and motor fitness characteristics of 10- to 15-year old girls in the Northwest province. Potchefstroom: NWU. (Dissertation).

Vaeyens, R., Lenoir, M., Williams, A.M. & Philippaerts, R.A. 2008. Talent identification and development programmes in sport: Current models and future directions. *Journal of sports medicine*, 38 (9):703-714.

Viru, A., Loko, J., Harro, M., Volver, A., Laaneots, L. & Viro, M. 1999. Critical periods in the development of performance capacity during childhood and adolescence. *Physical education and sport pedagogy*, 4(1):75-119.

Volver, A., Viru, A. & Viru, M. 2007. A two-year longitudinal study of sexual maturation effects on motor abilities in girls. *Medicine in sport*, 70:57-63.

Waffelbakker, F. 1970. Adolescent growth spurt in relation to age and maturation: a longitudinal study. In, Tome II. Paris: Centre International de l'Enfance. p33-38.

Wells, J.C.K. 2007. Sexual dimorphism of body composition. *Best practice and research-clinical endocrinology and metabolism*; 21:415-430.

Wheeler, M.D. 1991. Physical changes of puberty. *Endocrinology and metabolism clinics of North America*, 20(1):1-14.

Williams, A. M. & Reilly, T. 2000. Talent identification and development in soccer. *Journal of sports science*, 18(9):657-667.

Wilmore, J.H. & Costill, D.L. 1999. Physiology of sport and exercise. Champaign, Ill: Human Kinetics Publishers. 710p.

Williams, A. M. & Reilly, T. 2000. Talent identification and development in soccer. *Journal of sports science*, 18(9):657-667.

World Health Organization. 2006. WHO Child Growth Standards: Stature/Height-for-Age, Mass-for-Age, Mass-for-Stature, Mass-for-Height and Body Mass Index-for-Age: Methods and Development. Geneva: World Health Organization.

World health organization (WHO). 2015a. Adolescent health.
http://www.who.int/topics/adolescent_health/en/. Page visited 9 April 2015.

World health organization (WHO). 2015b. BMI classification.
http://apps.who.int/bmi/index.jsp?introPage=intro_3.html. Page visited 9 April 2015

Xie, Y.J. & Ho, S.C: 2016. Age at menarche, mass change from young adulthood to middle age, and adult adiposity: Evidence from the Hong Kong women's health study. *AP292*:133.

Zverev, Y. & Chisi, J. 2005. Estimating height from arms span measurements in Malawian children. *College of anthropology*, 29(2):469-473.

CHAPTER 3

**TWO YEAR FOLLOW-UP OF DIFFERENCES IN
ANTHROPOMETRIC GROWTH BETWEEN PRE- AND
POST- MENARCHEAL GIRLS: IMPLICATIONS FOR SPORT
PARTICIPATION**

Research paper

Two-year follow-up of differences in anthropometric growth between pre- and post-menarcheal girls: Implications for sport participation

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Two-year follow-up of differences in anthropometric growth of pre- and post menarcheal girls: Implications for sport participation

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ABSTRACT

Introduction: Puberty signifies developmental changes that differ in timing and tempo contributing to noteworthy changes in growth between early and late developing girls.

Methods: This longitudinal study included a convenience sample where girls ($N=58$) aged 13.51 ± 3.51 were divided into pre- ($n=13$) and post-menarche ($n=45$) groups according to their menarche status. Anthropometric variables were measured, 4 months apart over 3 years and analyzed by means of a repeated measures ANOVA.

Results: Post-menarche girls were taller and heavier with longer body segments and a higher BMI at a younger age. Differences were significant at baseline but declined to similar values at 16.25 years at the end of the pubertal phase.

Conclusion: Timing of menarche results in temporary significant growth differences between girls. Initially, early maturing girls have anthropometric advantages, but these benefits dissipate to more ideal body compositions among late developers that might benefit them in sport at a later age.

Key words: Anthropometric; Adolescence; Girls; Longitudinal; Maturation; Menarche

INTRODUCTION

Adolescence, including the pubertal phase, is an important transition period between childhood and adulthood, accompanied by sexual maturation and physical growth (Sawyer *et al.*, 2012). From a biological perspective, puberty in females is one of the most dynamic periods in life, producing changes in stature, body composition, and the neuroendocrine axis, as well as the achievement of fertility (Lee, Tsai & Lin, 2016). Puberty involves a series of developmental changes that differ in timing and tempo among individuals including a cascade of endocrine actions that contributes to noteworthy changes in growth (Eisenmann & Wickel, 2009). This, in turn, influences performance based on physical- and motor abilities (Hill, 2015).

Adolescence is documented to widely stretch between 10 and 25 years in girls (UNESCO, 2014; WHO, 2015a) and includes the pubertal phase. Girls enter the pubertal phase during early adolescence (11.8 to 13.0 years) (Malina, Bouchard & Bar-Or, 2004; Gluckman & Handson, 2006) when sexually transmitted glands become functional, and secondary sexual characteristics begin to develop. This period includes reaching menarche during late adolescence (Anderson, 2009). Menarche refers to the onset of the menstrual cycle, when a girl begins to ovulate for the first time (Towne, Czerwinski, Denarath, Blangero & Siervogel, 2005). Menarche is reached on average at the end of puberty (average 12.8 years) and about 6 months to 1 year after peak height velocity (PHV) (Malina *et al.*, 2004; Gluckman & Handson, 2006; Karapanou & Papadimitriou, 2010). The age at which menarche occurs, is not rigid and is influenced by a variety of factors, including genetic factors, nutrition and health status (Kaprio *et al.*, 1995; Salces, Rebato, Susanne, San Martin & Rosique, 2001).

Achievement of menarche has been documented for decades due to its relation to various somatic, endocrine and psychological manifestations (Marshall & Tanner, 1986). The most significant variation in sexual maturity (menarche, among others) among girls is found between the ages of 11 and 16 years, showing clear differences in anthropometric growth between early and late maturing girls, while also influencing physical and motor development (Van den Berg, Coetzee &

Pienaar, 2006; Gluckman & Handson, 2006). This is due to significant hormonal changes that are taking place during the onset of menarche (Tanner & Davies, 1985; Dimeglio, 2005). Menarche is therefore, an important milestone to take into consideration when analysing the growth, physical- and motor fitness of girls during their pubertal period (Davis, Bull, Roscoe & Roscoe, 1997; Parent et al., 2003; Van den Berg et al., 2006; Gluckman & Handson, 2006). Measurements of stature are important for the evaluation of adolescents' growth, calculation of a nutritional index and the calculation and standardization of physiological characteristics such as lung volumes, muscle strength and basal metabolic rate (WHO, 2006).

Physical aging and differential timing of menarche from pre-pubertal age to adulthood represents a continuum that includes both early and late developers (Carel & Leger, 2008). The long-term effects of menarche occurring at an earlier or later age in relation to sports participation, have for some time been a subject of research (Apter, Reinila & Vihko, 1989; Forman et al., 1994; Van Lenthe, Kemper & van Mechelen, 1996; Okasha, McCarron, McEwen & Davy-Smith, 2001), as it is important to take biological maturation into account in order to correct for developmental differences. Some researchers agree that early, average or late occurrence of maturity is associated with differences in anthropometric development, including more than just changes in longitudinal growth (Biro et al., 2001). Estrogen plays an important role in the lipogenic profile of girls during the puberty phase, especially after menarche (Rogol, Roemmich & Clark, 2002). Consequently, girls with a higher body mass index (BMI) and fat percentage tend to be more advanced in their maturation status compared to girls with a lower BMI and fat percentage (Kaplowitz, Slora, Wasserman, Pedlow & Herman-Giddens, 2001; Biro et al., 2001). Decades ago Deutsch and Mueller (1985) indicated that girls, who reach menarche earlier, have a more central pattern of fat deposition compared to girls who reach menarche at a later age. In this regard Cumming, Sherar, Gammon, Standage and Malina (2012) report differences in BMI of up to 7.1 kg/m² between early and late developers in the age group 13 to 14 years with the highest values found in early developers. Furthermore, Bronikowski and Bronikowska (2008) report longer lengths among

early-developing girls compared to average and late developing girls at the age of 13 years with differences of 5 cm between maturity groups. Mass differences of 14.9 kg at age 12 years and 12.8 kg at 14 years are reported by Myburgh, Cumming, Silva, Cooke and Malina (2016) between females at different stages of development. Consequently, maturation and achieving of menarche plays an important role in the anthropometric growth and development of girls. Mirwald, Baxter-Jones, Bailey and Beunen (2001) are therefore of the opinion that it is important to link growth with an individual's maturation status during research or monitoring studies and furthermore account for this information during sport participation and talent identification in girls.

Structural features such as body length, mass and limb lengths relate directly to the choice of a particular sport and also to the ability to perform in a particular position during team sports (Hill, 2015). Each individual and team sport requires a combination of health and motor (performance-related) fitness factors. In this regard researchers have found that early maturing girls are taller and heavier than late maturing girls during the early periods of puberty, although late maturing girls tend to catch up and surpass early maturing girls by having longer and leaner bodies with a more preferable BMI (Malina et al., 2004). With regard to these changes in girls of differential maturation, AberbergaAugskalne and Kemper (2007) found in their longitudinal study of 45 girls from Riga between 7 and 16 years of age, that late developing girls (as determined by the age at PHV), showed more effective cardiovascular adjustments at each level of peak growth in response to exercise compared to early and average developers. Furthermore, although not reported for different maturity groups, Abbott and Collins (2002) found various correlations between anthropometric growth and physical fitness abilities in Scottish girls including correlations between the seated basketball throw and height, mass, sitting height and arm span, while the shuttle run (aerobic endurance) correlated only with stature and mass.

Validity of older studies focusing on girls' linear and secular growth are currently questioned for application on current populations due to secular growth and maturation changes that has taken

place over the last few decades (Cole, 2003). These studies results however shows a decline in the average onset age of menarche by 3 months every decade since the start of the twentieth century (Parent et al., 2006). Furthermore, only a few South-African studies focused on maturational growth (Monyeki et al., 2006; Richter, Norris, Yack & Cameron, 2007), although differences between early and late maturing girls were not the main focus in these analyses. Consequently, new and more current data, researched over a longitudinal period, is needed.

Therefore, this study aims to address the gap regarding differences in anthropometric growth of pre- and post-menarche girls, measured over a follow-up period of two years. Information about the timing of menarche, and its relation to different growth rates associated with this timing could be used in understanding of how the magnitude of these growth differences will affect the physical- and motor fitness development of girls in different stages of pubertal development. In this regard important information can be obtained regarding motor- and physical fitness relative to menarche. Accordingly, this novel knowledge could be used during the development of exercise and sports programmes to account for maturational differences between girls. Furthermore, it could be applied during talent selection to more accurately identify and develop girls who have the potential to excel in sport (Balyi & Way, 2010).

METHODOLOGY

Research design

This longitudinal study, “Growth and sport psychological characteristics of talented adolescents”, was performed from early 2010 until the end of 2012 (3 years) resulting in follow-up measurements over a two-year period (2010-2012) during which growth characteristics and physical and motor abilities were analysed. The sample was based on a convenient and purposeful sampling of all grade 8 learners from one quintile 5 (quintile 1 = low socio-economic quintile, to quintile 5=high socio-economic) high school in Potchefstroom in the Northwest Province of South Africa. The data was collected by means of anthropometric tests as well as a Status Quo

questionnaire. The anthropometric measurements took place 3 times per year, 4 months apart. Baseline anthropometric measurements were taken in February 2010 and the final measurements took place in November 2012 accounting for nine time points of anthropometric measurements (T1-T9) in total.

Research group

In 2010, 200 subjects (girls and boys) were enrolled in the study with a mean age of 13.58 ± 0.25 years for boys ($n=105$) and 13.73 ± 0.48 years for girls ($n=95$). For the purpose of this study, only the data of the girls were analysed. The final group of girls, who completed all follow-up measurements, consisted of 58 participants with a mean age of 16.26 years during the final measurements in 2012. The group were divided into a pre- ($n=13$) and post-menarche group ($n=45$) according to their menstrual status at baseline measurements. The loss of subjects over the study period was 38% (37 girls) from baseline measurements in February 2010 to the final measurements in November 2012 due to various reasons including parents of children moving out of town, children moving between schools and injury.

Ethical approval

Ethical approval was obtained from the HREC Ethics Committee of the North-West University (NWU 00142-11-A1) for the execution of the study. Permission for the project was also obtained from the principal of the school, the parents and each participant. All grade 8 learners whose parents provided permission and who gave consent themselves were subjected to the testing protocol.

Measuring instruments

Age of menarche

The age of menarche was determined by the Status Quo method (Hediger & Stine, 1987) during February in 2010 (T1), 2011 (T4) and 2012 (T7) during the first measurements of each year. Girls had to indicate on the questionnaire by selecting YES or NO whether they have had their first menstrual cycle on or before the date of testing during the first measurements of each year in February. If they answered YES they also had to indicate the month and year when their first menstrual cycle took place.

From Table 2 it is clear that a high percentage of girls (77%) already reached menarche during baseline measurement (grade 8 - 2010) at a mean age of 13.51 years. Of these 77% who had reached menarche at baseline (post-menarche group), 8% reached menarche during grade 5, 22% during grade 6, 66% during grade 7 and 2% during their grade 8 year. During the first follow-up measurements in grade 9 (2011), 91% of the overall group (pre- and post-menarche) reached menarche at a mean age of 14.52 years with all but one girl (98%) reaching menarche at a mean age of 15.45 years during the last year of measurements (grade 10 - 2012).

Anthropometric measurements

The protocol as developed by the International Society for the Advancement of Kinanthropometry (ISAK) was used for stature and body mass measurements (Stewart, Marfell-Jones, Old & de Ridder, 2011). Sitting height was determined by a modified method (Simmons, 2000) and arm span according to the Canadian Sports for Life protocol (Balyi & Way, 2010). All researchers were trained level 2 Kinanthropometrists (theory and practical training), ranging from honours students to senior researchers in Kinderkinetics and Sport Science. Furthermore, these researchers were equipped with all necessary skills and knowledge beforehand to perform these measurements. All measurements were taken behind enclosed spaces to ensure the privacy of the

participants and were taken by researchers of the same gender as those of the participants. Participants had to wear minimal clothing during measurements.

Stature and Sitting height were measured to the nearest 0.1cm by means of a portable Harpenden stadiometer (Harpenden Holtain Ltd, Crymych, UK). Stature was measured with the subject standing, facing forward, with the heels, back and head against the stadiometer and with feet together. The head was held in the Frankfort position by the examiner, and the measurement was taken after the subject had inhaled deeply, to the nearest 0.1 cm. Two measurements were taken, of which an average value was used (Stewart et al., 2011). Inter-measurement reliability for stature was calculated as 0.98. **Sitting height** was measured by having the subject sit flat on the stadiometer with the back against the stadiometer and knees bent at about 90 degrees. The head of the subject was held in the Frankfort position by the examiner, and the measurement was taken to the nearest 0.1 cm while the subject had to inhale deeply (Simmons, 2000). **Mass** was measured by means of an electronically calibrated scale (Omro BF 511). The subject stood upright with weight evenly distributed over the scale with the arms at the sides of the body. The subject had to look straight forward while standing without shoes and as little clothing as possible and the measurement was then taken to the nearest 0.1 kg (Stewart et al., 2011). **Arm span** was measured by attaching a tape measure horizontally against a wall at about shoulder height of the subject with the starting point of the tape in a corner of a wall. The subject stood upright, with the front of the body and the toes against the wall. The arms had to be extended horizontally, with the palms facing the wall and the head turned to the left. The measurement was taken to the nearest 0.1 cm (Balyi & Way, 2010). **Leg length** was calculated by subtracting the sitting height value from the stature value. **Sitting height ratio** was calculated by using the following formula: $\text{Height/sitting height} \times 100$. **The body mass index (BMI)** is a statistically developed equation developed by Adolphe Quetelet in the 1900's for evaluating body mass and is not related to gender and age.

BMI was calculated by applying the following equation: Body mass in kilograms divided by height in meters squared or, $BMI = x \text{ KG} / (y \text{ M} * y \text{ M})$ (x =body mass in KG, y =height in M).

Statistical analysis

The data was analyzed by means of the “Statistica for Windows 2017” Statsoft computer programme package. For descriptive purposes, means, standard deviations (sd) and minimum and maximum values (StatSoft, 2017) were calculated. A repeated measures ANOVA was used to analyze changes in anthropometric variables over time with a Posthoc Bonferonni adjustment to determine statistical significance of differences between time point measurements. An independent *t*-test was also performed to investigate the differences in anthropometric characteristics between pre- and post-menarche girls with $p < 0.05$ set as the level of significance. Effect sizes were also calculated to determine practical significance of differences. The cut-off values of Cohen’s *d*-value (Cohen, 1992) was used with a $d > 0.2$ =small effect size, $d > 0.5$ (medium effect size) and $d > 0.8$ (large effect size).

RESULTS

Table 1 displays the descriptive characteristics of the group, including mean ages of pre- and post-menarche groups in year one (2010, T1-T3), year two (2011, T4-T6) and year three (2012, T7-T9) during the 2-year follow-up period.

At baseline (T1), 58 girls completed all measurements, where after they were classified into two groups according to their menarcheal status, namely pre-menarche ($n=13$, 23%) and post-menarche girls ($n=45$, 77%). Of the pre-menarche group ($n=13$) who were not menarcheal during baseline, 12 reached menarche in the following years, of which eleven at T4 and another one at T7, in February of each new school year. The group had a mean age of 13.51 years at baseline

with no significant age differences (0.01 years) between the pre- and post-menarche groups. All follow-up comparisons between the groups were done based on the baseline grouping.

Three time-point measurements, four months apart, took place during each school-year including T1-T3 during year one (2010, grade 8) starting at a mean age of 13.51 years, T4-T6 during year two (2011, grade 9) starting at a mean age of 14.51 years and T7-T9 in year three (2012, grade 10) starting at a mean age of 15.51 years and ending at a mean age of 16.26 years (T9). This contributed to two-year follow-up measurements of nine time-point measures, four months apart, taken over a three-year school period.

TABLE 1: DESCRIPTIVE AGE CHARACTERISTICS OF THE TOTAL GROUP AND THE PRE- AND POST-MENARCHE GROUPS

	Year 1 (T1-3)		Year 2 (T4-6)		Year 3 (T7-9)	
	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD
Group	58	(T1)13.51 $\pm$ 3.5 (T3) 14.26 $\pm$ 3.5	58	(T4) 14.51 $\pm$ 3.51 (T6) 15.26 $\pm$ 3.51	58	(T7) 15.51 $\pm$ 3.51 (T9) 16.26 $\pm$ 3.51
Pre-menarche	13	(T1) 13.52 $\pm$ 3.58 (T3) 14.27 $\pm$ 3.58	13	(T4) 14.52 $\pm$ 3.58 (T6) 15.27 $\pm$ 3.58	13	(T7) 15.52 $\pm$ 3.58 (T9) 16.27 $\pm$ 3.58
Post-menarche	45	(T1) 13.51 $\pm$ 3.53 (T3) 14.26 $\pm$ 3.53	45	(T4) 14.51 $\pm$ 3.53 (T6) 15.26 $\pm$ 3.53	45	(T7) 15.51 $\pm$ 3.53 (T9) 16.26 $\pm$ 3.53

T1-T3=Year one (grade 8); T4-T6=Year 2 (grade 9); T7-T9=Year 3 (grade 10); N=number of participants; M=Mean age

Table 2 reports the descriptive anthropometric characteristics that were obtained at each of the nine time points of the pre- and post-menarche groups, and significance of differences between the groups during each time point measure over time. Measurements included stature, arm span, mass, sitting height, sitting height ratio, leg length and BMI.

TABLE 2: DESCRIPTIVE STATISTICS AND SIGNIFICANCE OF GROUP AND TIME DIFFERENCES OF ANTHROPOMETRIC CHARACTERISTICS BETWEEN TIME POINTS (T1-T9)

	Pre-menarche n=13			Post-menarche n=45			Between groups		Over time T1-T9	
	M $\pm$ SD	Min	Max	M $\pm$ SD	Min	Max	p	d-	F	p
Stature										56.92
T1	156.89 $\pm$ 8.99	147.60	177.60	161.65 $\pm$ 6.48	144.60	174.90	0.03*	0.60 ^{##}		>0.01*
T2	159.20 $\pm$ 8.88	150.10	179.40	163.27 $\pm$ 6.64	146.90	177.00	0.07*	0.50 ^{##}		
T3	161.16 $\pm$ 8.62	150.40	180.40	163.99 $\pm$ 6.61	147.50	177.90	0.20	0.36 [#]		
T4	162.30 $\pm$ 8.61	151.70	180.80	164.41 $\pm$ 6.68	147.50	178.30	0.35	0.27 [#]		
T5	162.96 $\pm$ 8.58	152.00	181.10	164.50 $\pm$ 6.73	147.60	179.00	0.49	0.19		
T6	164.30 $\pm$ 9.03	152.90	182.70	165.04 $\pm$ 6.63	147.60	179.30	0.74	0.09		
T7	164.65 $\pm$ 8.90	152.90	182.70	165.16 $\pm$ 6.61	148.15	179.30	0.82	0.06		
T8	165.01 $\pm$ 8.90	152.90	182.70	165.48 $\pm$ 6.56	149.80	179.30	0.83	0.06		
T9	165.75 $\pm$ 8.80	153.90	182.80	165.78 $\pm$ 6.63	149.80	179.50	0.98	0.01		
Arm span										37.84
T1	158.91 $\pm$ 9.38	146.90	179.50	162.96 $\pm$ 7.03	146.10	178.60	0.09*	0.48 [#]		>0.01*
T3	162.13 $\pm$ 9.88	147.50	182.30	165.02 $\pm$ 7.21	146.80	183.20	0.24	0.33 [#]		
T4	163.57 $\pm$ 10.66	147.50	183.60	165.67 $\pm$ 7.42	146.80	184.00	0.42	0.22 [#]		
T5	165.24 $\pm$ 10.25	150.40	186.00	166.48 $\pm$ 7.30	148.50	184.30	0.62	0.13		
T6	166.34 $\pm$ 10.65	150.40	186.00	166.84 $\pm$ 7.51	148.50	185.80	0.85	0.27 [#]		
T7	167.20 $\pm$ 10.60	151.30	186.30	167.68 $\pm$ 7.45	148.60	185.80	0.85	0.05		
T8	167.63 $\pm$ 10.75	151.50	186.50	167.80 $\pm$ 7.50	148.60	185.90	0.94	0.02		
T9	168.41 $\pm$ 11.20	151.50	188.90	168.12 $\pm$ 7.61	148.70	185.90	0.91	0.03		
Mass										14.69
T1	48.36 $\pm$ 10.04	38.10	65.20	56.90 $\pm$ 9.42	43.60	81.60	0.01*	0.91 ^{###}		>0.01*
T2	51.93 $\pm$ 10.68	40.40	70.10	59.62 $\pm$ 9.41	44.80	82.20	0.01*	0.49 ^{##}		
T3	53.31 $\pm$ 11.44	40.70	76.50	59.17 $\pm$ 9.45	46.20	79.80	0.06*	0.55 ^{##}		
T4	55.63 $\pm$ 12.73	42.60	79.30	60.46 $\pm$ 9.62	46.80	82.00	0.14	0.42 [#]		
T5	57.43 $\pm$ 12.28	44.60	80.20	62.01 $\pm$ 9.75	48.90	84.70	0.16	0.41 [#]		
T6	58.23 $\pm$ 11.75	46.10	80.80	61.72 $\pm$ 9.39	48.30	83.60	0.27	0.32 [#]		
T7	58.79 $\pm$ 12.22	45.15	82.35	61.11 $\pm$ 8.82	48.35	81.00	0.45	0.21 [#]		
T8	61.00 $\pm$ 11.55	47.90	85.90	63.14 $\pm$ 8.95	48.70	83.40	0.48	0.20 [#]		
T9	59.78 $\pm$ 11.64	46.00	81.80	62.39 $\pm$ 9.55	47.40	85.90	0.41	0.24 [#]		
Sitting height										17.72
T1	79.51 $\pm$ 3.45	75.40	87.20	82.38 $\pm$ 3.27	73.80	89.60	0.01*	0.85 ^{###}		>0.01*
T3	82.09 $\pm$ 3.07	77.90	88.50	83.76 $\pm$ 3.59	75.30	92.00	0.13	0.50 ^{##}		
T4	83.01 $\pm$ 3.11	78.50	89.40	84.22 $\pm$ 3.55	75.60	92.00	0.27	0.36 [#]		
T5	83.94 $\pm$ 3.04	79.20	90.00	85.05 $\pm$ 3.53	76.60	92.80	0.30	0.33 [#]		
T6	84.66 $\pm$ 3.05	79.90	91.30	85.46 $\pm$ 3.45	76.60	93.50	0.44	0.24 [#]		
T7	85.12 $\pm$ 2.82	81.00	91.40	85.73 $\pm$ 3.47	76.70	93.50	0.56	0.19		
T8	85.63 $\pm$ 2.55	81.70	91.40	86.19 $\pm$ 3.59	77.70	93.50	0.60	0.18		
T9	85.92 $\pm$ 2.64	81.70	92.00	86.46 $\pm$ 3.59	78.10	93.90	0.61	0.17		
Sitting height ratio										17.62
T1	50.72 $\pm$ 1.32	48.80	52.84	50.98 $\pm$ 1.42	48.25	53.94	0.57	0.18		>0.01*
T3	50.99 $\pm$ 1.73	48.43	54.11	51.08 $\pm$ 1.44	48.08	54.44	0.84	0.05		
T4	51.20 $\pm$ 1.64	48.63	53.77	51.24 $\pm$ 1.39	48.57	54.57	0.93	0.26 [#]		
T5	51.56 $\pm$ 1.50	49.29	53.77	51.71 $\pm$ 1.214	49.43	54.60	0.71	0.10		
T6	51.58 $\pm$ 1.55	49.03	54.33	51.79 $\pm$ 1.19	49.32	54.60	0.60	0.15		
T7	51.76 $\pm$ 1.52	49.19	54.34	51.91 $\pm$ 1.23	49.32	54.58	0.69	0.10		
T8	51.96 $\pm$ 1.55	49.19	54.34	52.09 $\pm$ 1.26	49.29	54.77	0.75	0.09		
T9	51.90 $\pm$ 1.55	49.08	54.24	52.16 $\pm$ 1.20	49.73	54.84	0.51	0.18		
Leg length										0.05
T1	77.86 $\pm$ 6.33	70.20	91.80	79.18 $\pm$ 4.42	66.90	86.60	0.39	0.24 [#]		0.81
T3	78.85 $\pm$ 6.62	70.30	91.90	79.40 $\pm$ 4.39	66.90	86.60	0.72	0.09		
T4	79.19 $\pm$ 6.59	70.90	91.90	79.55 $\pm$ 4.42	67.00	86.80	0.81	0.06		

TABLE 2 CONTINUE

T5	79.25±6.59	71.10	91.90	79.65±4.41	67.00	86.80	0.79	0.07
T6	79.58±6.58	71.10	91.90	79.78±4.44	67.00	86.90	0.90	0.03
T7	79.78±6.66	71.20	92	79.86±4.40	67.55	86.90	0.96	0.01
T8	79.89±6.70	71.30	92.3	79.98±4.30	68.90	87.00	0.95	0.01
T9	80.17±6.86	71.30	92.8	80.09±4.30	68.90	87.00	0.95	0.01
BMI								
T1	19.59±3.50	16.59	26.79	21.79±3.73	16.79	39.02	0.06*	0.60##
T2	20.41±3.49	17.10	27.76	22.37±3.52	17.57	38.09	0.08*	0.55##
T3	20.43±3.68	17.11	29.18	22.00±3.36	17.60	35.99	0.15	0.44#
T4	21.02±4.07	17.50	29.88	22.36±3.36	17.54	36.53	0.23	0.35#
T5	21.56±3.86	18.14	29.81	22.98±3.52	18.64	38.51	0.21	0.38#
T6	21.43±3.67	18.37	29.46	22.65±3.24	18.35	36.22	0.25	0.35#
T7	21.65±3.78	18.08	30.02	22.49±2.91	18.80	33.91	0.39	0.25#
T8	22.37±3.46	19.58	31.06	23.11±3.04	18.35	35.27	0.45	0.22#
T9	21.68±3.49	18.55	29.75	22.72±3.25	18.29	36.09	0.31	0.30#

n=Number of participants; T1-T3= year 1 (grade 8); T4-T6=Time point measurements after 12 months (grade 9); T7-T9=Time point measurement after 24

months (grade 10); M=Mean; SD=Standard deviation, Min=Minimum value of group; Max=Maximum value of group; *=Statistical significance (p<0.05);

*=Borderline statistical significance (p<0.10) #=small effect size (d<0.2); ##=medium effect size (d<0.5); ###=large effect size (d<0.8)

Table 3 displays the mean four-monthly changes in anthropometric characteristics as well as annual changes over the two-year follow-up period (T1-T4, T4-T7, T7-T9 and T1-T9), and statistical and practical significance of these changes. Changes over the follow-up period are also displayed in figure 1 a-g for each of the growth characteristics. It is important to note that for arm span, sitting height, sitting height ratio and leg length, no measurements were available for T2, due to practical challenges during that specific measurement.

The repeated measures ANOVA analysis showed significant interactions between the groups over time regarding stature, arm span, mass, sitting height, leg length and BMI, as displayed in Fig. 1 a-g. The groups also differed significantly over time in the same variables, except for leg length (p<0.05, Table 2). A comparison of time point differences between the groups showed that the post-menarche group (n=45) was on average the taller and heavier group at baseline (T1) with longer upper limbs (p<0.09, d=0.48) and lower limbs (p=0.39, d=0.24), although pre-menarche girls had a lower BMI value (p=0.06, d=0.60). Differences of 4.76 cm (stature), 4.05 cm (arm span), 8.54 kg (mass), 2.87 cm (sitting height), 1.32 cm (leg length) and 2.2 (BMI) were all significant (p<0.05) between pre- and post-menarche girls during T1. Only the sitting height ratio (0.27%) was neither statistically nor practically

TABLE 3: STATISTICAL AND PRACTICAL SIGNIFICANCE OF CHANGES BETWEEN TIME POINTS (4-MONTHLY AND ANNUAL) IN ANTHROPOMETRIC CHARACTERISTICS OF PRE- AND POST MENARCHEAL GIRLS

	T1-T2	T2-T3	T3-T4	T4-T5	T5-T6	T6-T7	T7-T8	T8-T9	T1-4	T4-7	T7-9	T1-9
Stature (cm)												
Pre-menarche	2.30*	1.96*	1.13*	0.66	1.34*	0.35	0.35	0.73	5.41*	2.35*	1.10*	8.86*
Post-menarche	1.63*	0.75*	0.42	0.14	0.53	0.12	0.32	0.30	2.76*	0.75*	0.62*	4.12*
Arm span (cm)												
Pre-menarche	#3.21*		1.44*	1.66*	1.10*	0.85*	0.43	0.77*	4.66*	3.63*	1.21*	9.50*
Post-menarche	#2.05*		0.65*	0.80*	0.35	0.84*	0.12	0.32	2.71*	2.01*	0.44*	5.16*
Mass (kg)												
Pre-menarche	3.56*	1.37	2.32	1.79	0.80	0.56	2.20*	-1.21	7.27*	3.16*	0.99	11.41*
Post-menarche	2.72*	-0.45	1.29	1.54	-0.29	-0.61	2.03*	-0.75	3.57*	0.65	1.28	4.93*
Sitting height (cm)												
Pre-menarche	#2.57*		0.93	0.93	0.71	0.46	0.51	0.28	3.50*	2.11*	0.80	6.40*
Post-menarche	#1.38*		0.47	0.83*	0.43	0.26	0.46	0.27	1.84*	1.51*	0.73*	4.08*
Sitting height ratio (%)												
Pre-menarche	#2.57		0.92	0.93	0.71	0.46	0.51	0.28	0.48	0.56	0.14	6.40*
Post-menarche	#1.38		0.46*	0.83*	0.41	0.26	0.46	0.26	0.26	0.67*	0.25	4.08*
Leg length (cm)												
Pre-menarche	#0.99*		0.33	0.06	0.33	0.20	0.10	0.28	1.33*	0.59*	0.39	2.31*
Post-menarche	#0.22		0.15	0.09	0.12	0.08	0.12	0.10	0.37*	0.30*	0.23	0.91*
BMI (L/m²)												
Pre-menarche	0.82	0.02	0.58	0.54	-0.13	0.22	0.71	-0.69	1.43	0.63	0.03	2.08*
Post-menarche	0.58	-0.37	0.36	0.61	-0.33	-0.15	0.61	-0.38	0.57	0.13	0.23	0.93*

T1-3=grade 8 measurements; T4-6=grade 9 measurements; T7-9=grade 10 measurements; *=Statistical significant ($p>0.05$); #=No measurements for T2

significant at T1 (Table 2). Statistical significant differences were only found in the first year of the study between the groups (grade 8 year, T1-T3), after which differences became mostly statistical insignificant only showing differences of 0.03cm (stature), 0.29cm (arm span), 2.61kg (mass), 0.54cm (sitting height), 0.08cm (leg length), 0.26% (sitting height ratio) and 1.04 (BMI) between the pre- and post-menarche girls during T9 (Table 2).

Differences were, however, still of small practical significance up to the end of the second year (T1-T6). This is mainly due to pre-menarche girls having the most significant changes during 4-monthly measurements in all anthropometric characteristics throughout the follow-up period as are evident from the results displayed in Table 3 for pre- and post-menarche girls respectively.

The most significant increases in the pre- and post-menarche girls of 5.41 cm vs. 2.76 cm (stature), 4.66 cm vs. 2.71 cm (arm span), 7.27 kg vs. 3.57 kg (mass), 3.50 cm vs. 1.84 cm (sitting height), 1.33 cm vs. 0.37 cm (leg length) and 1.43 vs. 0.57 (BMI) were found during T1-T4. Sitting height ratio increased most during T4-T7 (14.51-15.51 years). Post-menarche girls' growth in stature and arm span started to reach a plateau from T4-T9 with pre-menarche girls only reaching this plateau effect at around T6, approximately 1 year after post-menarche girls.

During the final measurements (T9), post-menarche girls were still taller and heavier and displayed longer sitting heights although on a non-significant level ($p>0.05$, Table 2). The arm span of pre-menarche girls was slightly longer than post-menarche girls during T9 ($p=0.91$, Table 2).

Changes in stature co-exist with changes of body segments. Post-menarche girls had the longest upper bodies (sitting height) with a baseline group difference of 2.87 cm (T1), although the difference of 0.54 cm became smaller and insignificant at T9 (Table 2, Figure 1d). Sitting height of both pre- (3.50 cm) and post-menarche (1.84 cm) girls increased most significantly between T1-T4 (Table 3). Although only a few significant 4-monthly increases were found, the upper body

segments of both groups only showed a few statistical significant 4-monthly changes. Annual increases and also increases over the 3-year school period were, however, statistically significant in both groups. The pre-menarche group showed a bigger annual increase during all measurements accounting for a bigger increase in sitting height of 2.32 cm over the follow-up period. Both pre- and post-menarche girls had a late increase in sitting height between T7-T8, influencing their sitting height ratio that also showed a late increase during the same period.

Leg length, on the other hand, showed small, gradual and non-significant 4-monthly increases throughout the study (Table 2) in both groups. It therefore seemed that body stature was influenced more by increases of the upper body (sitting height) over the follow-up period. Although the post-menarche group on average were taller in stature and for most of the study until T8 had a longer arm span than the pre-menarche group, the tallest individual as well as the individual with the longest arm span was part of the pre-menarche group. Mass showed a similar developmental curve to stature, although mass showed time periods of decline which were also more evident in the post-menarche group, and, similar to stature, not all annual increases in mass were significant (Table 3).

Furthermore, mass and BMI showed similar growth curves as BMI is influenced by changes in mass. Post-menarche girls were the heavier group throughout the study, although differences between the groups (8.54 kg at T1, $p=0.01$, $d=0.91$ and 2.61 kg at T9, $p=0.41$, $d=0.24$), became smaller and less significant with increasing age (Table 2, Figure 1c). These smaller differences between the groups are attributed to higher increases in mass in pre-menarche girls over the T1-T9 period (11.41 kg vs 4.91 kg, Table 3). Four-monthly increases were however, only significant ($p<0.05$) between T1 and T2 in the pre- (3.56 kg) and post-menarche group (2.72 kg) and borderline at T3 ($p=0.06$), with both groups experiencing one further significant increase between T7-T8. The largest changes in mass occurred between T1-T4 (7.27 kg) and T4-T7 (3.16 kg) in the pre-menarche group ($p<0.05$) with the post-menarche group only showing a small, but significant increase in mass between T1-T4 of 3.57 kg. Declines in mass were also seen, but mostly in the

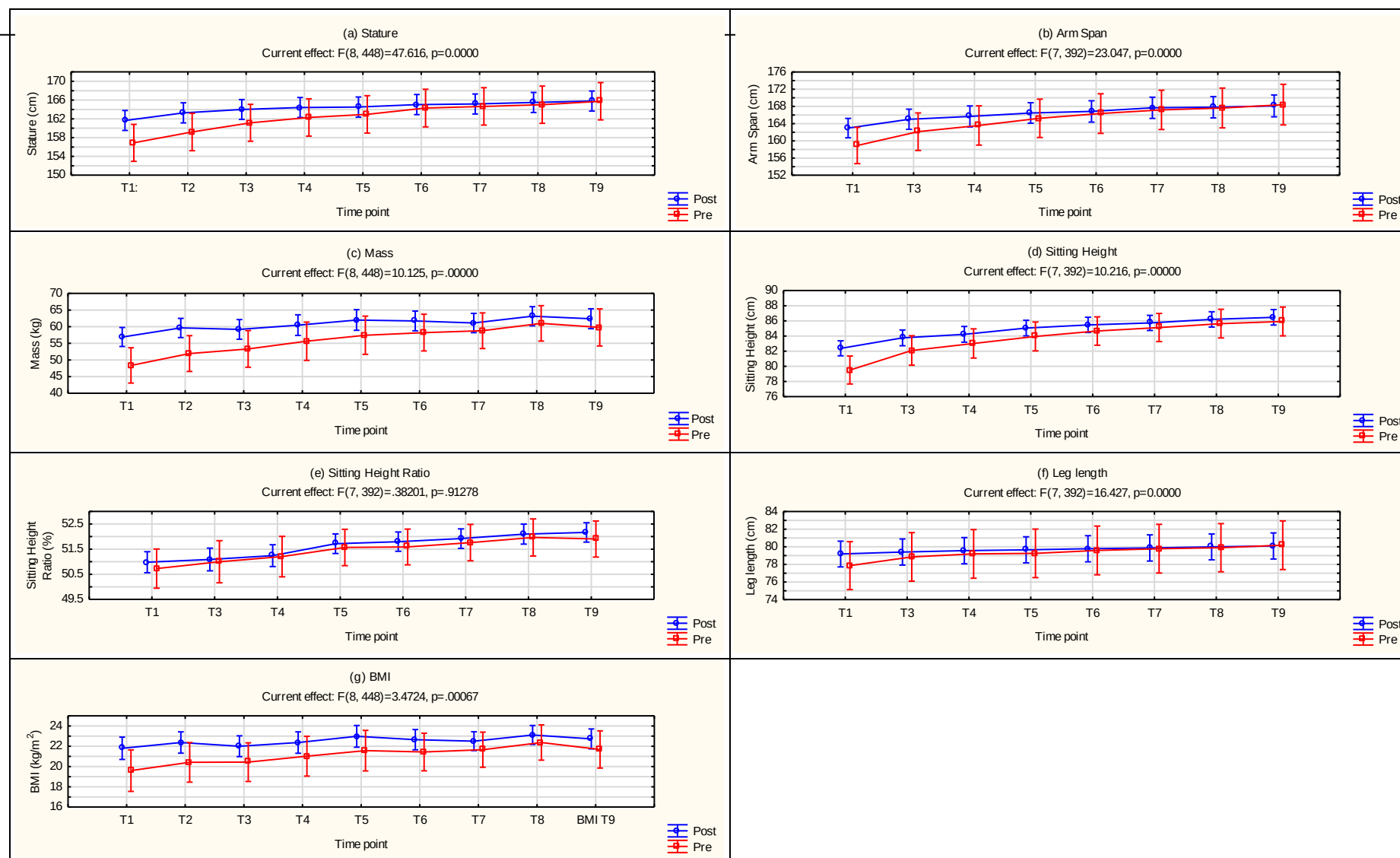


Figure 1 (a-f): Growth curves of pre- and post-menarche girls' anthropometric characteristics

post-menarche group between T2 and T3, T6 and T7 and T8 and T9, while pre-menarche girls only showed one decline between T7 and T8 (Table 3). Changes in mass seemed to reach a plateau between T4-T7, although a large significant increase was found between T7 and T8 with a decrease between T8 and T9 in both groups. These changes in mass also resulted in similar, larger than usual, changes in BMI during the same periods. Differences in BMI were borderline at T1 and T2 with the pre-menarche group showing the biggest increase of 2.08 kg/m² from T7-T9, ending with a similar, although still lower BMI to the post-menarche group at T9 (Tables 2 and 3, Figure 1g).

DISCUSSION

The objective of this study was to investigate anthropometric growth differences between girls of differing menarche status between the ages of 13 to 16 years over a 2-year follow-up period. This was done by comparing differences in growth characteristics of pre- and post-menarche girls over 2 years in 4-monthly increments based on their menarcheal status. Seventy-seven percent (n=45) of the group have reached menarche before the mean age of 13.51 years (T1), 95% (n=53) during grade 9 (T4) and almost all (98%, n=57) during their grade 10 year (T7) before reaching the mean age of 15.51 years (Table 1). All comparisons were done based on menarcheal status at T1, dividing the group into 13 pre-menarche and 45 post-menarche girls. The cut-offs for normal menarcheal onset as published by Malina et al. (2004) [early- (<11.8 years), average- (11.8-13.8 years) and late (> 13.8 years) maturing girls], indicate that most of the group can be categorized as average developing girls.

Overall, the results are in agreement with most studies that report differences in growth between girls of differing menarcheal status (Biro et al., 2001; Malina et al., 2004; AberbergaAugskalne & Kemper, 2007). At baseline, at a mean age of 13.51 years, post-menarche girls were statistically and practically significantly taller ($p < 0.05$, $d = 0.60$) and heavier ($p < 0.05$, $d = 0.91$) with longer body-segments (sitting height and arm span) in comparison to the pre-menarche group. Significant

differences of 4.76 cm (stature), 8.54 kg (mass), 4.05 cm (arm span), 2.87 cm (sitting height), 0.26 (sitting height ratio) and 2.20 in BMI between the pre- and post-menarche girls were found (Table 2), confirming that reaching menarche earlier, influences anthropometric growth in girls. These differences were also significant over time, although it became smaller and showed less significant time point differences with increasing age from T2 onwards. Differences decreased at T4 (first measurement of follow-up year) to 2.02 cm (stature), 6.09 kg (mass), 2.60 cm (arm span), 1.21 cm (sitting height), 0.04% (sitting height ratio) and 1.34 (BMI), showing no statistical significance ($p>0.05$), although all differences at this age were still of practical significance with mass differences ($d=0.42$) being the most significant (Table 2). These declines in differences with increasing age among early and late maturing girls, between the ages of 13 and 16 year in the current study, are in agreement with Bronikowski and Bronikowska (2008) who also report declines in differences, to similar results between early and late maturing girls and ascribed these results to this period being most affected by pubertal and maturational changes. Although pre-menarche girls showed lower mean values in all the anthropometric characteristics, they had larger 4-monthly, as well as annual increases, in all growth characteristics in comparison to the post-menarche group. This coincides with Biro et al. (2001) who stated that although late developing girls grow less at a younger age; their final stature is longer compared to average or early developing girls. Although this is not yet evident in the findings during the final measurements at 16.26 years, stature in particular showed resemblance with differences less than 1cm ($p>0.05$) from T6 onwards and final stature measures of 165.75 cm (pre) and 165.78 cm (post) during T9 (Table 2). As the post-menarche group was in their final stages of increasing stature as they only grew 4 cm over the nine time-point measures compared to 8 cm in the pre-menarche group, it is expected that the pre-menarche group will surpass them in most anthropometric characteristics with a further increase in age. Researchers report in this regard that late maturing girls surpass early maturing girls around the age of 15 years of age (Biro et al., 2001; Malina et al., 2004). In agreement with these findings, based on minimum and maximum values, the pre-menarche group

included girls that were the tallest from T1-T9 and heaviest during T7-T9 (last year of the study) (Table 2).

The bigger increases in growth characteristics seen in the pre-menarche group can be ascribed to the maturational affects that are associated with reaching the age of menarche, occurring late in the growth spurt phase (6 to 12 months after PHV), and which have a big influence on pre-menarche girls' growth at that age. According to Pearson et al. (2006) height and weight increases are primarily the result of increased hormone secretion, which is the highest during the onset of menarche, and therefore, linear growth is strongly associated with menarche status at the later end of the pubertal phase. Armstrong and McManus (2000) indicate that during the growth acceleration phase, which lasts 3 years, girls approximately grow 6-8-6 cm respectively and reach PHV at approximately 11.9 years. According to these statistics the post-menarche girls have already surpassed PHV as their maximum increase in stature was only 2.71 cm from T1-T4. The pre-menarche girls were probably in their last year of the growth acceleration phase during the same period with an annual increase of 5.41 cm from T1-T4, after which a levelling out of growth was also evident in this group from T4-T6 (2.35 cm) and T7-T9 (1.10 cm). These results also coincide with results from AberbergaAugskalne and Kemper (2007) finding that although early developing girls have larger PHV increases of 9.4 ± 1.7 cm in comparison to average- (8.2 ± 2.2 cm) and late developers (7.2 ± 1.9 cm), late developing girls on average has a longer growth period and as a result have a taller final stature. Furthermore, due to late developing girls reaching PHV almost 2 years later than early developing girls, they have 1 to 2 years longer of annual growth of approximately 5 cm/year (Malina et al., 2004). This is also confirmed by the results displayed in Table 3, where most statistically significant and also largest differences between 4-monthly measurements were found in the pre-menarche girls. Moreover, in terms of differences between measurements, it can be concluded that although these differences were statistically significant, increases in stature and arm span levelled out during T7-9. This is indicative of the pre-menarche group reaching the end of their growth spurt at around 15- to 16 years of age, almost 2 years later

than the post-menarche group providing them with an additional 2 years of growth before entering their growth spurt. Sitting height also showed a statistically significant change during this period (T7-T9) in the post-menarche group, although differences between the groups still became smaller. This is probably due to sitting height being in the final stages of development, which in turn affects stature increases at a later stage (Malina et al., 2004).

Regarding overall growth patterns (Table 3, Figure 1), it can be seen that late developing girls (pre-menarche) had a longer period of growth before reaching a plateau (Table 3). These girls also experienced a period of maximum growth in stature from T1-T6 with final significant ($p < 0.05$) increases in stature between T5 and T6, hereafter they reached a plateau from T6 onwards. Further, maximum increases in stature (T1-T6) also coincide with increasing mass between T1 and T5. These changes however, did not have a significant effect on pre-menarche girls' BMI as both mass and stature increased. Even so, this was not the case with increased age where changes in stature declined, but changes in mass did not (T7-T9 in pre-menarche girls) and as a result had the biggest effect on changes in BMI during this period (Table 3). In the same context post-menarche girls showed small changes in stature during the same period while reaching a plateau as early as T4 onwards with their last significant increase between T1 and T3. This resulted in post-menarche girls' mass already having an effect on their BMI from an earlier age (T1, 13.51 years). Sitting height ratio did not show statistical or practical significant differences during this phase. Once again this could be due to sitting height reaching peak development at a stage later than that of stature (Malina et al., 2004). No statistically significant group differences were found in sitting height from T3 onwards. A high once-off increase in mass was however seen in both the pre- (2.20 kg) and post-menarche (2.03 kg) group between T7-T8 also largely affecting their BMI during the same period. This increasing phenomenon in both groups are probably not a growth related increase but rather lifestyle related as it co-occurred just after a summer holiday period that fell between T6 and T7 that could have had an effect on their body-composition. Decreases in mass

were again seen afterwards most probably due to participation in sport and recreational activities at the start of the new year.

Practical implications of maturational differences for sport performance

The anthropometric growth differences that were found in this study can influence performance, based on motor- and physical fitness capabilities (Hill, 2015). Mid-adolescence, and more specifically the time period just before and after reaching menarche, is described as a vulnerable period in the development of physical- and motor skills due to the significant changes that occur in body segments and body dimensions during this period (Gaudineau et al., 2010). Increased stature, changes in upper and lower body dimensions and longer limbs, together with the development of more muscle mass, will be conducive in producing more power and strength and consequently contributing to higher performance outputs (Malina et al., 2004). However, increasing body mass and the distribution of fat to certain areas of the body, can influence the centre of gravity (Butcher & Eaton, 1989), with influences on locomotor skills and in turn, speed and agility. The percentage muscle and fatmass has not been tested during this study, due to practical and logistical reasons, and therefore conclusion can only be made by means of anthropometric measures and BMI scores. In this regard, a study on 14-year-old adolescent girls from Western Australia confirmed small, but negative correlations between BMI ($p=-0.13$), agility and muscle endurance ($p=-0.27$), with positive correlations between BMI and aerobic fitness ($p=0.27$) and muscle strength ($p=0.15$) (Hands, Larkin, Parker, Straker & Perry, 2008). Abbott and Collins (2002) also reported various correlations between anthropometric characteristics and fitness measures in 1217 Scottish girls with a mean age of 12.68 years. The over-head throw and vertical jump correlated positively with stature; agility correlated negatively with mass; while sitting height and speed correlated positively with height and negatively with mass.

The rate at which an action can be performed will also be influenced by stature and mass of the body and the specific limb lengths involved in the action. Our results indicated that early developing girls were significantly longer, with longer arm spans, higher mass and sitting heights at 13.51 years ($p < 0.05$), although differences levelled out over the follow-up period to not being statistically or practically significant at T9 (16.25 years). Hill (2015) indicates in this regard that a tennis player with longer arms will generate more speed and rotation on the ball due to the longer levers at their disposal, compared to players with shorter arms. Stature can however, also be detrimental where a lower gravity point is needed for an agile motion, such as during a rapid movement of the centre in netball. Mass also influences sports performance, as a larger and heavier player with a higher fat mass will have a reduced mobility and range of motion, although increased muscle tissue can possibly contribute to a person's strength and power outputs (Malina et al., 2004). Sitting height will also affect the performance of specific sports skills, as reported by Visnapuu and Jürimäe (2008). They found that the upper body strength in 14- to 15-year-old handball players was dependent on sitting height.

These anthropometric influences also have implications for sport selection. Williams and Reilly (2000) state in this regard that players chosen for individual or team sports are initially chosen (before the onset of puberty and menarche) based on physical characteristics. This results in inadequate opportunities for late developing girls to develop and excel in sport due to their current insufficient physical characteristics. In agreement, Van den Berg et al. (2012) also concluded that the physiological development of late developers, which had not yet fully developed, can lead to the elimination of talented players at a young age during the talent identification process. It is therefore important for sport administrators to take note of these early and late maturation influences of growth on sport performance, especially during the ages when all girls have not been fully exposed to the effects of puberty and menarche. Knowledge of these timing differences is especially important to more accurately identify girls with the potential to excel in sport.

Although the data were collected over a two-year follow-up period, that strengthens the results of the study, the study still had shortcomings that have to be kept in mind. The sample was collected by means of convenience and also did not have an even representation of the demographics of the South African population as it mainly included Caucasian girls. Environmental conditions such as adverse hot or cold weather conditions were not identical over the three-year school period and could have influenced the results. All participants were from one school in the Northwest Province of South Africa, although the school had hostel facilities with children from 46 primary schools' representative from the surrounding area, making the results more generalizable. The study only included data of girls between 13 and 15 years of age, which is a period that is quite late in the pubertal development of girls. Consequently, a larger age period including 11- to 16 years of age is needed to fully investigate influences of the pubertal phase. Further research is therefore recommended that include a longer developmental period and a larger and more representative group of participants in order to obtain a more complete understanding of the influences of developmental growth and physical fitness profile.

CONCLUSION

This study confirmed that the timing of the onset of the menstrual cycle significantly influence the tempo of anthropometric growth among girls. This includes changes in body proportions, body segments and differing BMI levels. Differences between pre- and post-menarche groups were the highest in grade 8 at the age of 13.51 years, while these differences were mostly levelled out by the age of 16 years. Early maturing girls were taller and heavier at a younger age and had longer body segments such as arm spans and sitting heights. These differences relating to body segment proportions may contribute to discrepancies in sport performance between early and late developing girls. It is concluded that the influence of growth between early and late maturing girls evens out around 16 years of age.

Information obtained during this study provided more insight into the timing and rate of biological and physiological changes occurring in girls of different maturing levels during mid-adolescence, and the impact of these changes on aspects such as physical and motor performance. This knowledge may inform a better understanding of the effects of differential timing of menarche on changes in anthropometric characteristics which are also valuable in the understanding of a girl's progression to adult growth characteristics. This information may therefore assist coaches and other sport administrators in better predicting which girls have the most preferable anthropometric characteristics to excel in sport. As differences in growth between early and late maturing girls declined to almost similar values by the end of the pubertal phase in the study, the findings suggest that girls can only be compared realistically and classified as potential talented sport players by the end of the pubertal phase at around age 16 years of age.

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REFERENCES

- Abbott, A., & Collins, D. (2002). A theoretical and empirical analysis of a “state of the art” talent identification model. *High Ability Studies*. 13(2):157-178.
- AberbergaAugskalne, L., & Kemper, H.C.G. (2007). Longitudinal relationship between cardiovascular functioning and peak height velocity during exercise in 7 to 16 year old boys and girls. *Human Movement Science*. 8(1):5-11.
- Anderson, S. (2009). Collins English dictionary: Complete & unabridged. 10th ed. London: Harper Collins.
- Armstrong. N., & McManus, P. (2000). Growth, maturation and physical education. In N. Armstrong, (ed), *New directions in physical education: Change and innovation* (p19-32.). London: Cassell Education.
- Biro, F.M., McMahon, R.P., Striegel-Moore, R., Crawford, P., Obarzanek, E., & Barton, B.A. (2001). Impact of timing of pubertal maturation on growth in black and white female adolescents: The NHLBI growth and health study. *Journal of Pediatrics*. 138(5):636-643.
- Apter, D., Reinila, M., & Vihko, R. (1989). Some endocrine characteristics of early menarche, a risk factor for breast cancer, are preserved into adulthood. *International Journal of Cancer*. 44(5):783-787.
- Balyi, I., & Way, R. (2010). Canadian Sports For Life: The role of monitoring growth in long-term athlete development. Calgary: Canadian Sports Centre.
- Biro, F.M., McMahon, R.P., Striegel-Moore, R., Crawford, P.B., Obarzanek, E., Morrison, J.A...Falkner, F. (2001). Impact of timing of pubertal maturation on growth in black and white female adolescents: The National Heart, Lung, and Blood Institute Growth and Health Study. *The Journal of Pediatrics*. 138(5):636-643.

- Bronikowski, M., & Bronikowska, M. (2008). Motor fitness in relation to the maturational process of pubertal boys and girls. *Papers on Anthropology*. 17:28-37.
- Butcher, J.E., & Eaton, W.O. (1989). Gross and fine motor proficiency in preschoolers: relationships with free play behaviour and activity level. *Journal of Human Movement Studies*. 16:27-36.
- Carel, J.C., & Leger, J. (2008). Precocious puberty. *The New England Journal of Medicine*. 358(22):2366-2377.
- Cohen, J. (1992). A power primer. *Psychological Bulletin*. 112:155-159.
- Cole, T.J. (2003). The secular trend in human physical growth: A biological view. *Economics and Human Biology*. 1:161-168.
- Cumming, S.P., Sherar, L.B., Gammon, C., Standage, M., & Malina, R.M. (2012). Physical activity and physical self-concept in adolescence: A comparison of girls at the extremes of the biological maturation continuum. *Journal of Research on Adolescence*. 22(4):746-757.
- Davis, B., Bull, R., Roscoe, J., & Roscoe, D. (1997). Physical education and the study of sport. 3rd ed. London: Mosby.
- Deutsch, M.I., & Mueller, W.H. (1985). Androgyn in fat patterning is associated with obesity in adolescents and young adults. *Annals of Human Biology*. 12(3):275-286.
- Dimeglio, A. (2005). Growth in pediatric orthopaedics. *Journal of Pediatric Orthopaedics*, 21:549-555.
- Eisenmann, J.C., & Wickel, E.E. (2009). Biology of physical activity in children: Revisited. *Pediatric Exercise Science*, 21:257-272.

Forman, D., Pike, M.C., Davey, G., Dawson, S., Baker, K., Chilvers, C.E.D., Coupland, C.A.C. (1994). Aetiology of testicular cancer: association with congenital abnormalities, age at puberty, infertility, and exercise. *British Medical Journal*. 308:1393-1399.

Gaudineau, A., Ehlinger, V., Vayssiere, C., Jouret, B., Arnaud, C. & Godeau, E. (2010). Factors associated with early menarche: results from the French Health Behaviour in School-aged Children (HBSC) study. *Bio Med Central Public Health*. 10:175:1-7.

Gluckman, P.D., & Handson, M.A. (2006). Evolution, development and timing of puberty. *Trends in Endocrinology and Metabolism*. 17(1):7-12.

Hands, B.P., Larkin, D., Parker, H., Straker, L., & Perry, M. (2008). The relationship between physical activity, motor competence and health-related fitness in 14-year-old adolescents. *Scandinavian Journal of Medicine and Science in Sports*. 19(5):655-663.

Hediger, M.L., & Stine, R.A. (1987). Age at menarche based on recall information. *Annals of Human Biology*. 14:133-142.

Hill, D. (2015). The advantages of a long arm span. <http://www.livestrong.com/article/552216-the-advantages-of-a-long-arm-span>. Last updated: 16 December 2015.

Kaprio, J., Rimpelä, A., Winter, T., Viken, R.J., Rimpelä, M., & Rose, M.J. (1995). Common genetic influences on BMI and age at menarche. *Human Biology*. 67(5):739-753.

Kaplowitz, P.B., Slora, E.J., Wasserman, R.C., Pedlow, S.E., & Herman-Giddens, M.E. (2000). Earlier onset of puberty in girls: relation to increased body mass index and race. *Pediatrics*. 108(2):347-53.

Karapanou, O., & Papadimitriou, A. (2010). Determinants of menarche. *Reproductive Biology and Endocrinology*. 8:115-122.

- Lee, C.H., Tsai, M.C., & Lin, C.Y. (2016). Carol StrongLongitudinal effects of self-report pubertal timing and menarcheal age on adolescent psychological and behavioral outcomes in female youths from northern Taiwan. *Pediatrics and Neonatology*. 1:1-8.
- Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). Growth, maturation and physical activity. Champaign, IL: Human Kinetics.
- Marshall, W.A., & Tanner, J.M. (1986). Puberty. In. Falkner, F. & Tanner, J.M (Eds). Human growth: A comprehensive treatise. (vol 2). Postnatal growth; Neurobiology. New York:Plenum. p171-209.
- Myburgh, G.K., Cumming, S.P., Silva, M.C.E., Cooke, K., & Malina, R.M. (2016). Growth and maturity status of elite British junior tennis players. *Journal of Sports Sciences*. 34(20):1957-1964.
- Mirwald, R.L., Baxter-Jones, A.D.G., Bailey, D.A., & Beunen, G.P. (2001). An assessment of maturity from anthropometric measurements. *Medicine and Science in Sports and Exercise*. 34(4), 689-694.
- Monyeki, K.D., Koppes, L.L.J., Kemper, H.C.G., Monyeki, K.D., Toriola, A.L., Pienaar, A.E., & Twisk, J.W.R. (2006). Body composition and physical fitness of undernourished South African rural primary school children. *European Journal of Clinical Nutrition*. 59:877-883.
- Okasha, M., McCarron, P., McEwen, J., & Davey Smith, G. (2001). Age at menarche: secular trends and association with adult anthropometric measures. *Annals of Human Biology*; 28(1):68-78.
- Parent, A.S., Teilmann, G., Juul, A., Skakkebaek, N.E., Toppari, J., & Bourguignon, J.P. (2003). The timing of normal puberty and the age limits of sexual precocity: Variations around the world, Secular trends, and changes after migration. *Endocrine Reviews*. 24(5):668-693.

- Pearson, D.T., Naughton, G.A., & Torode, M.(2006). Predictability of physiological testing and the role of maturation in talent identification for adolescent team sports. *Journal of Science and Medicine in Sport*. 9(4):277-287.
- Richter, L., Norris, S., Yack, D., & Cameron, N. (2007). Cohort profile: Mandela's children. The 1990 birth to twenty study in South Africa. *International Journal of Epidemiology*. 36:504-511.
- Rogol, A.D., Roemmich, J.N., & Clark, P.A. (2002). Growth at puberty. *Journal of Adolescent Health*. 31(6):192-200.
- Salces, I., Rebato, E.M., Susanne, C., San Martin, L., & Rosique, J. (2001). Familial resemblance for the age at menarche in Basque population. *Annals of Human Biology*. 28(2):143-156.
- Sawyer, S.M., Afifi, R.A., Bearinger, L.H., Blakemore, S.J., Dick, B., Ezech, A.C., & Patton, G.C. (2012). Adolescence: a foundation for future health. *Lancet*. 379:1630-1640.
- Simmons, D. (2000). Talent identification of British diving. Physiological and anthropometrical Test. [CD Rom]. British diving.
- Statsoft. (2017). Statistica for Windows: General conventions and statistics. Tilsa, OK. Statsoft.
- Steward, A.D., Marfell-Jones, M., Olds, T., & de Ridder, H. (2011). International standards for anthropometric assessment. Potchefstroom: International Society for Advancement of Kinanthropometry (ISAK).
- Tanner, J.M., Davies, P.S.W. (1985). Clinical longitudinal standards for height and height velocity for North American children. *Journal of Pediatrics*. 107:317-29.
- Towne, B., Czerwinski, S.A., Demarath, E.W., Blangero, J., & Siervogel, R.M. (2005). Heritability of age at menarche in girls from the Fels longitudinal study. *American Journal of Physical Anthropology*. 123:210-219.

United nations educational, scientific and cultural organization (UNESCO). (2014). What do we mean by youth. retrieved from: <http://www.unesco.org/new/en/social-and-human-sciences/themes/youth/youth-definition/>.

Van Den Berg, L., Coetzee, B., & Pienaar, A.E. (2006). The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *African Journal for Physical, Health Education, Recreation & Dance*. 18(3):510-515.

Van den Berg, L., Coetzee, B., & Pienaar, AE. (2012). The influence of biological maturation on anthropometric determinants of talent identification among U-14 provincial girl tennis players – A pilot study. *African Journal for Physical, Health Education, Recreation and Dance*. 18(3): 510-524.

Van Lenthe, F.J., Kemper, C.G., & van Mechelen, W. (1996). Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam growth and health Study. *American Journal of Clinical Nutrition*. 64(1):18-24.

Visnapuu, M., & Jurimae, T. (2008). The Influence of basic body and hand anthropometry on the results of different throwing tests in young Handball and Basketball players. *Journal of Biological and Clinical Anthropology*. 66(2):225-36.

Williams, A. M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Science*. 18(9):657-667.

World Health Organization (WHO). (2006). WHO Child Growth Standards: Length/Height-for-Age, Weight-for-Age, Weight-for-Length, Weight-for-Height and Body Mass Index-for-Age: Methods and Development. Geneva: World Health Organization. Date of access: June 2018.

World Health Organization (WHO). (2015). Adolescent health. Retrieved from: http://www.who.int/topics/adolescent_health/en/. Date of access: Aug 2018.

CHAPTER 4

**DIFFERENCES IN STRENGTH AND AEROBIC
ENDURANCE IN PRE- AND POST-MENARCHE GIRLS
DURING MID-ADOLESCENCE: A TWO-YEAR FOLLOW-
UP STUDY**

Research paper

Differences in strength and aerobic endurance in pre- and post-menarche girls during mid-adolescence: A two-year follow-up study

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Differences in strength and aerobic endurance between pre- and post-menarche girls during mid-adolescence: A two-year follow-up study

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ABSTRACT

Introduction: *Research indicates that early- and late-maturing girls' physical fitness capabilities are influenced differently by anthropometric changes, initially favoring early maturing girls. The aim of the study is therefore to investigate to what extent differences in pre- and post-menarche girls' physical fitness capabilities occur.*

Method: *Fifty-eight (N=58) girls with a mean age of 13.51 ± 3.51 , selected by means of convenience, were longitudinally followed over three school year. They were divided at baseline into a pre- (n=13) and post-menarche group (n=45). Strength and endurance measurements were taken annually (2010-2012) providing data over three time points. The Australian Sports Commission (1996) protocol was used. Basic statistics, a Spearman correlation analysis and a repeated measures ANOVA with a Bonferroni post hoc correction were applied.*

Results: *Strength and endurance differences between the pre- and post-menarche groups were relatively small and insignificant. Early menarche status showed advantages in strength while reaching menarche later positively affected aerobic endurance at younger ages. Changes in these abilities over the follow-up period were different but were mostly leveled out during the final measurements.*

Conclusion: *Timing of menarche contributes to differences in muscle strength and aerobic capacity of girls, particularly during mid-adolescence, although only on a practical level. The period at and immediately after reaching menarche is an unstable period for fitness changes, characterized by changes in strength and endurance that are associated with menarche status. Influences of somatic and biological growth in girls of the same age and the influence thereof on strength and endurance will only be leveled out 1-2 years after reaching menarche.*

Keywords: Endurance, Growth, Menarche, Longitudinal, Strength

INTRODUCTION

The adolescence period, which includes puberty, refers to the transition from childhood to adulthood and is a unique period of growth and development characterized by the occurrence of multiple physical and physiological changes (Dahl, 2004; Gaudineau *et al.*, 2010). The most perceivable anthropometric, physical and motor changes are found during the adolescent period when the so-called overflow effect occurs in various biological and physiological systems. This overflow effect results in changes that take place in one aspect, causing changes in surrounding or related aspects. Menarche (the first onset of menstruation) is one of several factors that are associated with other physical changes occurring during puberty (Marshall & Tanner, 1969; Danubio *et al.*, 2004; Rubin *et al.*, 2009). These changes can influence the development of motor and physical fitness of adolescent girls (Bronikowski & Bronikowska, 2008; Balyi & Way, 2010).

Physical fitness refers to the capacity to perform daily activities and tasks without any unnecessary exhaustion (Ortega *et al.*, 2008; Gallahue, Ozman & Goodway, 2012). Performance and health-related physical fitness involves body control, especially muscle control and coordination (Sener *et al.*, 2016) and includes muscle strength, muscle endurance, aerobic endurance, flexibility and body composition (Pienaar, 2018). Performance-related physical fitness is considered to be important building blocks in the development of talented athletes and for sports success and includes abilities such as running speed, power and agility (Ortega *et al.*, 2008; Gallahue *et al.*, 2012; Pienaar, 2018).

Physical ageing from pre-pubertal age to adulthood represents a continuum that includes both early and late developers (Carel & Leger, 2008). The age at which menarche occurs, is not rigid and is influenced by a variety of factors, such as genetic factors, nutrition, health status (Kaprio *et al.*, 1995; Salces *et al.*, 2001) as well as levels of physical activity (Salces *et al.*, 2001; Ayatollahi *et al.*, 2002). Early, middle and late developers are classified according to the timing and deviation of menarche in comparison with average values (about 12.4 years) within a certain population (Malina *et al.*, 2004). The long-term effects of reaching puberty and subsequently menarche at an earlier or later age and its relation to sports participation have for some time been a subject of research (Apter *et al.*, 1989; Forman *et al.*, 1994; Van Lenthe *et al.*, 1996; Okasha *et al.*, 2001). These research studies were conducted due to the importance of taking biological maturation into account, and not necessarily chronological age, to correct for developmental differences during research and sports classification of youths.

Inclusion of players into sports teams before puberty are mostly based on favorable physical characteristics. This may be the cause of late-developing girls not given the necessary opportunities to excel in sport due to their current insufficient physical characteristics (Williams & Reilly, 2000). However, research indicates that early developers with desired characteristics, such as body size, limb length or speed, cannot always maintain these early maturational benefits. This is due to late-developing girls being affected more positively by maturational changes including hormonal changes, resulting in them developing a more desired body composition and in turn better physical fitness capabilities (Vaeyens *et al.*, 2008). Therefore, research pertaining the development of physical fitness profiles of early and late developing girls and monitoring the use of the biological age instead of the chronological age of a group, geographical region or population, will aid in the better understanding of developmental differences between early, average and late maturing girls. This, in turn, will aid in optimizing training benefits for all girls who want to participate in sport.

Various studies were conducted worldwide (Rodriguez *et al.*, 2004; Deborah & Russel, 2005; Frederics *et al.*, 2005; Garnier *et al.*, 2005; Anderson, 2009) including in South Africa (Henneberg & Louw, 1995; Van Gent, 2001; Van den Berg *et al.*, 2006; Travill, 2007) focusing on the anthropometric, motor- and physical changes that take place in girls during adolescence. Longitudinal studies were also conducted internationally (Prahl-Anderson *et al.*, 1994; Beunen *et al.*, 1997; Kemper *et al.*, 2004; Lee *et al.*, 2005; Volver *et al.*, 2007) and to a lesser extent in South Africa (Monyeki *et al.*, 2006; Richter *et al.*, 2007). However, the age of onset of menarche (biological maturity), was not the main differential factor in these analyses. Therefore, this study aims to address this void regarding the extent of differences in early and late maturing girls' physical fitness capabilities. Findings from this study will aid in understanding of the influence of the phenomena of menarche on the strength and aerobic endurance development of adolescent girls. In addition, these findings could contribute to the development of sport development programs that are customized to girls' maturational status, while also contributing to more accurate identification of girls who have the potential to excel in sport.

METHODOLOGY

Research design

This study made use of a longitudinal research design. The main project, titled "Growth and sport psychological characteristics of talented adolescents", were performed over a 3-year school period

(2010-2012). The data was collected using anthropometric, and physical fitness tests as well as a questionnaires. The anthropometric measurements took place three times a year (4 months apart) with the physical fitness tests only once a year during the first measurements of each year. Overall, follow-up measures were obtained over a full two-year period. Baseline measurements were taken in February 2010, and the last measurements took place in November 2012, resulting in nine time-point measures for growth and three time-point follow-up measures for physical fitness capabilities. In this study, the results of only the fitness measures will be used and will be referred to as T1 (Feb 2010), T2 (Feb 2011) and T3 (Feb 2012).

Research group

All grade 8-learners of one quintile 5 school (quintile 1=low socio-economic quintile, to quintile 5=high socio-economic) in Potchefstroom in the Northwest Province of South Africa, were invited to take part in the study. Since the school had boarding facilities, all grade 8 learners enrolled in 2010 represented 46 different primary schools. In 2010, 200 subjects (girls n=95; boys n=105) with a mean age of 13.73 ± 0.48 years participated in the study. For the purpose of this study, the data of only the girls were subjected to further analysis. The final group, who completed all follow-up measurements in November 2012, consisted of 58 girls with a mean age of 16.27 ± 0.36 years. The loss of subjects to follow-up were 37 girls (38%) due to various reasons including parents of children moving out of town, children moving between schools and injury.

Ethical approval

Ethical approval for execution of the study was obtained from the Health Research Ethics Committee of the North-West University's Potchefstroom Campus (NWU 00142-11-A1 and NWU 00199-15-A1). Approval for the project was also obtained from the principal of the school involved. Subjects who had parental permission and gave consent themselves were subjected to the testing protocol.

Measuring instruments

Age of menarche

The age of menarche was determined by the Status Quo method (Hennenberg & Louw, 1995; Wang *et al.*, 2016) during the first measurements of each year in February 2010, 2011 and 2012 (T1, T2 and T3). The subjects had to indicate, by completing a questionnaire by selecting YES or NO, whether they have had their first menstrual cycle on or before the date of testing. If they

answered YES they also had to indicate the month and year when their first menstrual cycle took place.

Table 3 shows that the majority of the group (77%, n=45) had already reached menarche during the baseline measurement (grade 8 - 2010) at a mean age of 13.51 years, and they were assigned to the post-menarche group in this study. A further 8 subjects, representing 91% (n=53) of the total group, reached menarche during the first follow-up measurements (grade 9 - 2011) at a mean age of 14.52 years with all but one subject (98%) reaching menarche at a mean age of 15.52 years during the last year of measurements (grade 10 - 2012). The thirteen subjects who had not reached menarche during baseline measurements represented the pre-menarche group.

Physical Fitness measurements

Strength

The **cricket ball throw** for distance was used to test upper-body shoulder and chest strength. During the cricket ball throw test, the subject had a 10m run-up to throw a cricket ball (224mm, 156 grams) as far as possible. During the run-up before the throwing action, the subject was not allowed to touch or cross the starting line from where the measurement was taken. Each subject received two attempts, and the best attempt was recorded in meters (Topendsport, 2012).

Aerobic endurance

The multistage **Beep-test** was used to test aerobic endurance (Australian Sports Commission, 1996). This is a 20-meter running test with a progressive increase in intensity/speed each time a new level is reached after a one minute duration. Subjects are instructed to run to the opposite side and place one foot behind the line before the next beep sounds and wait for the beep to start running again back and forth. Subjects continues running for as long as possible until they can no longer keep up with the pace and failed to reach the line for two consecutive times before the beep sounded. The result of the beep-test is noted as the total "shuttles" and levels completed (Australian Sports Commission, 1996). Absolute and relative $\dot{V}O_{2\max}$ were calculated from these scores. In order to calculate $\dot{V}O_{2\max}$ from the Beep-tests result, the Beep-results had to be converted to PACER scores by means of set conversion tables. Absolute $\dot{V}O_{2\max}$ (maximal oxygen uptake per minute measured in ml/kg/min taking a person's body weight into consideration) was calculated by using the equation $\dot{V}O_{2\max}=41.76799 + (0.49261 \times \text{PACER}) - (0.00290 \times \text{PACER}^2) -$

$(0.61613 \times \text{BMI}) + (0.34787 \times \text{Gender} \times \text{Age})$ (Matsuzaka, 2004). Relative $\dot{V}O_{2\max}$ (maximal oxygen uptake per minute) was calculated in ml/min without taking body weight into consideration.

Anthropometric measurements

Stature was measured to the nearest 0.1cm by means of a portable Harpenden stadiometer (Harpenden Holtain Ltd, Crymch, UK). Stature was measured with the subject standing, facing forward, with the heels, back and head against the stadiometer and with feet standing together. The head was held in the Frankfort position by the examiner, and the measurement was taken after the subject had inhaled deeply, to the nearest 0.1 cm. Two measurements were taken, of which an average value was used (Stewart et al., 2011). Inter-measurement reliability for stature was calculated as 0.98. **Mass** was measured by means of an electronically calibrated scale (Omro BF 511). The subject stood upright with weight evenly distributed over the scale with the arms at the sides of the body. The subject had to look straight forward while standing without shoes and as little clothing as possible and the measurement was then taken to the nearest 0.1 kg (Stewart et al., 2011).

Body composition

BMI, Percentage fat mass and muscle mass were also used in the study. Percentage fat mass and muscle mass were measured with an electronically calibrated bio-impedance, body composition apparatus (Omro BF 511). According to the Omron official website, the accuracy of the Omron models differs from bio-impedance scales from model-to-model (+3.5 and 4.1%) based on the "Standard Estimation Error (SEE). The SEE indicates that 68% of all measurements for different users are accurate within 3.5 - 4.1%, relative to body fat percentage (kg.m²). (<https://www.omron-healthcare.com/en/products/weightmanagement>). The following formula determined body mass index (BMI): Bodyweight in kilograms divided by height in meters squared or, $\text{BMI} = \frac{x \text{ KG}}{y \text{ M} \times y \text{ M}}$ (x=bodyweight in KG, y=height in M).

Statistical analysis

The data was analyzed with the "Statistica for Windows 2017" Statsoft computer program package (StatSoft, 2017). Descriptive statistics, including means, standard deviations (SD) and minimum and maximum values were determined. Independent t-testing determined differences between the groups, where a p-level of <0.05 was considered as a significant difference. Effect sizes were calculated to determine practical significance of group differences using Cohen's d-value with $d > 0.2$ = small effect size, $d > 0.5$ (medium effect size) and $d > 0.8$ (large effect size) (Cohen, 1992). A

correlation coefficient analyses were conducted to investigate the correlation between changes in physical fitness abilities, with the statistical ($p < 0.05$) cut-off point set at 0.1 (small correlation), 0.3 (medium correlation) and 0.5 (strong correlation) among the two groups (Adler, 2010). A repeated measures ANOVA was used to analyze changes in physical fitness over time with a Posthoc Bonferonni adjustment to determine the statistical significance of differences between measurements amongst the two groups ($p < 0.05$).

RESULTS

Table 1 reports the descriptive characteristics of the pre- and post-menarche groups at baseline (Feb 2010) and at the two follow-up measurements (Feb 2011 and Feb 2012).

TABLE 1: DESCRIPTIVE CHARACTERISTICS AND PERCENTAGE OF PRE- AND POST-MENARCHE GROUPS REACHING MENARCHE

	Year 1 (T1)		Year 2 (T2)		Year 3 (T3)	
	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD
Group	58	(Feb)13.51 $\pm$ 3.50	58	(Feb) 14.51 $\pm$ 3.51	58	(Feb) 15.51 $\pm$ 3.51
		(Nov) 14.26 $\pm$ 3.50		(Nov) 15.26 $\pm$ 3.51		(Nov) 16.26 $\pm$ 3.51
Pre-menarche	13	(T1) 13.52 $\pm$ 3.58	13	(T2) 14.52 $\pm$ 3.58	13	(T3) 15.52 $\pm$ 3.58
Post-menarche	45	(T1) 13.51 $\pm$ 3.53	45	(T2) 14.51 $\pm$ 3.53	45	(T3) 15.51 $\pm$ 3.53

Time of onset of menarche in pre and post-menarche group				
	Pre-menarche		Post-menarche	
	N	%	N	%
Grade 5	0	0%	4	8.8%
Grade 6	0	0%	10	22.2%
Grade 7	0	0%	30	66.7%
Grade 8	2	15.4%	1	2.3%
Grade 9	4	30.8%	-	-
Grade 10	6	46.2%	-	-
Grade11+	1	7.6%	-	-
Total	13	100%	45	100%

T1=Year one (Gr8); T2 Year 2 (Grade 9); T3=Year 3 (Grade 10); N=number of subjects; M=Mean age

Baseline measurements were taken at the age of 13.51 years in the group, with the final measurements at 15.51 years. This provided follow-up fitness data for two consecutive years. The group (N=58) had a mean age of 13.51 years at baseline with no significant age differences (0.01 years) between the pre- (13.52 years, n=13, 23%) and post-menarche (13.51 years, n=45, 77%) groups. All follow-up comparisons between the groups were made based on the baseline grouping.

Of the 77% post-menarche girls, 8.8% reached menarche during Grade 5, 22.2% during Grade 6, 66.7% during Grade 7 and 2.3% during their Grade 8 year. During the first (T2) follow-up measurements 46% (8) of the initial pre-menarche group also reached menarche with all but one girl (92.3% of the pre-menarche group and 97.8% of the total group) having reached menarche during the last follow-up measurement (T3). According to these statistics, 68% of the girls reached menarche within 12 months of baseline measurements with only 2% reaching this milestone within 2 months of baseline measurements. These statistics were determined by the Status Quo questionnaire information.

Table 2 reports the body composition of the pre- and post-menarche group during T2 (Grade 9) and T3 (Grade 10). No data is available for T1 due to the body composition apparatus that were only available from T2. Table 2 shows that pre-menarche girls had an advantage in percentage muscle strength during T2 and T3 with differences between groups staying unchanged from T2 (1.26%) to T3 (1.25%) ($p>0.05$). Differences were however of medium practical significance ($d=0.61$). Post-menarche girls had a higher percentage body fat throughout although the difference between groups decreased from T2 (4.82%; $p<0.05$, $d=0.68$) to a statistically insignificant difference of 2.71% during T3, although of small practical significance. The BMI of pre- and post-menarche girls differed marginally significant during T1 although during T2 and T3 differences between the groups (post-menarche group higher) were only of small practical significance.

Table 3 and Figure 1(a-d) report the descriptive statistics of the muscle strength and aerobic capacity (level) of the groups, also reported as absolute and relative $\dot{V}O_{2max}$, and significance of differences between the groups. Significance of changes in these strength and endurance variables (T1-T2, T2-T3, T1-T3) for each group, are also displayed in Table 4.

Regarding muscle strength, the results show that post-menarche girls outperformed the pre-menarche group at each time point, from T1 to T3, with the most significant throwing difference of 3.53m found during the first year (13.51-14.51 years). The only statistical significant change

($p < 0.05$) between time points were found in the post-menarche group between T1 and T2 which were also the only decrease found between time points of -0.83m ($p < 0.05$, Table 4).

TABLE 2: BODY COMPOSITION OF THE PRE- AND POST-MENARCHE GROUP DURING T1, T2 AND T3

	Pre	Post	Difference	p-value	d-value
T1 (Grade 8)					
Mass (kg)	48.36±10.04	56.90±9.42	8.54	0.01*	0.91###
BMI	19.59±3.50	21.79±3.73	2.2	0.06	0.60##
T2 (Grade 9)					
Mass (kg)	55.63±12.73	60.46±9.62	4.83	0.14	0.42 [#]
Fat %	21.02±7.62	25.84±6.45	4.82	0.02*	0.68 ^{##}
Muscle %	34.90±2.63	33.38±2.33	1.25	-2.02	0.61 ^{##}
BMI	21.02±4.07	22.36±3.36	1.34	0.23	0.35 [#]
T3 (Grade 10)					
Mass (kg)	58.79±12.22	61.11±8.82	2.32	0.45	0.21 [#]
Fat %	26.26±10.01	28.97±7.54	2.71	0.29	0.31 [#]
Muscle %	40.24±5.68	38.98±4.25	1.26	0.39	0.25 [#]
BMI	21.65±3.78	22.49±2.91	0.84	0.39	0.25 [#]

T2=First follow up measurement (Grade 9); T3=Second follow up measurement (Grade 10); Pre=Pre-menarche; Post=Post menarche; *=Statistical significance ($p < 0.05$); #=small effect size ($d < 0.2$); ##=medium effect size ($d < 0.5$); ###=large effect size ($d < 0.8$)

No interaction effects were evident between the groups over the period [$F(2, 110)=1.3370$, $p=0.2668$, Figure 1a]. Furthermore, group difference over time was also not significant ($F=1.53$; $p=0.22$).

The pre-menarche group showed a gradual increase in muscle strength throughout the study, compared to the post-menarche group who showed a small decline (-0.82m) in their throwing distance of 22.95m (T1) to 22.13m (T2) between 13.51 and 14.51 years of age (Table 4, Figure 1a). This resulted in a smaller difference between pre- and post-menarche girls' performance of this muscle strength task during 14.51 years (T2) and 15.51 years (T3) although the post-menarche group still outperformed the pre-menarche group ($p > 0.05$) at T2 and T3.

TABLE 3: PHYSICAL FITNESS CHARACTERISTICS AND DIFFERENCES BETWEEN THE PRE- AND POST-MENARCHE GROUPS AT T1, T2 AND T3

TP	Pre-menarche (n=13)			Post-menarche (n=45)			Significance of differences		
	M $\pm$ SD	Min	Max	M $\pm$ SD	Min	Max	Diff	p-value	d-value
Strength (meters) (Maturity group*Time F=1.53, p=0.22)									
T1	19.42 $\pm$ 6.60	10.34	34.90	22.95 $\pm$ 7.60	9.29	44.00	3.53	0.13	0.50 ^{##}
T2	20.47 $\pm$ 5.80	11.80	32.00	22.13 $\pm$ 6.91	12.10	40.30	1.66	0.43	0.26 ^{##}
T3	21.23 $\pm$ 5.81	14.33	30.37	23.79 $\pm$ 7.39	11.88	39.59	2.56	0.25	0.38 [#]
Aerobic capacity (Level) (Maturity group*Time F=1.17, p=0.28)									
T1	5.90 $\pm$ 1.95	3.10	8.70	5.01 $\pm$ 1.73	1.50	8.90	0.89	0.12	0.48 [#]
T2	5.97 $\pm$ 2.23	3.10	9.40	5.43 $\pm$ 1.89	2.10	9.20	0.54	0.39	0.26 [#]
T3	6.26 $\pm$ 2.40	3.20	10.00	6.06 $\pm$ 1.79	2.10	9.20	0.15	0.74	0.09
Absolute $\dot{V}O_{2max}$ (Maturity group*Time F=0.04, p=0.84)									
T1	2.09 $\pm$ 0.42	1.59	2.78	2.25 $\pm$ 0.32	1.51	3.03	0.16	0.16	0.42 [#]
T2	2.39 $\pm$ 0.44	1.84	1.89	2.40 $\pm$ 0.34	1.69	3.27	0.01	0.92	0.02
T3	2.52 $\pm$ 0.43	1.89	3.29	2.42 $\pm$ 0.40	1.60	3.16	0.10	0.41	0.24 [#]
Relative $\dot{V}O_{2max}$ (Maturity group*Time F=3.25, p=0.07)									
T1	43.76 $\pm$ 6.08	34.94	50.85	40.24 $\pm$ 6.00	20.11	51.65	3.52	0.08	0.56 ^{##}
T2	43.84 $\pm$ 6.39	32.72	51.03	40.49 $\pm$ 6.84	23.01	50.60	3.35	0.12	0.50 ^{##}
T3	43.66 $\pm$ 6.26	33.20	51.54	40.30 $\pm$ 7.81	25.50	50.22	3.36	0.16	0.47 [#]

T1=Baseline measurements (Grade 8), T2=First follow-up measurement (Grade 9); T3=Second follow-up measurement (Grade 10); Pre=Pre-menarche; Post=Post menarche; TP=Time points; $\dot{V}O_{2max}$ =maximum oxygen uptake; *=Statistical significance ($p<0.05$); #=small effect size ($d<0.2$); ##=medium effect size ($d<0.5$); ###=large effect size ($d<0.8$)

Strength differences between the groups were not statistically significant although the differences of 3.53m (T1, $d=0.50$), 1.66m (T4, $d=0.26$) and 2.56m (T7, $d=0.38$) showed small to medium practical significance between the groups (Table 3).

With regard to aerobic capacity, pre-menarche girls outperformed the post-menarche group during all measurements ($p>0.05$), although the differences between groups became smaller over time (T1-T3).

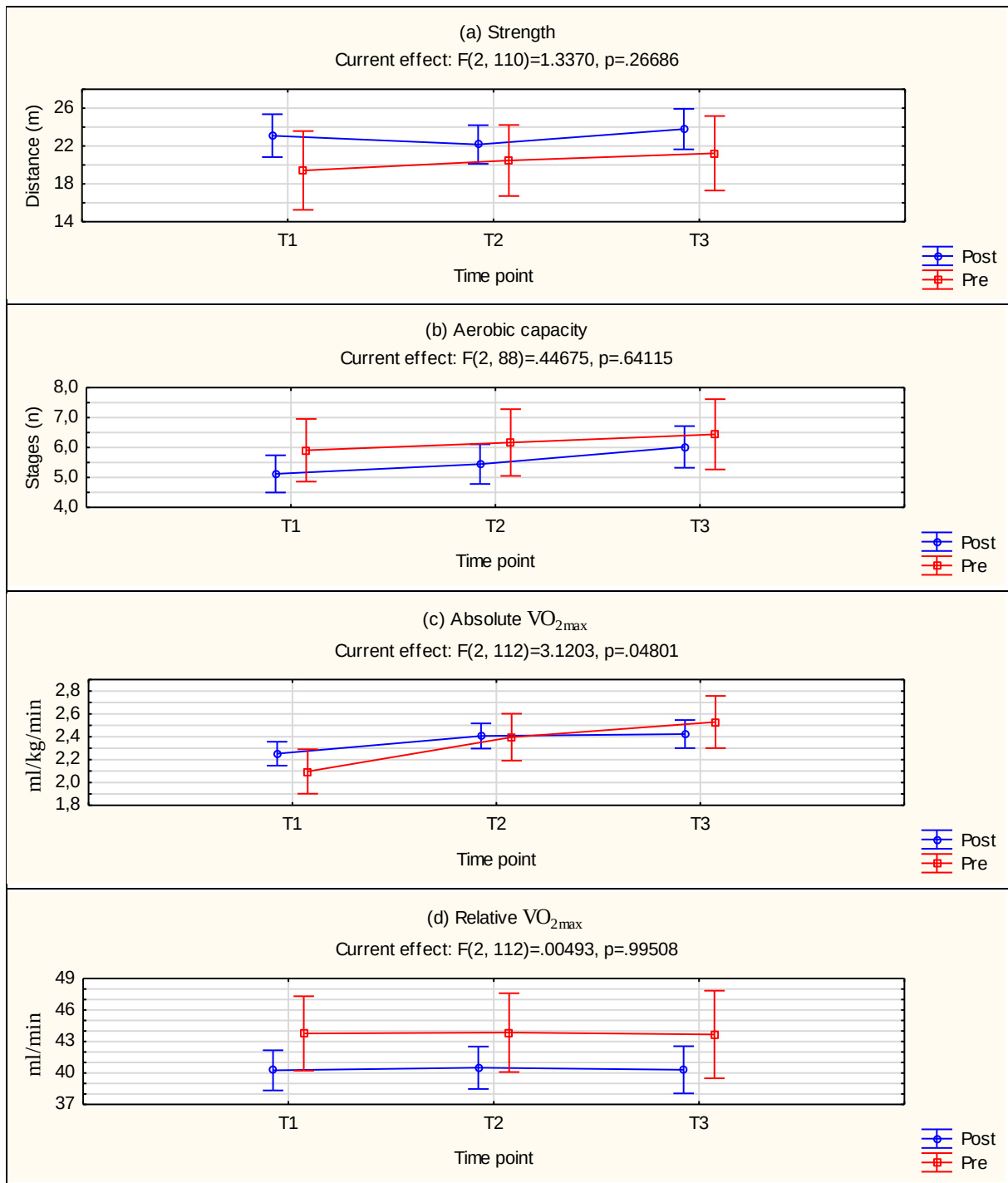
TABLE 4: SIGNIFICANCE OF CHANGES IN PHYSICAL FITNESS CHARACTERISTICS IN PRE- AND POST-MENARCHE GROUPS

	T1-T2		T2-T3		T1-T3	
	Pre	Post	Pre	Post	Pre	Post
Muscle strength (m)	1.05	-0.83*	0.76	1.66	1.81	0.84
Aerobic capacity (levels)	0.07	0.42	0.29	0.63	0.36	1.05*
Absolute $\dot{V}O_{2max}$	0.30*	0.15	0.13*	0.02	0.43*	0.17
Relative $\dot{V}O_{2max}$	0.08	0.24	-0.18	-0.19	-0.1	0.06

*= Statistical significance ($p < 0.05$); T1=Baseline measurements (Grade 8), T4=First follow-up measurement (Grade 9); T7=Second follow-up measurement (Grade 10); Pre=Pre-menarche; Post=Post-menarche; SH=Sitting height; SHR %=Sitting height ratio

The post-menarche group showed a higher mean improvement from T2 to T3 (0.63 levels versus 0.29 levels) (Table 4, Figure 1b). Only the post-menarche girls showed a significant change (an increase) of 1.05 levels from T1 to T3 (Table 4), although they still displayed lower mean aerobic capacity than the pre-menarche group. Interaction effects [$F(2, 110)=1.3370$, $p=0.641$], Figure 1b] and group differences over time were both insignificant ($F=1.17$, $p=0.28$) (Table 3).

Regarding aerobic capacity expressed as $\dot{V}O_{2max}$, pre-and post-menarche girls' absolute $\dot{V}O_{2max}$ increased among all measurements with the pre-menarche group having the biggest increases of 0.30 L/min vs 0.15L/min (T1-2) and 0.13 L/min vs 0.02 L/min (T2-3) between measurements ($p > 0.05$). Differences in absolute $\dot{V}O_{2max}$ at each time point were not significant ($p > 0.05$) (Table 3) however interaction effects between groups over time were significant [$F(2, 112)=3.1203$, $p=0.048$, Figure 1c] where the pre-menarche group started with a lower absolute $\dot{V}O_{2max}$ value at 13 years but ending with a higher mean absolute $\dot{V}O_{2max}$ at 15 years. Group differences over time were however insignificant ($F=0.04$; $p=0.84$) (Table 3). This contributed to post-menarche girls having a higher absolute $\dot{V}O_{2max}$ between T1 and T2 where after the pre-menarche group surpassed them at T3. The relative $\dot{V}O_{2max}$ of both groups were very similar at T3 compared to T1 with no significant changes ($p > 0.05$) between time points or interaction effects between T1 and T3 in both groups over the follow-up period [$F(2, 112)=0.0049$, $p=0.9950$, figure 1d). The pre-menarche group displayed higher relative $\dot{V}O_{2max}$ scores throughout the study. Group difference over time were borderline significant ($F=3.25$; $p=0.07$) (Table 3).



Vertical bars denote 0.95 confidence intervals; T1=Grade 8; T2=Grade 9; T3=Grade 10

Figure 1 (a-d): Growth curves of pre- and post-menarche girls' anthropometric capabilities

DISCUSSION

The objective of the study was to investigate possible differences in strength and endurance in pre- and post-menarche girls over a two-year follow-up period by comparing pre- and post-menarche girls based on their menarche status when they entered their first high school year at a mean age of 13.51 years.

Our first finding was that developmental differences between the pre- and post-menarche groups were relatively small and insignificant regarding muscle strength and aerobic capacity. These results are consistent with other research findings (Henneberg & Louw, 1995, Van Gent, 2001, Frederics *et al.*, 2005, Van Den Berg *et al.*, 2006; Travill, 2007, Anderson, 2009). Based on higher mean scores during each time point, post-menarche girls showed advantages in muscle strength during all three time points ($p>0.05$), although these differences were only of small to medium practical significance (Table 3). At T1 (13.51 years), a difference in throwing distance of 3.53m ($p>0.05$) was found between the groups (22.95m and 19.42m), which decreased to 1.66m during T2 (14.51 years). Between T1 and T2 (Table 4) the throwing distance of post-menarche girls declined with 0.83m. This deterioration might be explained by anthropometric changes in the group contributing to possible changes in body proportions and possible increases in fat percentage relative to muscle percentage during this period. Although fat percentage was not measured during T1 a definite increase in fat percentage was found from T2 to T3 and therefore it is hypothesised that this increase might have started from T1. During the same period the throwing distance of the pre-menarche group improved by 1.23 meter. The pre-menarche group also showed the biggest improvements in throwing distances over the follow-up period, although the mean value of the group was still lower at T3 where a difference of 2.56 meters was observed between the groups. A clear levelling off in strength improvement was however seen in the post-menarche group which is consistent with other research findings. According to researchers, muscle strength development is influenced during puberty by various aspects including linear growth, body mass and muscle size (Melanese *et al.*, 2010) which could either positively or negatively influence changes in strength related physical fitness capabilities. Melanese and co-workers (2010) report in this regard that muscle strength develops linearly from birth to puberty, reaching peak development at the same time as achieving peak height velocity (PHV) (average 12-years) and about 0.6 years after peak mass velocity (PMV). With the average onset of PHV and muscle strength development relative to PHV as reported by researchers (Malina *et al.*, 2004; Melanese *et al.*, 2010) in mind, our results where the muscle strength of the pre-menarche group showed the biggest increase (1.05m) (Table 3) between 13.51 and 14.51 years (T1-T2), are consistent with current literature findings. This improvement contributed to the difference between the groups (2.56m) becoming smaller from T1 but still in favor of the post-menarche group. As more than 90% of the total group did reach menarche, including 92.4% of the pre-menarche group during the follow-up period of the study, hormonal changes could subsequently have influenced both groups. Aspects other than hormonal changes could, however, be also influential in these differences. In this regard researchers reported that changes in body-segments (for example, shoulder girths and

arm lengths) play a role in changing muscle strength while changes in sitting height play a significant role in changes in upper body chest and shoulder strength between 14 and 16 years of age (Malina *et al.*, 2004). Malina and co-workers (2004) further explain that girls tend to gain muscle strength proportionally to body size before PHV, although after PHV, girls tend to increase less in biceps strength proportionally to body size. Our results regarding muscle and fat percentage of the groups at T2 and T3 showed that, although pre-menarche girls had a higher percentage muscle mass (34.9%) and lower percentage fat mass (21.02%) compared to post-menarche girls' muscle mass (33.8%, $p>0.05$) and fat mass (25.84%, $p<0.05$) at T2, the post-menarche group still outperformed them in muscle strength activities during the late stages of follow-up although these differences between groups were insignificant. This advantage that the post-menarche group still displayed at T3, could also possibly be ascribed to the transfer of training effects in this group. Based on higher strength levels in pre-menarche girls at younger ages, this might have provided them with more exposure to sport and coaching opportunities consequently contributed to improved strength and neuromotor coordination to perform strength related activities.

With regard to aerobic capacity, as measured in the number of shuttles completed, interaction effects (Figure 1a-c), as well as group differences over time (Table 3), were not significant. The interaction effects ($F(2, 112)=3.1203$, $p=0.048$) for absolute $\dot{V}O_{2max}$ (Figure 1c), was however significant ($p=0.04$), although group differences over time ($F=0.04$; $p=0.84$) were not significant. Relative $\dot{V}O_{2max}$, where mass is not taken into consideration in the aerobic performance, showed no significant interaction effects ($F=0.0049$; $p=0.99$, Figure 1d), although significant group differences were found during T1 ($F=3.25$; $p=0.07$, Table 3). The pre-menarche group showed higher mean shuttle levels compared to the post-menarche group during all three measurements. Relative $\dot{V}O_{2max}$ of this group was also higher at all time-points and over the entire follow-up period, while they only had higher mean absolute $\dot{V}O_{2max}$ values at T3 when body mass was taken into consideration. This difference at T3 was also of practical significance. These results agree with that of Van den Berg *et al.* (2006) who found in a cross-sectional analysis of female 14-year-old tennis players, that late developing girls (level 7.15) performed better than early developing girls (level 6.80), although the differences were not significant. Both groups still showed gradual improvement in aerobic capacity between the time points, but post-menarche girls showed the largest increases (Table 4). However, none of these improvements between time points were statistically significant ($p>0.05$), although the increases over the follow-up period (T1-T3) were statistically significant ($p<0.05$) in the post-menarche group (Table 4). This result could be explained by more anthropometric, physiological and hormonal adaptive responses that would

have taken place during this period within the pre-menarche group. Such changes included higher increases in percentage fat mass (+5.24%, T2-T3) in the pre-menarche group compared to 3.13% in the post menarche group during the same period. Although post-menarche girls still displayed the highest fat percentage at T3, they most probably have already adapted to their changed body composition while it might not have been the case in the pre-menarche group where large body composition changes still took place which they might not yet have adapted to. Other influences such as heart rate and heart rate variability might also have influenced the results. Armstrong *et al.* (1990) report in this regard that the largest increase in heart rate occurs approximately one year before PHV in girls, which will have a direct positive influence on girls' aerobic capacity. This might be indicative that aerobic capacity is not only influenced by increased mass and percentage body fat but by a combination of heart rate and stroke volume together with changes in mass and percentage body fat (Armstrong *et al.*, 1990). Aberberga-Augskalne and Kemper (2007) report that cardiovascular functioning in late developing girls, show more effective patterns in terms of cardiovascular responses to exercise, although Armstrong *et al.* (1990) reported no influences of maturity on aerobic capacity response at maximal exercise among 12-year-old girls.

Our study, therefore, confirms that the level of maturation as assessed by attaining menarche status does influence the muscle strength and aerobic capacity of girls, particularly during mid-adolescence and more specifically on a practical level. Earlier developing girls, initially display advantages associated with earlier growth changes in strength, and although they showed decreases in muscles strength, they still showed advantages in muscle strength at all time points, T1-T3, although only on a practical level. Pre-menarche or late developing girls displayed better aerobic capacity although only of practical significance, where the differences were most probably the result of post-menarche girls been negatively influenced by higher body mass [58.79kg (pre) versus 61.11kg (post), T3], fat mass and BMI. These findings are furthermore indicative that the period between 13-16 years of age should still be considered to be an unstable developmental period regarding changes in strength and endurance levels of girls of similar chronological ages but differing maturational ages. From the above findings, it can be concluded that the strength and endurance of girls of similar chronological ages can only be compared realistically after the influences of maturational development differences have been diminished which should be later than 15 years of age.

Despite the noteworthy findings of this study, the study had limitations that need to be taken into consideration when interpreting the findings. Although the data was collected over a follow-up

period of two years, which strengthens the results of the study, the study was done late in the pubertal development period. It therefore only focused on the period between 13 and 15 years of age, while a more substantial age-span period might be needed to investigate the full influence of the pubertal phase. The data was also collected using a convenience sample where all the subjects were from one school in the Northwest Province of South Africa, which limits the generalization of the results, although the school had hostel facilities which represented children coming from various schools from the surrounding area. Our sample also did not evenly represent multiple racial groups and results are mostly based on data of white (Caucasian) girls. Lastly, changes in environmental conditions such as weather conditions over the 3 years were out of the researchers' control and could have influenced the performance of the subjects on the day of testing.

CONCLUSION

During mid-adolescence, at the mean ages between 13 and 15 years, girls of the same chronological age but differing maturity status tend to differ in their strength and aerobic fitness, although differences are only of practical significance. Changes associated with maturation contributed to late maturing girls having overall more significant increases in muscle strength while the $\dot{V}O_{2\max}$ of post-menarche girls remained at a higher level between 13.51 and 15.51 years of age. The findings confirm that age at menarche is a significant marker of strength and endurance differences between girls especially at the age of 13 years. As seen from the current literature it is most likely the result of changes in hormonal levels, that drives anthropometric changes and changes in body composition. This is especially due to increases in body mass, that seem to be the driving factor in leveling out maturational differences in girls of differing levels of maturity's strength and endurance. It can therefore be argued that the time of reaching menarche is an unstable developmental period for muscle strength and aerobic capacity. The reaching of menarche provides advantages for strength development, but negatively influences girls' aerobic endurance. Girls will consequently only be homogeneous in their strength and aerobic endurance, 1-2 years after all girls of the same chronological age have reached menarche which will often only be around the age of 16 years. Therefore, our findings confirm that the potential of girls to excel in sports based on strength and endurance capabilities could only be accurately determined more than two years after all same-aged girls have reached menarche, especially in an age-based sport competition structure.

Information obtained by this study provided more insight into the significance of strength and endurance changes that occur in girls after the onset of menarche and how it influences females of

differing maturity status. This novel knowledge that show practical significant differences between differing maturity groups is important as it can assist coaches by incorporating this knowledge into training programs adapted for maturational differences between individuals and groups. Furthermore, it can contribute to improved sports development and talent identification processes, by providing an understanding of the temporary weaknesses but also strengths that are associated with early or late development and by applying this knowledge in appropriate short- and long-term goals for girls that participate in sport. More research is however recommended that should span over a longer developmental age period, to obtain complete strength and endurance fitness profiles of early and late maturing girls.

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REFERENCES

- Aberberga-Augskalne, L., & Kemper, H.C.G. (2007). Longitudinal relationship between cardiovascular functioning and peak height velocity during exercise in 7 to 16-year-old boys and girls. *Human Movement Science*, 8(1), 5-11.
- Adler, J. (2010). Quantifying colocalization by correlation: The Pearson correlation coefficient is superior to the Manders overlap coefficient. *Journal of the International Society for Advancement of Cytometry*, 77(8), 1552-4922.
- Anderson, S. (2009). *Collins English dictionary: Complete & Unabridged* (10th ed.). London: Harper Collins.
- Armstrong, N., Balding, J., Gentle, P., Williams, P., & Kirby, B. (1990). Peak oxygen uptake and physical activity in 11 to 16-year-olds. *Pediatric Exercise Science*, 2, 349-358.
- Apter, D., Reinila, M., & Vihko, R. (1989). Some endocrine characteristics of early menarche, a risk factor for breast cancer, are preserved into adulthood. *International Journal of Cancer*, 44(5), 783-787.
- Australian Sport Commission. (1996). *Sport search program*. Canberra: ASC.
- Ayatollahi, S.M., Dowlatabadi, E., & Ayatollahi, S.A. (2002). Age at menarche in Iran. *Annals of Human Biology*, 29(4), 355-362.
- Balyi, I., & Way, R. (2010). *Canadian sports for life: The role of monitoring growth in long-term athlete development*. Calgary: Canadian Sports Centre.
- Beunen, G.P., Ostyn, M., Simons, J., Renson, R., Claessens, A.L., Vanden Eynde,.... van't Hof, M.A. (1997). Development and tracking in fitness components: Leuven longitudinal study on lifestyle, fitness and health. *International Journal of Sport Medicine*, 18(3), S171-S178.
- Bronikowski, M., & Bronikowska, M. (2008). Motor fitness in relation to the maturational process of pubertal boys and girls. *Papers on Anthropology*, 17, 28-37.

Carel, J.C., & Leger, J. (2008). Precocious puberty. *The new England journal of medicine*, 358(22), 2366-2377.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112, 155-159.

Dahl, R.E. (2004). Adolescent brain development: a period of vulnerabilities and opportunities. *Annals New York academy of sciences*, 1021, 1-22.

Danubio, M.E., DE Simone, M., Vecchi, F., Amicone, E., Altobelli, E., & Gruppioni, G. (2004). Age at menarche and age of onset of pubertal characteristics in 6–14-year-old girls From the Province of L'Aquila (Abruzzo, Italy). *American Journal of Human Biology*, 16, 470-478.

Deborah, C., & Russel, V. (2005). ABC of adolescence: Adolescent development. *British Medical Journal*, 330, 301-304.

Forman, D., Pike, M.C., Davey, G., Dawson, S., Baker, K., Chilvers, C.E.D... Coupland, C.A.C. (1994). Etiology of testicular cancer: association with congenital abnormalities, age at puberty, infertility, and exercise. *British medical journal*, 308, 1393-1399.

Frederiks, A.M., van Buuren, S., van Heel, W.J.M., Dijkman-Neerincx, R.H.M., Verloove-Vanhorick, S.P., & Wit, J.M. (2005). Nationwide age reference for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Archives of Diseases in Childhood*, 90, 807-812.

Gallahue, D.L., Ozmun, J.C., & Goodway, J.D. (2012). *Understanding motor development* (7th ed.). New York, NY: McGraw-Hill.

Garnier, D., Simondon, K.B., & Benefice, E. (2005). Longitudinal estimates of pubertal timing in Senegalese adolescent girls. *American Journal of Human Biology*, 17, 718-730.

Gaudineau, A., Ehlinger, V., Vayssiere, C., Jouret, B., Arnaud, C., & Godeau, E. (2010). Factors associated with early menarche: results from the French health behavior in school-aged children (HBSC) study. *Biomed Central Public Health*, 10, 175-182.

Henneberg, M., & Louw, G.J. (1995). Average menarcheal age of higher socioeconomic status urban Cape coloured girls assessed by means of status quo and recall methods. *American Journal of Physical Anthropology*, 96, 1-5.

Kaprio, J., Rimpelä, A., Winter, T., Viken, R.J., Rimpelä, M., & Rose, M.J. (1995). Common genetic influences on BMI and age at menarche. *Human Biology*, 67(5), 739-753.

Kemper, H.C.G., Snel, J., & van Mechelen, W. (2004). Amsterdam growth and health longitudinal study. *Journal of Science and Medicine in Sport*, 47, 1-198.

Lee, T.S., Chao, T., Tang, R.B., Hsieh, C.C., Chen, S.J., & Ho, L.T. (2005). A longitudinal study of growth in schoolchildren in one Taipei district II: sitting height, arm span, body mass index and skinfold thickness. *Chinese Medical Association*, 68(1), 16-20.

Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). *Growth, maturation and physical activity*. Champaign, IL: Human Kinetics.

Marshall, W.A., & Tanner, J.M. (1969). *Puberty*. In Falkner, F. & Tanner, J.M (Eds). *Human growth: A comprehensive treatise*. (vol 2). Postnatal growth: Neurobiology (pp 171-209. New York, NY: Plenum.

Melanese, C., Bortolami, O., Bertucco, M., Verlato, G., & Zancanaro, C. (2010). Anthropometry and motor fitness in children aged 6-12 years. *Journal of Human Sport and Exercise*, 5(2), 265-279.

Monyeki, K.D., Koppes, L.L.J., Kemper, H.C.G., Monyeki, K.D., Toriola, A.L., Pienaar, A.E... Twisk, J.W.R. (2006). Body composition and physical fitness of undernourished South African rural primary school children. *European Journal of Clinical Nutrition*, 59, 877-883.

Okasha, M., McCarron, P., McEwen, J., & Davey Smith, G. (2001). Age at menarche: secular trends and association with adult anthropometric measures. *Annals of Human Biology*; 28(1), 68-78.

Ortega, F.B., Artero, E.G., Ruiz, J.R., Vincente-Rodriguez, G., Bergman, P., Hagstro, M... Castillo, M.J. (2008). Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. *International Journal of Obesity*, 32, S49-S57.

Pienaar, A.E. (2018). Motor development, growth, motor assessment and the intervention thereof: A textbook for students in Kinderkinetics. Potchefstroom: Ivyline printers.

Prahl-Anderson, B., Kowalski, C.J., & Heydendaal, P. (1994). *A mix longitudinal interdisciplinary study of growth and development*. New York, NY: Academic.

Richter, L., Norris, S. Yack, D., & Cameron, N. (2007). Cohort profile: Mandela's children. The 1990 birth-to-twenty study in South Africa. *International Journal of Epidemiology*, 36(3), 504-511.

Rodriguez, G., Moreno, L.A., Blay, M.G., Blay, V.A., Garagorri, J.M Sarri'al, A... Bueno, M. (2004). Body composition in adolescents: measurements and metabolic aspects. *International Journal of Obesity*, 28, S54-S58.

Rubina, C., Maisoneta, M., Kieszaka, S., Monteilha, C., Holmesa, A., Flandersa, D... Marcusa, M. (2009). Timing of maturation and predictors of menarche in girls enrolled in a contemporary British cohort. *Paediatric and Perinatal Epidemiology*, 23, 492-504.

Salces, I., Rebato, E.M., Susanne, C., San Martin, L., & Rosique, J. (2001). Familial resemblance for the age at menarche in Basque population. *Annals of Human Biology*, 28(2), 143-156.

Sener, U., Ucok, K., Ulasli, A.M., Genc, A., Karabacak, H., Coban, N.F...Cevik, H. (2016). Evaluation of health-related physical fitness parameters and association analysis with depression, anxiety, and quality of life in patients with fibromyalgia. *International Journal of Rheumatic Diseases*, 19(8), 763-772.

Statsoft. (2017). *Statistica for Windows: General conventions and statistics*. Tulsa, OK: Statsoft.

Topendsports. (2012). *Fitness testing for swimming*. Retrieved from <http://www.topendsports.com/sport/swimming/testing.htm>

Travill, A.L. (2007). Growth and physical fitness of socially disadvantage boys and girls aged 8-17 years living in the western cape, South Africa. *African Journal for Physical, Health Education, Recreation and Dance*, 13(3), 279-293.

Vaeyens, R., Lenoir, M., Williams, A.M., & Philippaerts, R.A. (2008). Talent identification and development programmes in sport: Current models and future directions. *Journal of Sports Medicine*, 38(9), 703-714.

Van Den Berg, L., Coetzee, B., & Pienaar, A.E. (2006). The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *African Journal for Physical, Health Education, Recreation & Dance*, 18(3), 510-15.

Van Gent, M.M. (2001). *Anthropometrical, physical and motor fitness characteristics of 10- to 15-year old girls in the Northwest province* (Unpublished Master's dissertation). NWU, Potchefstroom.

Van Lenthe, F.J., Kemper, C.G., & van Mechelen, W. (1996). Rapid maturation in adolescence results in greater obesity in adulthood: the Amsterdam growth and health Study. *American Journal of Clinical Nutrition*; 64(1), 18-24.

Volver, A., Viru, A., & Viru, M. (2007). A two-year longitudinal study of sexual maturation effects on motor abilities of girls. *Medicina Della Sport*, 60(1), 57-63.

Wang, Z., Dang, S.; Yuan, X., Li, Q., & Hong, Y. (2016). Correlation of body mass index levels with menarche in adolescent girls in Shaanxi, China: a cross-sectional study. *BMC Women's Health*, 16(1), 472-6874.

Williams, A.M., & Reilly, T. (2000). Talent identification and development in soccer. *Journal of Sports Science*, 18(9), 657-667.

CHAPTER 5

**DIFFERENCES IN MOTOR FITNESS CAPABILITIES OF
PRE- AND POST-MENARCHE GIRLS DURING MID-
ADOLESCENCE: A TWO-YEAR FOLLOW-UP STUDY**

Research paper

Differences in motor fitness capabilities of pre- and post-menarche girls during mid-adolescence:
A two-year follow-up study

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ABSTRACT

Background: Growth as a result of puberty and the onset of menarche influences the physical and motor performance of girls. However, the magnitude of these influences on girls of varying maturity status is not clear.

Aim: To investigate differences in explosive strength, speed, agility and hand-eye coordination between pre- and post-menarche girls over a two-year follow-up period.

Subjects and method: A longitudinal research design was used that included a two-year follow-up period. A convenience sample ($N=58$) of Grade 8 high school girls aged 13.51 ± 3.51 , divided based on the Status Quo method into a pre- ($n=13$) and post-menarche ($n=45$) group, was used. Motor fitness was tested once a year by standardized protocols. Basic statistics, an independent t -test and a repeated measures ANOVA with a post hoc Bonferonni correction were used, where $p < 0.05$ signifies statistical significance. Effect sizes were calculated and determined by Cohen's d -values.

Results: Only explosive upper body strength differed significantly between groups during baseline measurements, favoring post-menarche girls. Post-menarche girls further had an advantage in hand-eye coordination and speed ($p > 0.05$) with pre-menarche girls performing slightly better in agility, and explosive leg strength ($p > 0.05$) at 13.51 years. At 15.51 years no significant between-group differences were found with pre-menarche girls surpassing post-menarche girls in hand-eye coordination and 0-40m speed, and post-menarche girls displaying higher explosive leg and upper body strength scores after two years ($p > 0.05$).

Conclusion: Significant differences in motor capabilities between girls of differing maturity status, are mostly evident just before and after reaching menarche. The potential to excel in sport based on motor capabilities can only be accurately determined 1-2 years after reaching menarche.

Key words: Growth, Longitudinal, Menarche, Motor capabilities

Introduction

The largest variation in sexual maturity among girls is found between the ages of 12 and 16, showing clear resemblances with anthropometric characteristics and motor fitness (Osinski 1988; Saczuk et al. (1999) as quoted by Bronikowski and Bronikowska (2008). Menarche is one of several factors that are associated with various physical changes that occur during puberty (Marshall and Tanner 1986). These changes can have an influence on the development of motor and physical fitness of adolescent girls (Balyi and Way 2010).

Girls enter the pubertal phase during early adolescence (11.8 to 13 years) (Malina et al. 2004; Gluckman and Handson 2006) when sexually transmitted glands become functional and secondary sexual characteristics begin to develop. This period includes the reaching of menarche during late adolescence (Anderson 2009). Menarche refers to the onset of the menstrual cycle in girls, when a girl begins to ovulate for the first time (Towne et al. 2005). Worldwide, menarche is reached on average at the end of puberty at an average age of 12.8 years (Malina et al. 2004) and about 6 months to 1 year after peak height velocity (PHV) (Gluckman and Handson 2006; Karapanou and Papadimitriou 2010). The age at which menarche occurs, is not rigid and is influenced by a variety of factors, such as genetic factors, nutrition and health status (Kaprio et al. 1995; Salces et al. 2001). The onset of menarche affects the physical and motor capabilities of girls (Malina et al. 2004) which have consequences, specifically for those who participate in sport.

Sport performance is influenced by various motor abilities, including speed, agility, explosive power, hand-eye coordination and muscle strength (Malina et al. 2004). Pubertal changes and the reaching of menarche are associated with fat related weight increases (Malina et al. 2004; Gluckman and Handson 2006). The abovementioned maturation processes will influence adolescent girls' body composition and physical abilities, which consequently will affect the performance of motor skills (Baquet et al. 2006; Van den Berg et al. 2006; Des te Croix 2007;

Bronikowski and Bronikowska 2008; Pienaar 2018). Speed, agility and explosive power are directly influenced by body dimensions such as stature, weight and arm span, and are therefore influenced by biological maturity (Malina et al. 2004). In this regard, Van den Berg et al. (2006) found significant differences in explosive leg strength in girls of differing maturity status, where average developing girls performed the best followed by early- and late developing girls. Literature, however, indicates that biological maturity is not the only role player in girls' motor development. Freitas et al. (2015) report in this regard that biological maturity only accounts for approximately 2.8% of variation in girls' coordination. Controversial results are also reported where some studies report a gradual increase in coordination while others report declines at a certain age (Van Gent 2001). Literature also indicates that anaerobic development occurs after puberty indicating that biological maturity plays a significant role in speed (Malina et al. 2004). In this regard peak development in muscle strength and -endurance, which is directly related to speed and agility, commences approximately 0.5-1 years after reaching PHV (Malina et al. 2004), and a plateau in speed and agility is only reached beyond 14-years of age.

On a global scale, various cross-sectional studies have been conducted (Rodriguez et al. 2004; Garnier et al. 2005; Frederics et al. 2005; Deborah and Russel 2005; Anderson 2009) including in South Africa (Henneberg and Louw, 1995; Van Gent 2001; Van den Berg et al. 2006; Travill 2007) that focused on the motor and physical changes that take place during adolescence in girls. These include worldwide studies pertaining to the development of speed, agility, coordination and explosive strength as well as studies exploring the possible correlations between these variables through cross-sectional and longitudinal study designs (Beunen et al. 1997; Prah-Anderson et al. 1994; Kemper et al. 2004; Lee et al. 2005; Volver et al. 2007), although to a lesser extent in South Africa (Monyeki et al. 2006; Richter et al. 2007). Results from the above studies concluded that motor capabilities are influenced by biological maturity although neurological development and fitness and sport training also has an influence. However, biological maturity differences related to

the age of onset of menarche were not the main differential factor in these analyses. Researchers also report that the motor development of girls undergoes only minor changes that are largely the result of anthropometric growth differences from just before the onset of menarche, to about three years after menarche (Malina 1994; Malina et al. 2004). However, Malina et al. (2004) summarized the literature by stating that no correlation is found between peak motor development before, during and after menarche in relation to the onset of menarche. This is contrary to the results of Van den Berg et al. (2006) whom have found significant differences between early, middle and late developing girls.

Since it can take up to ten years to reach elite performance in a particular sport (Durand-Bush and Salmela 2002), it is important to understand developmental motor fitness patterns of girls of differing maturity status so that girls with true potential are identified as soon as possible to ensure optimal development. The aim of this study is therefore to address the controversy that still exists regarding the magnitude of differences in speed, agility, explosive power and coordination in pre- and post-menarche girls by studying it over a longitudinal period during the mid-adolescence period. Findings from the study will aid in a better understanding of the influence of the phenomena of menarche on girls' explosive upper body strength, hand-eye coordination, explosive leg strength, agility and speed development. This understanding can contribute to the compilation of sport development programs that are aligned with girls' maturational status. In addition, the results of this study can contribute to a more accurate selection of girls during the mid-adolescent period who have the potential to excel in sport, based on motor specific characteristics.

Methodology

Research design

This study made use of a longitudinal research design. The main project, "Growth and sport psychological characteristics of talented adolescents", were performed over a two-year follow-up

period spanning over a 3-year school period (2010-2012). The data was collected using anthropometric and motor tests as well as questionnaires. The anthropometric measurements took place three times a year (four months apart) with the motor tests measured once a year during the baseline measurements of each year. Baseline measurements were taken in February 2010 and the last measurements took place in November 2012, resulting in nine time-point measures for growth (T1-9) and three time point follow-up measures for motor fitness skills (T1, T2, T3). Overall, follow-up measures were obtained over a full two-year period.

Research group

All grade 8-learners of one quintile 5 school (quintile 1 = low socio-economic quintile, to quintile 5 = high socio-economic quintile) in Potchefstroom in the Northwest Province of South-Africa, were invited to take part in the study. Learners who had parental permission and who gave assent themselves were subjected to the testing protocol. Permission for the project was also obtained from the principal of the school involved. Since the school had boarding facilities, all grade 8-learners enrolled in 2010 represented 46 different primary schools. In 2010, 95 girls with a mean age of 13.73 ± 0.48 years participated in the study. The final group, who completed all follow-up measurements in November 2012, consisted of 58 girls with a mean age of 16.27 ± 0.36 years. The loss of subjects to follow up were 37 girls (38%) due to various reasons including parents of children moving elsewhere, children moving between schools and injury.

Ethical approval

Ethical approval for the execution of the study based on the Declaration of Helsinki was obtained from the Health Research Ethics Committee of the North-West University's Potchefstroom Campus (NWU 00199-15-A1).

Measuring instruments

Body composition

BMI, Percentage fat mass and muscle mass were also used in the study. Percentage fat mass and muscle mass were measured with an electronically calibrated bio-impedance, body composition apparatus (Omron BF 511). According to the Omron official website, the accuracy of the Omron models differs from bio-impedance scales from model-to-model (+3.5 and 4.1%) based on the "Standard Estimation Error (SEE). The SEE indicates that 68% of all measurements for different users are accurate within 3.5 - 4.1%, relative to body fat percentage (kg.m²). (<https://www.omron-healthcare.com/en/products/weightmanagement>). The following formula determined body mass index (BMI): Bodyweight in kilograms divided by height in meters squared or, $BMI = \frac{x \text{ KG}}{y \text{ M} * y \text{ M}}$ (x=bodyweight in KG, y=height in M).

Age of menarche

The age of menarche was determined by the Status Quo method (Hennenberg and Louw 1995; Wang et al. 2016) during the baseline measurements of each year in February in 2010, 2011 and 2012 (T1, T2 and T3). The girls had to indicate on a questionnaire by selecting YES or NO whether they have had their first menstrual cycle on or before the date of testing. If they answered YES they also had to indicate the month and year when their first menstrual cycle had started.

A high percentage of the group (77%, n=45) already reached menarche during the baseline measurement in grade 8 (2010) at a mean age of 13.51 years. During the first follow-up measurements in grade 9 (2011) at a mean age of 14.52 years an additional eight girls (now 91% of the group) had reached menarche (n=49), with all but one girl (98%) reaching menarche (n=57) at a mean age of 15.52 years during the last year of measurements in grade 10 (2012). For the purpose of this study the group was divided into a pre-menarche group (n=13) and post-menarche

group (n=45) according to menarche status at baseline. All comparisons were done based on this grouping.

Motor capabilities measurements

The Australian Sport Search Program protocol commonly used in Australia for sports talent identification in children of 12 years and older was used (Australian Sport Commission 1996). The test protocol involves six motor tests (beep test, basketball throw, 40m speed test, 10m agility test, vertical jump and throw-and-catch-test). All motor tests were conducted according to this protocol. In addition, girls 0-10m speed were also tested.

Basketball throw

The basketball throw is designed to measure upper body strength. The subject sits with the buttocks, back and head resting against a wall, with the legs horizontally on the floor in front of the body. The subject uses a two-handed chest pass to push the ball (size 7 ball) in a horizontal direction as far forward as possible. The measurement is taken to the nearest 5cm. Each subject is allowed two trials of which the best trial is recorded (Australian Sports Commission 1996).

10m and 40m speed test

Anaerobic ability was measured using the Fusion Sport Smart Speed System (Fusion Sport Pty Ltd, 2009) developed in Brisbane, Australia. All subjects underwent a thorough warm-up session beforehand. The test included 4 speed lights, placed on 0m, 5m, 10m and 40m. Only the time of 0-10m and 0-40m were used for the purpose of this study. The test is performed from a standing position from where the subject had to accelerate to the last measuring speed light. The better of two attempts is recorded and expressed in seconds to the nearest 0.01 second. The subject receives two attempts, with two minutes of rest between efforts.

10m agility test

The 10m agility test is completed between markers placed five metres apart on a hard surface. The subject starts standing behind one line with the front foot on the line. On command “go” the subject runs as fast as possible to the other line, pivots, while both feet must touch behind the line, and returns to the starting line. This constitutes one cycle, with five required in total. Two attempts are given, with 2 minutes of rest in between, and the best effort is then scored with a calibrated stopwatch and expressed in seconds to the nearest 0.01 second (Australian Sports Commission 1996).

Vertical jump

The vertical jump test is a test of explosive leg strength (ELS). The subject has to stand upright and stretch as high as possible against a wall while the feet remain flat on the ground. The distance (reaching height) is taken to the nearest 1cm. The subject then goes into a crouch position with the preferred hand raised vertically, and the non-preferred hand held by the side (not allowed to swing arms for momentum) and jumps upward and touches the wall at the highest point possible. The “vertical jump height” is recorded to the nearest 1cm. The subject receives two attempts, with approximately 30 seconds of rest in between attempts, and the best result is recorded in centimetres. Lastly, the reaching height is subtracted from the vertical jump height to obtain the vertical jump distance (Australian Sports Commission 1996).

Throw-and-catch test (Hand-eye coordination)

The throw and catch test for accuracy consists of 20 underhand tosses, where ten throws are first thrown and caught with the dominant hand followed with ten throws with the non-dominant hand. The subject is instructed to throw a tennis ball with the preferred hand towards the target (circle target, 30cm diameter) that is 2.5m away and attempt to catch the ball with the same hand. Practice trials are allowed until the subjects demonstrate that they understand the instructions. The

ball must be thrown underarm and is not allowed to bounce before being caught. Each trial is only successful if the ball hits the target and the subject catches the ball cleanly (not trapped against the body) (Australian Sports Commission 1996).

Statistical analysis

The data was analyzed with the “Statistica for Windows 2017” Statsoft computer program package (StatSoft 2017). Descriptive characteristics, including means, standard deviations (sd) and minimum and maximum values were calculated. Repeated measures ANOVA was used to analyze changes in motor skills and capabilities over time followed by a Posthoc Bonferonni adjustment to determine the statistical significance of differences between measurements amongst the pre- and post-menarche groups ($p < 0.05$). Effect sizes were calculated using Cohen’s d-values with $d > 0.2$ indicating a small effect size, $d > 0.5$ a medium effect size and $d > 0.8$ a large effect size (Cohen 1992).

Results

Table 1 reports the descriptive characteristics of the groups at baseline (Feb 2010, T1) and during the two follow-up years [Feb 2011, (T2) and Feb 2012 (T3)].

TABLE 1: DESCRIPTIVE CHARACTERISTICS OF THE PRE- AND POST-MENARCHE GROUPS

	Year 1 (T1)		Year 2 (T2)		Year 3 (T3)	
	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD
Group	58	(T1)13.51 $\pm$ 3.5	58	(T2) 14.51 $\pm$ 3.51	58	(T3) 15.51 $\pm$ 3.51
Pre-menarche	13	(T1) 13.52 $\pm$ 3.58	13	(T2) 14.52 $\pm$ 3.58	13	(T3) 15.52 $\pm$ 3.58
Post-menarche	45	(T1) 13.51 $\pm$ 3.53	45	(T2) 14.51 $\pm$ 3.53	45	(T3) 15.51 $\pm$ 3.53

T1=Year one (Gr8); T2=Year 2 (Grade 9); T3=Year 3 (Grade 10); N=number of subjects

At baseline, 58 girls completed all measurements and were classified into two groups according to their menarche status namely a pre-menarche (n=13, 23%) and post-menarche group (n=45, 77%). During the first (T2) and second (T3) follow-up measurements, 91% (T2) and 98% (T3) of the girls had reached menarche respectively. The group had a mean age of 13.51 years at baseline with no significant age differences (0.01 years, $p>0.05$) between the pre- and post-menarche groups. All follow-up comparisons between the groups were done based on the baseline grouping.

Table 2 reports the body composition of the pre- and post-menarche group during T2 (Grade 9) and T3 (Grade 10). No data is available for T1 due to the body composition analyzer only being introduced during T2. From Table 2 it was found that pre-menarche girls had an advantage in percentage muscle mass during T2 and T3 with differences between groups staying unchanged from T2 (1.26%) to T3 (1.25%) ($p>0.05$).

TABLE 2: BODY COMPOSITION OF THE PRE- AND POST-MENARCHE GROUPS DURING T2 AND T3

	Pre	Post	Difference	p-value	d-value
T2 (Grade 9)					
Fat %	21.02±7.62	25.84±6.45	4.82	0.02*	0.68 ^{##}
Muscle %	34.90±2.63	33.38±2.33	1.25	-2.02	0.61 ^{##}
BMI	21.02±4.07	22.36±3.36	1.34	0.23	0.35 [#]
T3 (Grade 10)					
Fat %	26.26±10.01	28.97±7.54	2.71	0.29	0.31 [#]
Muscle %	40.24±5.68	38.98±4.25	1.26	0.39	0.25 [#]
BMI	21.65±3.78	22.49±2.91	0.84	0.39	0.25 [#]

T2=First follow up measurement (Grade 9); T3=Second follow up measurement (Grade 10); Pre=Pre-menarche; Post=Post menarche; *=Statistical significance ($p<0.05$); #=small effect size ($d<0.2$); ##=medium effect size ($d<0.5$); ###=large effect size ($d<0.8$)

Differences were however of small to medium practical significance. With regard to percentage fat post-menarche girls had a higher percentage fat throughout although the difference between

TABLE 3: MOTOR FITNESS CHARACTERISTICS AND DIFFERENCES BETWEEN THE PRE- AND POST-MENARCHE GROUPS AT T1, T2 AND T3

TP	Pre-menarche (n=13)			Post-menarche (n=45)			Significance of differences		
	M±SD	Min	Max	M±SD	Min	Max	Diff	p-value	d-value
Explosive upper body strength (EUBS) (m) (Maturity group*Time F=2.65; p=0.11)									
T1	4.65±0.83	3.10	6.18	5.24±0.63	4.05	6.72	0.59	0.01*	0.80###
T2	5.42±0.97	4.20	7.20	5.58±0.57	4.50	7.00	0.12	0.58	0.15
T3	5.34±0.80	4.04	6.73	5.60±0.63	4.20	7.10	0.26	0.23	0.36 [#]
Explosive leg strength (ELS) (cm) (Maturity group*Time F=0.02; p=0.87)									
T1	32.57±4.16	26.00	39.00	31.23±5.77	18.50	45.00	1.34	0.43	0.26 [#]
T2	29.80±8.60	19.00	42.50	29.13±7.96	16.50	51.50	0.67	0.79	0.08
T3	31.43±6.98	21.00	41.50	33.97±6.06	22.00	48.20	2.54	0.20	0.38 [#]
Agility (sec) (Maturity group*Time F=0.06; p=0.80)									
T1	20.46±1.22	18.57	22.43	20.72±1.27	18.02	24.88	0.26	0.52	0.20 [#]
T2	19.23±1.35	17.87	22.91	19.23±1.86	16.37	24.71	0.00	0.99	0.00
T3	20.53±1.31	18.24	22.32	20.62±1.28	18.84	24.27	0.09	0.83	0.06
Speed (0-10m) (sec) (Maturity group*Time F=0.53; p=0.47)									
T1	2.18±0.15	1.92	2.45	2.13±0.14	1.90	2.54	0.05	0.30	0.34 [#]
T2	3.67±0.62	1.90	4.28	3.50±0.59	1.78	4.34	0.16	0.42	0.28 [#]
T3	2.13±0.15	1.88	2.39	2.12±0.11	1.90	2.41	0.01	0.79	0.07
Speed (0-40m) (sec) (Maturity group*Time F=0.04; p=0.84)									
T1	7.12±0.61	6.17	8.39	6.95±0.64	5.81	8.90	0.17	0.39	0.27 [#]
T2	6.88±0.69	5.87	8.04	6.74±0.63	5.67	8.61	0.14	0.50	0.21 [#]
T3	6.75±0.70	5.84	8.15	6.80±0.63	6.00	8.59	0.05	0.82	0.07
Hand-eye coordination (HEC) (n) (Maturity group*Time F=0.41; p=0.52)									
T1	4.84±4.45	0.00	14.00	5.60±4.08	0.00	15.00	0.76	0.56	0.17
T2	6.15±4.68	0.00	14.00	8.06±5.02	0.00	20.00	1.91	0.22	0.39 [#]
T3	5.61±4.53	0.00	12.00	5.46±4.02	0.00	16.00	0.15	0.88	0.04

TP=Time points; T1=Baseline measurements (Grade 8), T2=First follow up measurement (Grade 9); T3=Second follow up measurement (Grade 10); Pre=Pre-menarche; Post=Post menarche; M=Mean values; SD=Standard deviation; *=Statistical significant (p<0.05); Practical significance-#=small effect size (d<0.2); ##=medium effect size (d<0.5); ###=large effect size (d<0.8)

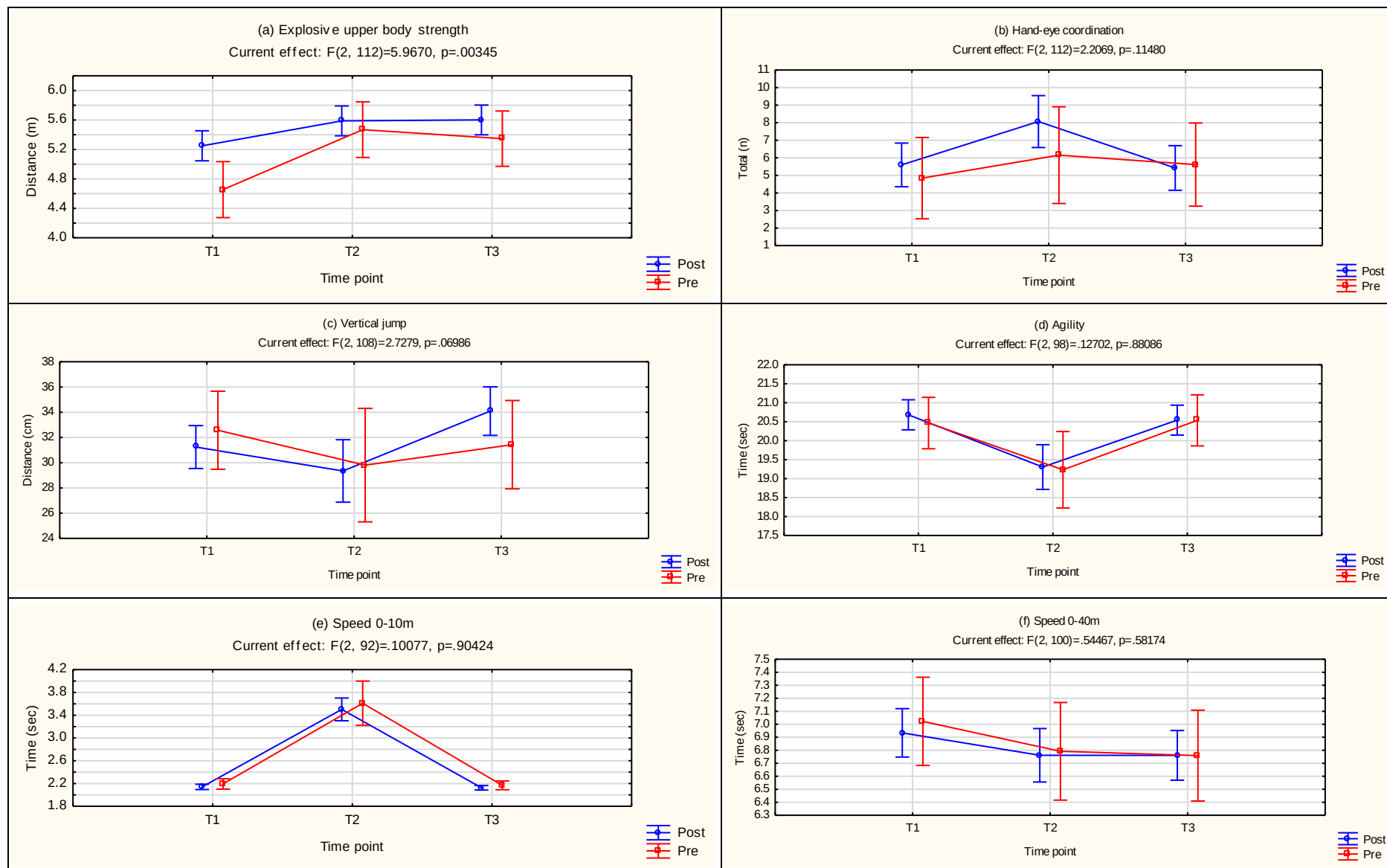
groups became smaller from T2 (4.82%; p<0.05, d=0.68) to a statistical insignificant difference of 2.71% although of small practical significance during T3 (Table 2). No statistically significant

difference was found between pre- and post-menarche girls' BMI during T2 or T3 although differences were of small practical significance.

Table 3 reports the descriptive statistics of explosive upper body strength, hand-eye coordination, explosive leg strength, speed and agility of the groups during each time point and the statistical and practical significance of differences that were found between the groups. Changes in these capabilities between measurements (T1-T2, T2-T3, T1-T3), are displayed in Table 4 for each group.

Figure 1(a-f) also displays these differences graphically. During baseline measurements in the Grade 8-year at a mean age of 13.51 years, post-menarche girls obtained higher mean values compared to the pre-menarche group in four of the six motor tests, including explosive upper body strength (EUBS), hand-eye coordination (HEC), 0-10m and 0-40m speed (Table 3). Between-group differences in these tests, HEC (catches=0.76, $d=0.17$), 0.10m speed (0.05sec, $d=0.27$) and 0-40m speed (0.17sec, $d=0.27$) during T1 were not statistically significant ($p>0.05$) although differences were of small practical significance (Table 3). One statistically significant group difference was however found at T1 in EUBS, showing a difference of 0.59m in the basketball throw ($p=0.01$, $d=0.80$) (Table 3). Figure 1(a-f) presents the results of the repeated measures ANOVA of differences between the groups over the three time points (T1-T3). Explosive upper body strength also showed statistic significant differences in changes over time between the groups (Figure 1a).

Post-menarche girls still displayed higher mean values in EUBS, HEC, 0-10m and 0-40m speed ($p>0.05$) with pre-menarche girls still having an advantage in explosive leg strength (ELS) ($p>0.05$) (Table 3). Similar mean values were found between girls' agility during T2. Differences in EUBS (0.12m), ELS (0.67cm), agility (0.00sec) and 0-40m speed (0.14sec) declined from T1 to T2 showing no statistical significance, while only 0-40m speed differences showing small



Vertical bars denote 0.95 confidence intervals; T1 =Grade 8; T2=Grade 9; T3=Grade

Figure 1 (a-f): Growth curves of pre- and post-menarche girls' motor fitness capabilities

practical significance ($d=0.21$). Differences in HEC and 0-10m speed increased from T1 to T2 ($p>0.05$) showing a small practical significance (Table 3).

Less significant changes were found between T2 and T3 where pre-menarche girls only showed significant changes in agility and speed (0-10m) and post-menarche girls in ELS, agility, speed (0-10m) and HEC during the same period (Table 4). Still, no significant group differences were evident during T3 in their Grade 10 year (Table 3). Only strength differences showed small practical significance. Post-menarche girls caught up and surpassed the pre-menarche group in ELS with the difference of 2.54cm between groups also becoming larger from T2 to T3 ($p>0.05$, $d=0.38$) (Table 3). Post-menarche girls also still showed more favorable results in EUBS with a between groups difference of 0.26cm increasing from T2 to T3 ($p>0.05$, $d=0.36$) (Table 3).

Furthermore, post-menarche girls showed a slight advantage in 0-10m speed during T3 with the between-group difference of 0.01sec decreasing further to similar values from T2 to T3 ($p>0.05$, Table 3). Pre-menarche girls however caught up and surpassed post-menarche girls at a mean age of 15.51 years in HEC and 0-40m speed, although not on a statistical significant level (0.15 catches in HEC and 0.05sec in 0-40m speed) ($p>0.05$). Pre-menarche girls still showed slightly lower agility values although the difference of 0.09sek between groups becoming slightly larger from T2 to T3 were still statistically insignificant (Table 3). The interaction affects over time point measures for all motor skills were only significant for explosive upper body strength although marginally significant for explosive leg strength (Figure 1a-f). Maturity group differences over time were insignificant for all motor skills ($p>0.05$) (Table 3). These follow-up changes led to overall changes favoring pre-menarche girls in EUBS, HEC and 0-40m speed and post-menarche girls in ELS and agility with 0-10m speed having similar changes (Table 4). Changes in motor capabilities were not significant except for explosive upper body strength and 0-40m speed in both groups and explosive leg strength in the post-menarche group (Table 4). This contributed to pre-menarche girls catching up and surpassing post-menarche girls in HEC and 0-40m speed although their larger increase in EUBS could not result in them catching up to post-

menarche girls (Table 3). Larger changes in ELS of post-menarche girls contribute to them surpassing pre-menarche girls during T3 although they could not catch up with pre-menarche girls in agility after showing a bigger increase as well (Table 4). Overall the means in the different tests portray that the pre-menarche girls' performance is approximately two years behind post-menarche girls over this follow-up period, as can be seen by similar values of pre-menarche girls during T3 compared to post-menarche girls values during T1.

TABLE 4: SIGNIFICANCE OF CHANGES IN MOTOR FITNESS CHARACTERISTICS OF PRE- AND POST-MENARCHE GROUPS

	T1-T2		T2-T3		T1-T3	
	Pre	Post	Pre	Post	Pre	Post
Explosive upper body strength	0.81*	0.34*	-0.12	0.02	0.69*	0.36*
Explosive leg strength	-2.77	-1.90	1.63	4.75*	-1.14	2.85*
Agility	-1.23*	-1.38*	1.30*	1.24*	0.07	-0.14
Speed (1-10m)	1.42*	1.36*	-1.45*	-1.38*	-0.03	-0.02
Speed (0-40m)	-0.23*	-0.17*	-0.04	0.00	-0.27*	-0.17*
Hand-eye coordination	1.31	2.46*	-0.54	-2.64*	0.77	-0.18

*= Statistical significance ($p < 0.05$); T1=Baseline measurements (Grade 8), T2=First follow-up measurement (Grade 9); T3=Second follow-up measurement (Grade 10); Pre=Pre-menarche; Post=Post-menarche

Discussion

The objective of this study was to determine if differences exist in explosive power, speed, agility and hand-eye coordination between girls of differing menarcheal status over a two-year follow-up period. This aim was investigated by comparing pre- and post-menarche girls longitudinally over time, based on their menarche status at baseline (February of Grade 8) when they had a mean age of 13.51 years.

Our first finding was that developmental differences between the pre- and post-menarche groups were relatively small and mostly insignificant in speed, agility and hand-eye coordination. This finding is in agreement with most other studies, as reviewed by Malina et al. (2004) that also reported similar findings. This finding is most probably attributable to the groups being already late in their pubertal phase with most of the participants ($n=45,77\%$) having already reached menarche at baseline (T1) (Table 1). A large percentage ($<38\%$) of the post-menarche group were also in their menarche phase for a considerable time as 4.4% reached menarche at 10 years, 2.2% at 11 years, 31.1% at 12 years and 60% at 13 years and only 2.2% at 14 years. Of the pre-menarche group, 9 (93%) reached menarche during Grade 9 (T2) at 14.51 years, and all but one (98%) of this group before (T3) in their grade 10 year at the mean age of 15.51 years.

The post-menarche girls showed slightly more favorable results in the 10m and 40m speed although differences between the groups were insignificant. These differences were however of small practical significance at 13.51 years (10m and 20m speed) and at 14.51 years for 40m speed. The largest, although also insignificant differences ($p>0.05$) were found in 10m speed during T2 at a mean age of 14.51 years and in 40m speed during T1 at a mean age of 13.51 years. These results coincide with the findings of Van den Berg et al. (2006) who also found insignificant differences between 14-year-old girl tennis players of differing maturity levels in 10m speed. Our study also showed similar non-significant differences in agility with the largest, mean differences ($p>0.05$) found during T1, favoring the pre-menarche group. This could also be ascribed to pre-menarche girls having a higher percentage muscle mass (34.9%) and lower percentage fat mass (21.02%) compared to post-menarche girls' muscle mass (33.8%) and fat mass (25.84%) at T2 ($p<0.05$) although differences in body composition became insignificant during T3 (Table 2). In hand-eye co-ordination insignificant differences of 1.91 catches were found during T2, favoring the post-menarche group. These small insignificant differences that were found, and also mostly during the baseline measurements, could in some way be ascribed to the explained small differences in the time of reaching maturational status during baseline measurements in the groups. As most of the

group have reached menarche in grade 9 at age 14.51 years, it can be assumed that almost all have already experienced PHV at the baseline measurements, as this event occurs on average one year before reaching menarche. The adolescent growth spurt in muscle strength and muscle endurance, which is directly linked to speed and agility, takes an onset approximately 0.5-1 year after reaching PHV where after a plateau is reached at around 14-years of age (Pauole et al. 2000; Malina et al. 2004). Therefore, due to the current maturational status of our group, where most girls have already reached menarche, which occurs on average two years after PHV, most girls including girls from the pre-menarche group would have reached peak development in speed and agility. This might explain the small difference between the groups in speed and agility. Furthermore, with regard to body composition influences, Aberberga-Augskalne and Kemper (2007) state that the biggest increase in mass occurs between 12 and 14 years, congruent to the average age of menarche. From the onset of menarche, estrogen plays an important role in the lipogenic profile of girls during the puberty phase (Rogol et al. 2002). Consequently, higher levels of estrogen results in a higher percentage body-fat and also the distribution of fat within the body changes to where a large percentage of fat is being distributed among the hips and surrounding areas. Increased fat distribution will have an effect on girls' BMI and according to Kaplowitz et al. (2001) and Biro et al. (2001), girls with a higher BMI and fat percentage tend to be more advanced in their maturation status compared to girls with a lower BMI and fat percentage. As peak mass increases are concurrent with the onset of menarche, the BMI of pre-menarche girls' (who are still to reach peak mass increases) were not affected as much compared to the post-menarche groups' BMI. These changes could, therefore, be suggestive as possible explanations for the insignificant differences that were found in the speed and agility of girls of differing maturity levels where pre-menarche girls are still to be affected by mass increases, while post-menarche girls most probably have already adapted to peak mass increases.

Our second finding was that differences in muscle strength between the pre- and post-menarche groups had a statistically significant interaction for upper body strength (EUBS) ($p=0.003$) and marginally significant interaction for explosive leg strength (ELS) ($p=0.069$) (Fig 1 a and c), although group differences over time were insignificant for EUBS ($F=2.65$; $p=0.11$) and ELS ($F=0.02$; $p=0.87$). Differences in upper body strength during baseline measurements were also of statistical- ($p=0.01$) and large practical significance ($d=0.80$), favoring post-menarche girls (Table 3). Post-menarche girls furthermore outperformed the pre-menarche group throughout the study, although the differences declined from T1 to T3, but remained practically significant (Table 3). With regard to explosive leg strength, post-menarche girls also outperformed ($p>0.05$, $d=0.38$) the pre-menarche girls although the pre-menarche girls initially had an advantage in ELS ($p>0.05$, $d=0.26$). The results still showing an increase in strength of post-menarche girls between 14.51 and 15.51 years in EUBS ($p>0.05$) and ELS ($p<0.05$), can possibly be explained by peak development of submaximal power output in girls that occurs more than a year after peak height velocity (Malina et al. 2004). Therefore, due to a large percentage of our group who has already surpassed menarche and PHV, as PHV occurs approximately 12-24 months before menarche, the post-menarche group still had a slight strength advantage due to their advanced maturation. Furthermore, post-menarche girls, usually have broader shoulders as a result of earlier growth in body dimensions such as shoulder width (Malina et al. 2004), which may have aided them in producing more power to perform upper-body strength tests. To the contrary, peak mass increases take place between 12 and 14 years, congruent to the average age of menarche, and consequently the pre-menarche group was most probably still affected by significant mass changes that result in fat deposits such as around the hips, which again moves the center of gravity point lower. As a result they will have to displace more weight during upward jumping which in turn can affect performance in activities performed against gravitation negatively. The post-menarche girls might have already adapted to these body compositional changes.

Thirdly our results showed that the performance of the pre-menarche girls, in the different tests, based on the means that are reported during each year of measurement, was approximately two years behind that of the post-menarche group. In this regard, only small differences of 0.10m (EUBS), 0.20cm (ELS), 0.19sec (agility), 0.20sec (0-40m speed) and 0.01 catches (HEC) were seen in the mean values of the pre-menarche group during T3 compared to the post-menarche girls' performance during T1 (Table 3). This coincides with findings reported by Malina and co-workers (2004) that showed a two-year difference in the mean onset of menarche between early (11.8 years) and late (> 13.8 years) maturing girls. Furthermore, the adolescent acceleration in muscle strength and muscle endurance, directly linked to motor abilities, takes an onset approximately 0.5-1 year after reaching PHV (Malina et al. 2004). This link between the last-mentioned factor is the result of similar accelerations in morphological and biochemical determinants (the proportion of various vessel types) (Little & Williams 2005). Furthermore, in the course of maturation, a variety of biological and physiological structures in the body functions at a higher level (Pienaar, 2018) and consequently, individuals of the same chronological age, but differing maturity status, will differ in terms of physical- and motor performance (Davis et al. 1997; Van den Berg et al. 2006). In this regard, Freitas et al. (2016) report that factors including neuromuscular maturation, specific instruction, practice and sport participation will also affect motor capabilities between the ages of 11 and 14 years and that skeletal maturity (skeletal age according to chronological age) explains only a maximum of 2.8% variance in motor capabilities in girls, after corrections for stature and body mass. The hand-eye coordination that was tested in the study is based on a skill which might be affected by experience and training which might explain the inconsistent results that were found in this test.

Due to growth and maturation differences that were leveled out by the end of the follow-up period at a mean age of 15.51 years, where no significant differences were evident between the groups, it can be concluded that the speed, agility and coordination and also strength of pre- and post-

menarche girls can be considered to be nearly at the same level between girls of the same chronological age at 16 years. Differences between pre- and post-menarche groups decreased to almost similar values in 5 of the 6 motor fitness capabilities tested. Explosive leg strength differences, however, increased from T1-T3 (13.51-15.51 years) in favor of the post-menarche group although the difference was still insignificant. This could be due to a larger muscle mass in relation to total body mass. Furthermore, the post-menarche girls could have had a better, well-established ratio between sitting height and leg-length, resulting in a more efficient weight distribution/center of gravity. Lastly, because of earlier maturation, post-menarche girls could have a higher functioning neurological system that contributes to improved coordination, which pre-menarche girls have not yet reached.

This study had limitations that need to be acknowledged. All participants were recruited from one school, which limits the generalization of the study although the school had hostel facilities which represented children enrolling from 46 primary schools from the surrounding area. Our sample also did not evenly represent different racial groups and results are mostly based on data of white (Caucasian) girls. Changes in environmental conditions such as weather conditions (rain, hot conditions) over the 3-year period were out of the researchers' control and could also have influenced the results. Although the data was collected over a longitudinal period of two years, which strengthens the results of the study, it has to be kept in mind that the study only incorporated high school learners and could subsequently only focus on a late age period in the development of girls which was between 13 and 15 years of age. It is acknowledged that a larger age-period is needed to fully investigate the influence of the pubertal phase. Although groups would have become too small for comparison purposes in the current study, it can be considered in future studies to only include girls who are the furthest in the menarche phase (post-menarche) group, and those who are the furthest away from reaching menarche (pre-menarche), to make a more realistic comparison of early and late development differences.

Conclusion

This study signifies that the onset of menarche influences anthropometric development that contributes to biological changes such as the development of higher fat percentages and subsequently differing body composition. The results furthermore confirm that although there were differences in the motor capabilities of girls of differing maturity status, based on their menarche status during mid- to late adolescence, these differences were only of statistical and practical significance in strength capabilities. Differences were, however, of small practical significance with regard to agility and speed at the mean age of 13.51 years. Differences were also larger at a younger age (13.51 years) but declined with increased age. Performance in the motor tests of pre-menarche girls, were approximately two years behind that of the post-menarche girls. Based on these findings it can be concluded that the motor capabilities of girls, once they have reached menarche, will only be comparable with other girls of the same chronological age who have reached menarche earlier, 1-2 years later when the influences of puberty on their fitness performance can be considered to have been levelled out. These results confirmed that potential to excel in sport based on motor capabilities can only be accurately determined a few years after all girls have reached menarche.

Information obtained by this study provided insight into the biological and physiological changes that occur in girls before and after the onset of menarche and the impact of these changes on their motor fitness capabilities. This knowledge can assist coaches by incorporating it into better-planned training programs, which aid in optimal skill development and reduce the risk of injury and drop-out. Furthermore, it will contribute to improved sports development and talent identification processes, by providing an understanding of the temporary weaknesses in speed, agility and hand-eye coordination and gains in strength associated with early or late development and by applying this knowledge in appropriate short- and long-term motor performance goals. Further research is however recommended that include a longer developmental period, especially

from a younger age. This will aid in obtaining more complete data on growth differences between early and late developing girls and consequently the effect of differential growth on girls of different maturation's motor capability profiles.

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REFERENCES

- Aberberga-Augskalne L, Kemper HCG. 2007. Longitudinal relationship between cardiovascular functioning and peak height velocity during exercise in 7- to 16-year-old boys and girls. *Hum Mov Sci* 8(1):5-11.
- Anderson S. 2009. *Collins English dictionary: Complete & Unabridged*. 10th ed. London: Harper Collins.
- Australian Sport Commission. 1996. *Sport search program*. Canberra: ASC.
- Balyi I, Way, R. 2010. *Canadian sports for life: The role of monitoring growth in long-term athlete development*. Calgary: Canadian Sports Centre.
- Baquet C, Twisk JWR, Kemper E, van Praagh E, Berthoin S. 2006. Longitudinal follow-up of fitness during childhood: interaction with physical activity. *Am J Hum Biol* 18:51-58.
- Beunen GP, Ostyn M, Simons J, Renson R, Claessens AL, Vanden Eynde, van't Hof MA, et al. 1997. Development and tracking in fitness components: Leuven longitudinal study on lifestyle, fitness and health. In *J Sport Med* 18(3):S171-S178.
- Biro FM, McMahon RP, Striegel-Moore R, Crawford P, Obarzanek E, Barton BA. 2001. Impact of timing of pubertal maturation on growth in black and white female adolescents: The NHLBI growth and health study. *J Pediatrics* 138(5):636-643.
- Bronikowski M, Bronikowska M. 2008. Motor fitness in relation to the maturational process of pubertal boys and girls. *Papers on Anthropology* 17:28-37.
- Cohen J. 1992. A power primer. *Psychological Bulletin* 112:155-159.
- Danubio ME, Simone M, Vecchi F, Amicone E, Altobelli IE, Gruppioni G. 2004. Age at menarche and age of onset of pubertal characteristics in 6–14-year-old girls from the Province of L'Aquila (Abruzzo, Italy). *Am J Hum Biol* 16:470-478.

Deborah C, Russel V. 2005. ABC of adolescence: Adolescent development. *BMJ* 330:301-304.

Des te Croix M. 2007. Advances in paediatric strength assessment: changing our perspective on strength development. *J Sports Sci Med* 6:292-304.

Durand-Busg N, Salmela JH. 2002. The development and maintenance of expert athletic performance: perceptions of world and Olympic champions. *J Appl Sport Psychol* 14(3):154-171.

Davis, B., Bull, R., Roscoe, J. & Roscoe, D. 1997. *Physical education and the study of sport*. 3rd ed. London: Mosby.

Fredriks AM, van Buuren S, van Heel WJM, Dijkman-Neerincx RHM, Verloove-Vanhorick SP, Wit JM. 2005. Nationwide age reference for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. *Arch Dis Child*, 90:807-812.

Freitas DL, Lausen B, Maia JA., Lefevre J, Gouveia E.R, Thomis M, Malina RM. 2015. Skeletal maturation, fundamental motor capabilities and motor coordination in children 7–10 years. *J Sports Sci* 33(9):924–934.

Gallahue D.L, Ozmun JC, Goodway JD. 2012. *Understanding motor development*. 7th ed. New York, NY: McGraw-Hill.

Garnier D, Simondon KB, Benefice E. 2005. Longitudinal estimates of pubertal timing in Senegalese adolescent girls. *Am J Hum Biol* 17:718-730.

Gluckman PD, Handson MA. 2006. Evolution, development and timing of puberty. *Trends in Endocrinology and Metabolism* 17(1):7-12.

Grasso B. 2006. *Coordination & Movement Skill Development - The key to long-term athletic Success*. [accessed 2017 Nov18] <http://www.performbetter.com/webapp/wcs/stores/-servlet/PBOnePieceView?storeId=10151&catalogId=10751&languageId=-1&pagename=209>.

Henneberg M, Louw GJ. 1995. Average menarcheal age of higher socioeconomic status urban Cape coloured girls assessed by means of status quo and recall methods. *Am J Phys Anthropol* 96:1-5.

Kaplowitz PB, Slora EJ, Wasserman RC, Pedlow SE, Herman-Giddens ME. 2001. Earlier onset of puberty in girls: relation to increased body mass index and race. *Paediatrics* 108(2):347-53.

Kaprio J, Rimpelä A, Winter T, Viken RJ, Rimpelä M, Rose MJ. 1995. Common genetic influences on BMI and age at menarche. *Hum Biol* 67(5):739-753.

Karapanou O, Papadimitriou A. 2010. Determinants of menarche. *Reprod Biol Endocrinol* 8:115-122.

Kemper HCG, Snel J, van Mechelen W. 2004. Amsterdam growth and health longitudinal study. *J Sci Med Sport* 47:1-198.

Lee TS, Chao T, Tang RB, Hsieh CC, Chen SJ, Ho LT. 2005. A longitudinal study of growth in schoolchildren in one Taipei district II: sitting height, arm span, body mass index and skinfold thickness. *Chin Med J* 68(1):16-20.

Little T, Williams AG. 2005. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 19(1):76-78.

Malina RM. 1994. Physical growth and biological maturation of young athletes. *Exerc Sport Sci Rev* 22(1):389-433.

Malina RM, Bouchard C, Bar-Or O. 2004. Growth, maturation and physical activity. Champaign, IL: Human Kinetics.

Stewart M, Olds T, Steward AD, Carter JEL. 2011. International standards for anthropometric assessment. Potchefstroom: International Society for the Advancement of Kinanthropometry (ISAK).

Marshall WA, Tanner JM. 1986. Puberty. In: Falkner, F. & Tanner, J.M (Eds). Human growth: A comprehensive treatise. (vol 2). Postnatal growth; Neurobiology. New York: Plenum. p171-209.

Monyeki KD, Koppes LLJ, Kemper HCG, Monyeki KD, Toriola AL, Pienaar AE, Twisk JWR, et al. 2006. Body composition and physical fitness of undernourished South African rural primary school children. Eur J Clin Nutr 59:877-883.

Pauole K, Madole K, Garhammer J, Lacourse M, Rozenek R. 2000. Reliability and validity of the t-test as a measure of agility, leg power, and leg speed in college-aged men and women. J Strength Cond Res 14(4):443-450.

Pienaar AE. 2018. Motor development, growth, motor assessment and the intervention thereof: A textbook for students in Kinderkinetics. Potchefstroom: Ivyline printers.

Prahl-Anderson B, Kowalski CJ, Heydendael P. 1994. A mix longitudinal interdisciplinary study of growth and development. New York, NY: Academic.

Richter L, Norris S, Yack D, Cameron N. 2007. Cohort profile: Mandela's children. The 1990 birth to twenty study in South Africa. Int J Epidemiol 36(3):504-511.

Rodríguez G, Moreno LA, Blay MG, Blay VA, Garagorri JM, Sarri'al A, Bueno M. 2004. Body composition in adolescents: measurements and metabolic aspects. Int J Obes 28:S54-S58.

Rogol DR, Roemmich JN, Clark P.A. 2002. Growth at Puberty. J Adolesc Health 31:192-200.

Rubina C, Maisoneta M, Kieszaka S, Monteilha C, Holmesa A, Flandersa D, Heronc J, et al. 2009. Timing of maturation and predictors of menarche in girls enrolled in a contemporary British cohort. Paediatr Perinat Epidemiol 23:42-504.

Salces I, Rebato EM, Susanne C, San Martin L, Rosique J. 2001. Familial resemblance for the age at menarche in Basque population. An Hum Biol 28(2):143-156

Statsoft. (2017). Statistica for Windows: General conventions and statistics. Tulsa, OK. Statsoft.

Towne B, Czerwinski SA, Demarath EW, Blangero J, Siervogel RM. 2005. Heritability of age at menarche in girls from the Fels longitudinal study. *Am J Phys Anthropol* 123:210-219.

Travill AL. 2007. Growth and physical fitness of socially disadvantage boys and girls aged 8-17 years living in the western cape, south Africa. *Afr J Phys Health Educ Recreat Dance* 13(3):279-293.

Van Den Berg L, Coetzee B, Pienaar AE. 2006. The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *Afr J Phys Health Educ Recreat Dance* 18(3):510-515.

Van Gent MM. 2001. Anthropometrical, physical and motor fitness characteristics of 10- to 15-year old girls in the Northwest province. Potchefstroom: NWU. (Dissertation).

Volver A, Viru A. Viru M. 2007. A two-year longitudinal study of sexual maturation effects on motor abilities of girls. *Medicina Della Sport* 60(1):57-63.

Viru A, Loko J, Harro M, Volver A, Laaneots L, Viro M. 1999. Critical periods in the development of performance capacity during childhood and adolescence. *Phys Educ Sport Pedagogy* 4(1):75-119.

Wang Z, Dang S, Yuan X, Li Q, Hong Y. 2016. Correlation of body mass index levels with menarche in adolescent girls in Shaanxi, China: a cross sectional study. *BMC Women's Health* 16(1): 472-480.

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CHAPTER 6

Classification agreement between self-reported age of
menarche and calculated maturity offset in adolescent girls: A
two-year follow-up study

Research paper

Classification agreement between self-reported age of menarche and calculated maturity offset in adolescent girls: A two-year follow-up study.

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Shortend tilte: Actual onset of menarche versus calculated maturity offset

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ABSTRACT

Introduction: *The onset of menarche is an important pubertal event for classification of maturational status, although it occurs late in the pubertal phase. As a substitute, maturity off-set equations were developed to determine years from reaching peak height velocity that occur much earlier in the pubertal development of girls. However, the accuracy of these equations remains uncertain when used in populations different to those that it was developed for.*

Method: *Fifty-eight girls divided into a pre- (n=13) and post-menarche group (n=45) with a mean age of 13.51 ± 3.51 years at baseline were analyzed over three school years. Anthropometric characteristics were measured three times annually over the three school years providing data over nine time points. The Status Quo method determined menarche status and a Maturity offset equation determined APHV. An independent t-test, cross-tabulation and Roc Curve statistics were used to analyze the classification agreement of these markers.*

Results: *All three statistical analysis showed that the maturity offset equation was able to determine differences in maturity offset with a degree of accuracy when compared to the actual reaching of menarche status. Correct classification was the highest at younger ages and closer to PHV time frame in this South African group.*

Conclusion: *Classification by means of Maturity offset equations are more accurate closer to PHV when girls are within 2 years pre- or post PHV. Although such equations are easy and non-invasive methods to use, our results suggest that it should be used with caution in different populations based on the unique growth characteristics of that population. More research is recommended to develop population specific maturity offset equations.*

Key words: Adolescence; Girls; Maturation; Menarche

INTRODUCTION

Adolescence is a critical time period in human life due to various changes that occur between childhood and adulthood (Malina, Bouchard & Bar-Or, 2004). Among girls, adolescence is characterized by a global acceleration in growth and maturation between the ages of 12 and 21 years (Rodriguez *et al.*, 2004; Anderson, 2009). Furthermore, the adolescent period is characterized by three main changes including sexual maturity, growth in stature and weight and changes in body composition (Malina *et al.*, 2004). When focusing on biological development and sexual maturity of girls entering the pubertal stage, the landmarks of maturational events are the onset of puberty, peak height velocity (PHV) and menarche (Pantsiotou *et al.*, 2008). The pubertal phase signifies the beginning of adolescence when the gonads become functional and consequently, females begin to develop secondary sexual characteristics (Anderson, 2009). This period includes girls reaching PHV at a mean age of 12-years (AberbergaAugskalne & Kemper, 2007). The onset of menarche, which is reached around 6-12 months after PHV at an average age of 12.8 years, is one of the most remarkable morphological changes that occur during adolescence with significant consequences in terms of changes in physical and psychological aspects (Garnier, Simondon & Benefice, 2005, Waylen & Wolke, 2004; Nwankwo, Danborno & Hamman, 2016). Data from a population in the United States (US) indicates that menarche on average occurs at 12.6 ± 1.5 years, with 12.0 years as the median age (Chen *et al.*, 2016). Chinese girls reach menarche on average at age 12.5 ± 1.4 years, while almost a quarter of these girls (23.9%) reached menarche early (≤ 11 years) (Xie & Ho, 2016). In agreement, Malina *et al.* (2004) reported that menarche occurs on average at 12.8 ± 1.0 years in Caucasian girls. This mean age has been used to categorize girls as early ($< 11.8y$), average (11.8-13.8y) and late ($> 13.8y$) maturers. Menarche leads to diverse hormonal changes and in turn changes in body composition including increased fat deposition (Lee, Tsai & Lin, 2016) and it also affects the psychological and cognitive development of girls necessary for coping with adulthood (Lee *et al.*, 2016).

The occurrence of this milestone as part of biological maturation (Waylen & Wolke, 2004) can be used to determine early or typical development in females. Differences in biological maturation before menarche, but also as a result of menarche, results in growth differences and more specifically weight related that in turn will affect other aspects of life such as motor- and physical skill performance (Davis, Bull, Roscoe & Roscoe, 1997; Van den Berg, Coetzee & Pienaar, 2006). To manage participation in sports, most sporting codes group children by chronological age and not by biological age (Davids & Baker, 2007), although chronological age is of limited utility in the assessment of growth and maturation (Malina, 2000). The need to assess maturation and the tempo and timing of the progress toward the mature state is however imperative in the study of child growth. Existing methodology does provide the required mechanisms to assess maturation processes before maturity offset but also, regarding menarche status, although there are limitations to the available methodologies (Beunen, 1989).

Different research methods are used to determine age of menarche including monitoring studies based on prospective and longitudinal methods where girls are examined every 3-6 months. Interviews with girls or their mothers is also conducted where researchers rely on recall information about when menarche, the age at first menstruation, started. This recall method may be less valid, and the accuracy decrease with a greater time interval between menarche and the date when girls were asked to recall onset (Mirwald, Baxter-Jones, Bailey & Beunen, 2001). Furthermore, all girls to be evaluated by this method should be at an age where they have already reached menarche, because it is a recall of a past event and not a method that examines the current state of menarche (Karapanou & Papadimitriou, 2010). Several studies have studied the correlation between the actual age and the recall age of menarche and have found correlations of 0.75 after 17 years of recall and 0.60 after 39 years of recall (Damon & Bejema, 1974). Koo and Rohan (1997) found after a 2-year recall period that only 59.1% of the group could recall the correct month and year while 77.3% showed a deviation of less than 1 month of real time. Lastly the Status Quo method is another method (Malina *et al.*, 2004) to obtain information regarding age

of menarche by only asking the girl (or the mother) about the current status of menarche, in other words whether she had her first menstruation before or during the time of assessment. The answer in this method will be indicated by a YES or a NO, and if YES a year and month of the first menstruation should be included (Karapanou & Papadimitriou 2010).

Some of these methods are, however, costly, time consuming and invasive to girls' privacy (Gay, Smith, Torre-McGehee, Monsma & DeFreese, 2014). Menarche is also a late event in the maturation of girls. Because of differences in the timing of the adolescent growth more non-invasive methods are needed to classify girls into pre-, average or post-menarche groups (Malina, Choh, Czerwinski & Chu, 2016). It is well known that maturational status is linked with distinct physical characteristics, particularly for those who mature early and late compared with average maturing girls (Gay et al., 2014). Therefore, the need for a valid, less invasive once off assessment of biological growth and maturation of girls that can be used in schools and field settings was considered by researchers to be an important matter (Malina et al., 2016).

Peak height velocity (PHV) is a one of these milestones that can be used to determine maturity status earlier in the pubertal phase of girls. Maturity offset is a cross-sectional measure that estimates age at PHV, and is expressed in years around PHV. A negative value will indicate pre-PHV and a positive value, post-PHV. Mirwald and co-workers (2001) suggest that calculated maturity offset equations are accurate up to four years pre-PHV but no more than two years post-PHV, and within 8- to 16 years of age. Growth measurements and ratios that are used in these equations for prediction purposes are based on age and include measurements of stature, sitting height, sub-ischial leg length, and weight (Malina *et al.*, 2016). Interactions between leg length and sitting height are also used (Mirwald et al., 2001). Lastly, different ratio's, including weight to height, sitting height to total stature, leg length to total stature, and leg length to sitting height ratios are calculated in these equations (Mirwald et al., 2001). Mirwald et al. (2001) furthermore report a small average difference of only 0.021 ± 0.489 years for boys and girls between the predicted age and actual age of PHV. This equation can subsequently be useful in reducing the

limitations of other methods in determining differences in the development of girls (Mirwald et al., 2001; Sherar, Mirwald, Baxter-Jones & Thomis, 2005).

Several researchers have tested these equations including Mirwald and co-workers (2001) who have developed an equation. In this regard, Malina et al. (2016) investigated the usefulness of the equations. They found certain limitations including variations in body segmental lengths between ethnical groups and furthermore that prediction of maturity offset is dependent on chronological age and had reduced ranges of variation. Malina and co-workers (2016) concluded that on average, equations over-predicted age of maturity offset among early maturing youth and under-predict age of maturity among late maturing youth. They concluded that more work is still needed in this area as it is important to simplify and calibrate equations to accurately fulfill the need for a valid, less invasive, once-off assessment of biological growth and maturation.

In the South African context, limited studies have used or tested these developed equations on a South African youth population. One study used the equation, but only on boys and only to classify boys into maturity groups and did not focus on the agreement between actual and predicted ages of maturity (Gerber, Pienaar, Kruger & Ellis, 2014). In order to determine the utility of such equations among a group of South African girls, longitudinal knowledge of growth and the status of pubertal onset of menarche are needed. Therefore, the aim of the study was to investigate the level of agreement in classification between the timing of the Status Quo (self-reported) method and the calculated method of maturity offset (reaching of PHV) of adolescent girls, based on longitudinal data from a two-year follow-up study. Positive results from this investigation will provide practitioners of different fields that are involved in the physical development of girls, with a non-invasive tool to determine the state of biological maturation of girls earlier in their biological development. Such information can provide them with a better understanding of developing differences in girls, and more specifically physical developmental differences in girls, that can aid them in developing more customized training and development programs to manage girls during physical activity and sport development.

METHODOLOGY

Research design

This study made use of a longitudinal research design. The main project, “Growth and sport psychological characteristics of talented adolescents”, was performed over a 3-year school period (2010-2012). The data was collected by means of anthropometric measurements as well as questionnaires. The anthropometric measurements took place 3 times a year (4-months apart). Baseline measurements were taken in February 2010 and the last measurements took place in November 2012, including 9 time-point measures for growth (T1-9). Overall, follow-up measures were obtained over a full two-year period. For the purposes of this study, anthropometric measures taken at T1 (Feb 2010, Grade 8), T4 (Feb 2011, Grade 9) and T7 (Feb 2012, Grade 10) will be used.

Research group

All grade 8-learners of one quintile 5 school (quintile 1 = low socio-economic quintile, to quintile 5 = high socio-economic) in Potchefstroom in the Northwest Province of South-Africa, were invited to take part in the research project. Since the school had boarding facilities, grade 8 learners enrolled in 2010 represented learners from 46 different primary schools. The final group of girls, who completed all follow-up measurements at T7, was 58 girls with a mean age of 15.52 years at the final measurements in 2012. This group were divided into a pre- (n=13) and post-menarche group (n=45) according to their menstrual status at baseline measurements. Over the study period 37 girls (38%) were lost to follow-up due to various reasons including parents of children moving out of town, children moving between schools and injuries.

Ethical approval

Ethical approval was obtained from the Health Research Ethics Committee of the North-West University's Potchefstroom Campus (NWU 00199-15-A1) for the execution of the study. Permission for the project was also obtained from the principal of the school involved. All girls 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. Only the girls who had parental permission and who gave assent themselves were used in the study.

Measuring instruments

Age at menarche

The age of menarche was determined by the Status Quo method (Hennenberg & Louw, 1995, Ameade & Garti, 2016) during February in 2010, 2011 and 2012 (T1, T4 and T7) of the nine time-point measures, which was the first measurements of each school year. The subjects had to indicate on a questionnaire by selecting YES or NO whether they have had their first menstrual cycle on or before the date of testing during the first measurements of each year in February. If they answered YES they also had to indicate the month and year when their first menstrual cycle took place.

Table 2 shows that a high percentage of the 58 girls in the study (77%, n=45, post-menarche group), already reached menarche during baseline measurement (grade 8 - 2010) at a mean age of 13.51 years. Thereafter 91% (n=53) of the group (which include nine of the pre-menarche group) reached this milestone during the first follow-up measurements (grade 9 - 2011) at a mean age of 14.52 years with all (n=57) but one subject (98%) reaching menarche at a mean age of 15.52 years during the last year of measurements at T7 (grade 10 - 2012). For the purpose of this study, the 45 girls who had reached menarche at baseline (T1) and who were classified as

post-menarcheal were compared with the 13 girls that did not reach menarche at baseline and who were classified as pre-menarcheal.

Maturity offset

Maturity offset is calculated by means of an equation by using cross-sectional measures that estimates age at PHV and is expressed in years around PHV where negative values indicate pre- PHV and positive values post- PHV. Maturity offset was calculated through a gender specific equation that was developed by Mirwald and co-workers (2001). Following is the equation that was used:

Maturity offset in girls= $-9.376 + 0.0001882 \cdot x$ (Leg Length and Sitting Height interaction) $+ 0.0022 \cdot x$ (Age and Leg Length interaction) $+ 0.005841 \cdot x$ (Age and Sitting Height interaction) $- 0.002658 \cdot x$ (Age and Weight interaction) $+ 0.07693 \cdot x$ (Weight by Height ratio). The equation had a reliability of $R=0.94$, $R^2=0.890$, and Standard Error of Estimate of (SEE)=0.569.

In interactions (e.g. Leg length and Sitting height interaction), the two factors are multiplied (Leg length x Sitting height). Ratios are calculated by dividing the first variable in the parentheses by the second variable and then multiplying the answer by 100.

Anthropometric measurements

The protocol as developed by the International Society for the Advancement of Kinanthropometry (ISAK) was used for stature and body mass measurements (Stewart, Marfell-Jones, Old & De Ridder, 2011). Sitting height was determined by a modified method (Simmons, 2000) and arm span according to the Canadian Sports for Life protocol (Balyi & Way, 2010). All researchers were trained Level 2 Kinanthropometrists (theory and practical training), ranging from honors students to senior researchers in Kinderkinetics and Sport Science. Furthermore, these researchers were equipped with all necessary skills and knowledge beforehand to perform these

measurements. All measurements were taken in enclosed spaces to ensure the privacy of the participants and were taken by researchers of the same gender as those of the participants. Participants had to wear minimal clothing during measurements.

Stature and Sitting height were measured to the nearest 0.1cm by means of a portable Harpenden stadiometer (Harpenden Holtain Ltd, Crymych, UK). Stature was measured with the subject stood facing forward with the heels, back and head against the stadiometer and with feet together. The head was held in the Frankfort position by the examiner, and the measurement was taken to the nearest 0.1 cm after the subject had to inhale deeply. Two measurements were taken, of which an average value was used (Stewart *et al.*, 2011). Inter-measurement reliability for stature was calculated as 0.98. **Sitting height** was measured by having the subject sit flat on the stadiometer with the back against the stadiometer and knees bent at about 90 degrees. The head of the subject was held in the Frankfort position by the examiner, and the measurement was taken to the nearest 0.1 cm while the subject had to inhale deeply (Simmons, 2000). **Mass** was measured by means of an electronically calibrated scale (Omro BF 511). The subject had to stand upright while looking straight forward with the weight evenly distributed over the scale and with the arms at the sides of the body. The measurement was taken to the nearest 0.1 kg without shoes and with the subject wearing as little clothing as possible (Stewart *et al.*, 2011). **Arm span** was measured by attaching a tape measure horizontally against a wall at about shoulder height of the subject with the starting point of the tape in a corner of a wall. The subject stood upright, as near as possible to the wall with the front of the body facing the wall. The arms had to be extended horizontally, with the palms facing the wall and the head turned to the left. The measurement was taken to the nearest 0.1 cm (Balyi & Way, 2010). **Leg length** was calculated by subtracting the sitting height value from the stature value. **Sitting height ratio** was calculated by using the following equation: $\text{Height/sitting height} \times 100$. **The body mass index (BMI)** is a statistically developed equation developed by Adolphe Quetelet in the 1900's for evaluating body mass and is not related to gender

and age. BMI was calculated by applying the following equation: Body weight in kilograms divided by height in meters squared or, $BMI = x \text{ KG} / (y \text{ M} * y \text{ M})$ (x=bodyweight in KG, y=height in M).

Statistical analysis

The data were analyzed by means of the “Statistica for Windows 2017” Statsoft and “IBM SPSS Version 25” computer program packages. The data were analyzed descriptively by using means, standard deviations (SD) and minimum and maximum values (StatSoft, 2017). Independent T-testing analyzed maturity offset differences between pre- and post-menarche girls, where a $p < 0.05$ level was used as the set criteria for statistical significance. The effect sizes of differences were calculated by using cut off values as developed by Cohen where a d-value of $d > 0.3$ reflects a small practical significance, a $d > 0.5$ reflecting a medium significance and a $d > 0.8$ reflecting a large significance (Cohen, 1992). ROC Curves (Receiver Operating Characteristic) were also used to determine maturity offset cut-off points for early and late maturing girls with an asymptotic level < 0.05 used as the set criterion for statistical significance and an area value of 1 indicating a strong/accurate prediction potential (SAS, 2002-2010). Cross-tabulation with a Chi-square was used to determine the association between Status Quo and Maturity offset results with Cramer’s V cut-off points for Chi-square of $V > 0.1$ =Small predictive effect, $V > 0.3$ =Medium predictive effect and $V > 0.5$ =Strong predictive effect (Ellis & Steyn, 2003).

RESULTS

At baseline, 58 girls completed all the measurements, and they were classified into 2 groups according to their menarche status as reported by the Status Quo method, namely a pre-menarche (n=13, 23%) and post-menarche group (n=45, 77%). In the post menarche group of 45 participants (77%) who had reached menarche at baseline, 8.8% (n=4) reported reaching the milestone during Grade 5, 22% (n=10) during Grade 6, 66.6% (n=30) during Grade 7 and only 2%

(n=1) during their Grade 8 year. During the first (T4) and second (T7) follow-up measurements 93% (n=42, T4) and 98% (n=44, T7) of all the subjects in the study have reached menarche. These statistics point to differences of up to five years between the times that subjects who had reached menarche first and those who have reached this milestone late at a mean age of 15.51. One subject had not reached menarche at the final measurements.

Table 1 reports the descriptive age characteristics of the pre- and post-menarche groups at baseline (Feb 2010), at the age of 13.51 ± 3.50 years and again at the two follow-up measurements in February 2011 and February 2012 that were completed at the age of 14.51 ± 3.51 and 15.51 ± 3.51 years respectively. At baseline, no significant age differences (0.01 years, $p > 0.05$) were found between the pre- and post-menarche groups.

TABLE 1: DESCRIPTIVE AGE CHARACTERISTICS OF THE PRE- AND POST-MENARCHE GROUPS

	Year 1 (T1)		Year 2 (T4)		Year 3 (T7)	
	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD	N	Mean age $\pm$ SD
Group	58	(T1) 13.51 ± 3.50	58	(T4) 14.51 ± 3.51	58	(T7) 15.51 ± 3.51
Pre-menarche	13	(T1) 13.52 ± 3.58	13	(T4) 14.52 ± 3.58	13	(T7) 15.52 ± 3.58
Post-menarche	45	(T1) 13.51 ± 3.53	45	(T4) 14.51 ± 3.53	45	(T7) 15.51 ± 3.53

T1=Year one (Gr8); T4=Year 2 (Grade 9); T7=Year 3 (Grade 10); N=Group size;

Three statistical methods were used to determine the classification agreement between the pre- and post-menarche groups, based on known actual menarche status. These include independent t- testing a ROC curve analysis and Cross-tabulation.

Table 2 reports a comparison of the maturity offset values that were calculated for the pre- and post-menarche groups during T1, T4 and T7 by the maturity offset equation as developed by Mirwald et al. (2001). All categorization was done based on menarche status during T1, and only time point measures T1, T4 and T7 were used for further analysis.

TABLE 2: MATURITY OFFSET OF PRE- AND POST-MENARCHE GIRLS FROM GRADE 8 TO GRADE 10 AND THE STATISTICAL SIGNIFICANCE OF DIFFERENCES BETWEEN GROUPS

Variables	Pre-Menarche			Post-Menarche			Significance of difference	
	N	Mean	SD	N	Mean	SD	p-value	d-value
Grade 8 (T1)	13	+1.01	0.59	45	+1.44	0.36	0.00*	0.73 ^{##}
Grade 9 (T4)	13	+1.86	0.58	45	+2.09	0.41	0.11	0.40 [#]
Grade 10 (T7)	13	+2.59	0.58	45	+2.75	0.42	0.29	0.27

N=Group size; SD=Standard deviation; T1=Baseline measurements (Feb) in Grade 8; T4= First measurements (Feb) in Grade 9; T7=First measurements (Feb) in Grade 10; *=Statistical significance ($p<0.05$); d-value=Practical significance; #=small practical significances ($d>0.2$); ##=medium practical significance ($d>0.5$); ###=large practical significance ($d>0.8$); +=Predicted maturity as years post PHV

The mean values of each group as displayed in Table 2 are an indication of the years relative to the onset of PHV as compared to a score of 0.00 that represents the PHV. In this regard a score further away from 0.00 indicates the number of years the subject is pre-PHV (negative score) or post-PHV (positive score). At T1 during baseline, both groups showed positive values indicating that they were post-PHV. The independent t-test showed that the pre-menarche group displayed a lower average maturity offset (+1.01 years) compared to the post-menarche group (+1.44 years) which agree with their developmental status at this age, compared to the post-menarche group. These differences between the groups were also statistical ($p<0.05$) and of moderate practical significance ($d>0.5$).

The maturity offset differences between the groups became smaller during T4 in the Grade 9 school year. Here the maturity offset scores of both groups moved further away from 0.00, with the pre-menarche group showing the largest change (+0.85 years) compared to +0.65 years in the

pre-menarche group. These differences became statistical insignificant ($p > 0.05$), although it still showed small practical significance ($d = 0.23$). At T7, during the final measurements in Grade 10, the mean maturity offset values of both groups continued to move further away from 0.00. A mean group difference of 0.16 years was found, showing no statistical or practical significance ($p > 0.05$, $d < 0.3$). A second analysis was done by means of a ROC Curve analysis to determine how well the maturity offset equation can distinguish between the pre- and post-menarche groups. Table 3 reports the cut-off points that was determined by this method by plotting the true positive (Menarche status) in the function of the false positive (Maturity offset value) for different cut-off points.

TABLE 3: CUT-OFF POINTS FOR MATURITY OFFSET TO CLASSIFY PRE- AND POST-MENARCHE GIRLS

Area	Std. Error	Asymptotic-Significance	Predicted cut-off	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
0.757	0.096	0.005*	1.250	0.569	0.946

“Area” closer to 1 = More accurate classification/prediction; * = Statistical significant ($p < 0.05$)

Each point on the ROC curve represents a sensitivity/specificity pair corresponding to a particular decision threshold. The area value (AUC) represent a measure of how well the maturity offset equation can distinguish between early or late developing subjects and post-menarche or early developing subjects. The results indicated a predictive maturity offset value of 1.250 which is considered to be a medium value, which can be used during the prediction process of predicting early and late maturing girls. In this regard scores below the medium value (closer or further beneath 0), will be an indication of late-maturing girls (pre-menarche) and scores above the medium value (further away and above 0) will be an indication of early-maturing girls (post-menarche). The results in Table 3 furthermore indicated an area value (AUC) of 0.757 where a

score of 1 is indicative of accurate prediction, which shows that the prediction capability of the maturity offset equation is of relative high accuracy. Therefore, the process of classifying early- and late maturing girls by means of the maturity offset equation is statistical significant as can be seen by the asymptotic significance of 0.005 (Table 3).

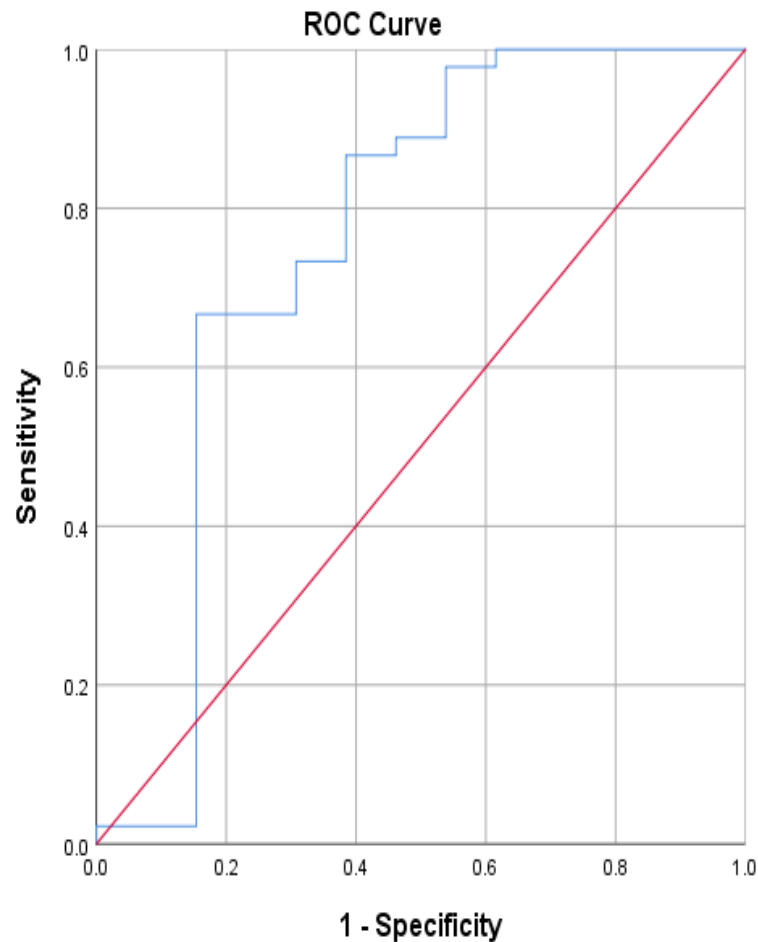


Figure 1: ROC curve of maturity offset equation

Table 4 reports the results of an analysis using Cross-tabulation regarding the distribution of maturity offset values within known pre- and post-menarche groups as determined by the Status-Quo method.

TABLE 4: DISTRIBUTION OF MATURITY OFFSET VALUES WITHIN KNOWN PRE- AND POST-MENARCHE GIRLS FROM GRADE 8 TO GRADE 10

	n	Maturity offset Grade 8			n	Maturity offset Grade 9			n	Maturity offset Grade 10		
		Lower group	Upper group	Chi-Square		Lower group	Upper group	Chi-Square		Lower group	Upper group	Chi-Square
Pre-M	10	61.54%	15.38%	0.331	10	53.85%	23.08%	0.242	6	46.15%	0.00%	0.164
Post-M	27	24.44%	35.56%		28	26.67%	35.56%		14	28.89%	2.22%	

N=Group size; %=Percentage distribution within each group; Chi-square>0.1=Small effectiveness; Chi-square>0.3=Medium effectiveness; Chi-square>0.5=Strong effectiveness; As-Sig=Asymptotic Significance (2-sided) – Significant at $p < 0.05$

For this analysis, derived maturity offset values were used to divide the group into three groups with the lower group representing late maturing girls and the upper group representing early maturing girls. The middle group was not used due to possible influences of both upper and lower group within the middle group. Due to this elimination of subjects the pre- and post-menarche groups were smaller and differed in size during analysis at T1, T4 and T7.

With regard to the pre-menarche group, (n=13) who is expected to be distributed within the lower group, it was found that 61.51% were distributed within the lower maturity group during baseline measurements in Grade 8 at a mean age of 13.51 years. Furthermore 53.85% (Grade 9) and 46.15% (Grade 10) of the pre-menarche group were distributed within the lower group at a mean age of 14.51 and 15.51 years respectively. This showed poorer classification when moving further away from PHV.

However, with regard to the post-menarche group, who is expected to be distributed within the upper group, only 35.56% were distributed within the upper group during baseline measurements while 24.44% were wrongly classified into the lower group in Grade 8, 35.56% in Grade 9 and 2.22% in Grade 10. Again, the girls were less accurately classified at older ages, and the percentage classification was poorer compared to in the pre-menarche group.

The significance of these classification distributions during each measurement was assessed by means of Chi-square values. A Chi-square of 0.331 were found during the baseline measurements in Grade 8 that showed a moderate predictive effectiveness ($0.3 < \text{Chi-square} < 0.5$). The significance of distributions however, decreased with increased age as a Chi-square of 0.242 (small predictive effect) were found during Grade 9 and 0.164 (small predictive effect) in Grade 10.

DISCUSSION

The objective of the study was to investigate the level of accuracy between known self-reported age at menarche and calculated maturity offset in pre- and post-menarche girls over a two-year follow-up period. This aim was investigated by comparing pre- and post-menarche girl's known menarcheal status with maturity offset values that were calculated for each individual. An independent t-test, a ROC curve- and a cross-tabulation analysis were done to determine classification agreement.

The percentage of girls who have reached menarche during T1 (77%, 13.51 years), T4 (93%, 14.51 years) and T7 (98%, 15.51 years) (Table 1) coincides with other researchers who found that girls on average reach menarche between 10 and 13 years of age, and approximately 6 to 12 months after peak height velocity (PHV) (Gluckman & Handson, 2006; Karapanou & Papadimitriou, 2010). In agreement with this, Malina and co-workers (2004) also reported that menarche occurs on average at 12.8 ± 1.0 years in girls.

Due to practical reasons such as grouping girls during team sports or using this information during TID, the importance of being able to classify girls as pre-, average or post-menarcheal or into different maturity groups as early or late developers, are relevant. Therefore, a non-invasive, valid, efficient, one-time assessment of biological growth and maturation of girls, which can be used in schools and field settings, is considered by researchers as important (Mirwald, 2001; and Malina, 2004). In this regard our study used the maturity offset equations that were developed by Mirwald and co-workers (2001) to classify girls into different maturity groups, according to

derived maturity offset values to determine the utility of such scores in our South African sample. The values of the equation for girls in the pre- and post- menarche groups were in the correct order and increased over time which showed that it has classification potential. The mean maturity-offset differences in values of our group during Grade 8 ($p=0.00$, $d=0.73$) at a mean age of 13.51 years were of statistical and medium practical significance with both groups having positive maturity offset scores above zero. With increased age, pre- and post-menarche groups yielded no statistical significant between group differences in maturity offset values during T2 in Grade 9 at a mean age of 14.51 years ($p=0.11$; $d=0.40$) and T3 in Grade 10 ($p=0.29$; $d=0.27$) at a mean age of 15.51 years (Table 2), with a small practical significance only during T2. This phenomenon could be ascribed to the maturity offset equation that incorporates measures of the timing of growth including interactions and ratios that is related to earlier and later growth period. As our group of girls were already relatively late within their pubertal phase at baseline, during follow-up measures, most of these parameters would have been changed to a more mature state with increased age in all the girls. Although variability in biological growth among individuals of the same chronological age is large around the adolescent growth spurt and the onset of menarche which occurs on average at 12.8 years of age (Malina et al, 2004), our mean group age were already 13.51 years at baseline (T1) with only a 0.01 years' difference between the pre- and post-menarche groups (Table 1). This higher mean age of the group compared to the mean age reported by Malina and co-workers (2004) for reaching menarche worldwide could have resulted in differences in growth characteristics between early and late maturing girls already becoming insignificant during baseline measurements. This in turn may have influenced the maturity offset equation, of the pre- and post-menarche groups at later chronological ages even more as they moved further away from their age of menarche. At older ages growth differences are levelled out between early and late maturing girls and they show similar growth characteristics and ratios (this equation includes stature, weight, sitting height and leg length and interactions) that imply

different stages of growth, which could result in more similar maturity offset values between groups.

With regard to the maturity offset values that are displayed in Table 2, both pre- and post-menarche girls showed positive values during all measurement in Grade 8, 9 and 10 indicating that on average, all of the girls have reached PHV. PHV is a developing stage that occurs before reaching menarche which is a very late marker in the puberty phase of girls (Pantsiotou et al., 2008). This indicates that girls within the pre-menarche group already surpassed PHV (+1.01 years) and is suggestive that they are within 1-2 years from reaching menarche, as menarche is reached 1-2 years after PHV (Malina et al., 2004). These results agree with the menarche information of the subjects that showed that 76% (10 of the 13) pre-menarche girls had reached menarche by the age of 15-years with only 3 (24%) being incorrectly classified. In this regard, caution should be raised when interpreting results from maturity offset equations, as Mirwald and co-workers (2001) explain that when population specific equations are applied to other samples, there may be a loss in the accuracy of the equation. They recommended that when this equation is used on other populations that it is standardized for, it should rather only be used as a classification tool. Within the current study the equation under-predicted age at PHV where the results indicated that post-menarche girls should have reached PHV 1.44 years prior to baseline measurements (Table 2). The medical history of the post menarche group indicated that 22 of the 45 post-menarche girls have already reached menarche before or at the age of 12-years which is indicative that they would have reached PHV, 6-12 months prior to 12-years of age. The post-menarch group (early developing girls) however, did display maturity offset values that were further above 0.00 (Table 2) compared to pre-menarche girls (late developing girls) that indicates that the equation does have potential as a classification tool. It should however be noted that the equation should be used rather on an individual level and not for group classification which might have contributed to these influences on the accuracy of the equation.

Consistent results were also found when testing the ability of the maturity offset equation to accurately predict early and late maturing girls by ROC Curve statistics. In this regard an asymptotic significance value of 0.005 (Table 3) for predicting early and late maturing girls were found that was statistical significant in predicting maturity status with an area value of 0.757 which are close to a perfect prediction score of 1 with confidence intervals of 0.569 to 0.946 (Table 3). Our cross-tabulation analysis furthermore showed that the pre-menarche or late developing girls was distributed more accurately (46.15 to 61.54%) within lower maturity offset values during all measurements in Grade 8, 9 and 10 (Table 4) compared to the post menarche group. Post-menarche or early maturing girls were correctly distributed below 40% within the higher maturity offset values. These results coincide with reported findings indicating that the accuracy of the equation is more accurate within certain ages. Mirwald and co-workers (2001) also suggested that their maturity offset equation are more accurate up to four years pre-PHV and no more than two years post-PHV and within 8- to 16 years of age. Although our groups fall within the set age range (8-16 years), a large percentage of the post-menarche group, have reached PHV more than 2 years before the baseline measurements of the study, as were evident from our statistics showing that 37% of the post-menarche group reached menarche before or at 12-years of age, while it is known that PHV happens 6-12 months prior to menarche. This might have been contributing to the group of early developers being less accurately predicted or distributed into the upper group through cross-tabulation. It should, however, be emphasized that the results are based on mean values of the group that varied considerably in their menarche status within the broadly classified pre- and post-menarche groups that were compared. The analysis of the accuracy of the equation should however, rather be based on how accurate each individual with an own medical history could be classified based on this history.

Our study therefore confirms that maturity-offset as calculated by using an equation that are based on age and growth characteristics has potential for classification purposes. Based on inaccurate classification of several of the participants, especially those who were the furthest in

their pubertal development, the equation in its current form is however considered to be less suitable for use in populations other than those it was developed for. More research is recommended in this regard to improve the utility of this equation by adjustments for specific population groups. However, our results do indicate that this equation have the potential to be used to broadly categorize girls earlier in the pubertal stage into maturational groups for research as well as practical purposes. Furthermore, the results confirm that the accuracy of these equations declines with increasing age after PHV was reached. These equations will also be more suitable for classification of females on an individual level, based on their own developmental history.

Although the study contributed to an improved understanding of using maturity offset equations in girls by comparing it to actual menarche status that occurs later in the biological development of girls, especially in a South African sample of girls, the study had limitations that need to be taken in consideration when interpreting the findings. Although the data were collected over a follow-up period of two-years, which strengthens the findings that were obtained, the study could only focus on the time period between 13 and 15 years of age, which is the time period when children enter into secondary schools in South Africa, which made it impossible to follow the group over a longer and especially earlier age period as they enroll into different secondary schools after finishing primary school. A larger age-span period, especially from before the age of onset of PHV, is however needed to fully investigate the usefulness and accuracy of maturity offset equations. The data were also collected by means of a convenience sample that included a small number of subjects, and also mainly from one ethnic group (white, Caucasian), which further limits the generalization of the results.

CONCLUSION

The use of a maturity-offset equation as a proxy of growth differences in same aged girls have value to categorize girls into early or late maturing groups. This assessment procedure capture height and leg related changes, therefore if researchers or practitioners are interested in

characteristics associated with these kinds of changes, this assessment procedure will be recommended for use. If weight related changes are mostly of interest, such as in sports where weight is an important performance factor, age of menarche will be the preferable categorization method (Brooks-Gunn, 1988). Assessment of both these criteria may therefore offer the best picture of growth during the mid-adolescence period, and it is thus also recommended that both assessment procedures should be utilized. Maturity offset equations are easy, non-invasive methods to determine differential maturational status of girls, although the accuracy of these equations is still in question as it declined when it was used in our population that was different from whom it was developed. It is therefore recommended that Maturity offset equations should be adjusted for each specific population regarding the growth characteristics of that population. Maturity offset equations seems to be more accurate and subsequently valid at a younger age, closer to PHV, which our results also confirmed, and it is therefore recommended that it should be used at younger ages and also closer to the PHV period.

Practitioners and researchers alike may benefit from identifying a valid and once off assessment of maturation that is measureable earlier than the age at menarche. In this regard results from maturity offset equations will be useful to broadly categorize girls earlier into different maturity groups. Further population specific research is therefore recommended that can improve the use of these beneficial equations, to improve their usefulness.

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Literature Cited

- Ameade, E.P.K., and Garti, H.A. 2016. Age at Menarche and Factors that Influence It: A Study among Female University Students in Tamale, Northern Ghana. *PLoS ONE*, 11(5), e0155310. doi:10.1371/journal.pone.0155310.
- Anderson, S. 2009. *Collins English dictionary: Complete & unabridged*. 10th ed. London: Harper Collins.
- AberbergaAugskalne, L., and Kemper, H.C.G. 2007. Longitudinal relationship between cardiovascular functioning and peak height velocity during exercise in 7 to 16 year old boys and girls. *Hum Mov Sci*, 8(1), 5-11.
- Balyi, I., and Way, R. 2010. *Canadian sports for life: The role of monitoring growth in long-term athlete development*. Calgary: Canadian Sports Centre.
- Beunen, G.P. 1989. Biologic age in pediatric exercise research. In Bar-Or (Ed.), *Advances in Pediatric Sport Sciences* (pp 1-39), Vol. 3. Champaign, IL: Human Kinetics.
- Brooks-Gunn, J. 1988. Antecedents and consequences of variations in girl's maturational timing. *J Adolesc Health Care*, 9:365-373.
- Chen, L., Li, S., He, C. et al... 2016. Age at Menarche and Risk of Gestational Diabetes Mellitus: A Prospective Cohort Study Among 27,482 Women. *Diabetes Care*, 39(3), 469-471.
- Cohen, J. 1992. A power primer. *Psychol Bull*, 112, 155-159.
- Damon, A., and Bajema, C.J. 1974. Age at menarche: Accuracy of recall after thirty-nine years Author. *Hum Biol*, 46(3), 381-384.
- Davids, K., & Baker, J. 2007. Genes, environment and sport performance: Why the nature-nurture dualism is no longer relevant. *J Sports Med*, 37(11), 1-20.
- Davis, B., Bull, R., Roscoe, J., et al... 1997. *Physical education and the study of sport*. 3rd ed. London: Mosby.

Ellis, S.M., and Steyn, H.S. 2003. Practical significance (effect sizes) versus or in combination with statistical significance (p-values). *Management Dynamics*, 12(4), 51-53.

Garnier, D., Simondon, K.B., and Benefice, E. 2005. Longitudinal estimates of pubertal timing in sengalese adolescent girls. *Am J Hum Biol*, 17, 718-730.

Gay, J.L., Smith, A.L., Torre-McGehee, T., et al... 2014. Assessment of growth and maturation in female athletes at a single point in time. *WSPAJ*, 22, 76-82.

Gerber, B.P., Pienaar, A.E., Kruger, A., et al... 2014. Interrelations between anthropometric and fitness changes during mid-adolescence in boys: A 2-year longitudinal study. *Am J Hum Biol*, 26, 617-626.

Gluckman, P.D., and Handson, M.A. 2006. Evolution, development and timing of puberty. *Trends Endocrinol Metab*, 17(1), 7-12.

Henneberg, M., and Louw, G.J. 1995. Average menarcheal age of higher socioeconomic status urban Cape colored girls assessed by means of status quo and recall methods. *American J Phys Anthr*, 96, 1-5.

Karapanou, O., and Papadimitriou, A. 2010. Determinants of menarche. *Reproductive Biology and Endocrinology*, 8, 115-122.

Koo, M.M., & Rohan, T.E. 1997. Accuracy of short-term recall of age at menarche. *An Hum Biol*, 24(1), 61-64.

Lee, C.T., Tsai, M.C., and Lin, C.Y. (2016). Longitudinal effects of self-report pubertal timing and menarcheal age on adolescent psychological and behavioral outcomes in female youths from northern Taiwan Carol Strong. *Pediatr Neonato*, 1, 1-8.

Malina, R.M. 2000. Growth and maturation: do regular physical activity and training for sport have a significant influence? In Armstrong, N. & van Mechelen W. (Eds.). *Paediatric Exercise Science and Medicine*. Oxford: Oxford University Press. p 95-106.

Malina, R.M., Bouchard, C., and Bar-Or, O. 2004. *Growth, maturation and physical activity*. Champaign, IL: Human Kinetics.

Malina, R.M., Choh, A.C., Czerwinski, S.A., et al... 2016. Validation of Maturity Offset in the Fels Longitudinal Study. *Pediatr Exerc Sci*, 28, 439-455.

Mirwald, R.L., Baxter-Jones, A.D.G., Bailey, D.A., et al... 2001. An assessment of maturity from anthropometric measurements. *Med Sci Sports Exerc*, 34(4), 689-694.

Nwankwo, M., Danborn, B., and Hamman, W.O. 2016. Relationship between age at menarche and anthropometric profiles, demography, and ethnicity among adolescent girls in Nigeria. *Ann Bioanthropol*, 4(1), 1-7.

Pantsiotou, S., Papadimitriou, A., Douros, K., et al... 2008. Maturational tempo differences in relation to the timing of the onset of puberty in girls. *Acta Paediatrica*, 97, 217-220.

Rodríguez, G., Moreno, L.A., Blay, M.G., et al. 2004. Body composition in adolescents: measurements and metabolic aspects. *Int J Obes*, 28s, 54-58.

SAS Institute Inc. 2002–2010. The SAS System for Windows Release 9.3 TS Level 1M0 Copyright© by SAS Institute Inc., Cary, NC, USA.

Sherar, L.B., Mirwald, R.L., Baxter-Jones, A.D.G., et al... 2005. Prediction of adult height using maturity-based cumulative height velocity curves. *J Pediatric*, 147(4), 508-514.

Simmons, D. 2000. Talent identification of British diving. Physiological and anthropometrical Test. [CD Rom]. British diving.

Statsoft. 2014. Statistica for Windows: *General conventions and statistics*. Tulsa, OK Statsoft.

Steward, A.D., Marfell-Jones, M., Olds, T., et al... 2011. *International standards for anthropometric assessment*. Potchefstroom: International Society for Advancement of Kinanthropometry (ISAK).

Van Den Berg, L., Coetzee, B., and Pienaar, A.E. 2006. The influence of biological maturity on physical and motor performance talent identification determinants of u-14 provincial girl tennis players. *Afr J Phys Health Educ*, 18(3), 510-15.

Waylen A., and Wolke D. 2004. Sex 'n' drugs 'n' rock 'n' roll: the meaning and social consequences of pubertal timing. *Eur J Endocrinol*;151, 151-159.

Xie, Y.J., and Ho, S.C. 2016. Age at menarche, weight change from young adulthood to middle age, and adult adiposity: evidence from the Hong Kong women's health study. *American Heart Association*. Abstract P292.

CHAPTER 7

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

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7.1 SUMMARY

The objectives of this dissertation were fourfold. The first objective was to investigate the extent to which menarche status will influence anthropometric growth characteristics such as height, mass, sitting height, ratio, arm span, leg length and body mass index (BMI) in adolescent girls over a two-year follow-up period. Secondly, the objective was to determine differences in muscle strength and cardio respiratory endurance as a result of differing maturity status in adolescent girls over a two-year follow-up period. The third objective was to determine differences in speed, agility, hand-eye coordination and power as a result of differing maturity status in adolescent girls over a two-year follow-up period. The last objective was to determine the level of classification agreement between the ability of a calculated maturity offset equation to predict maturity status earlier in the pubertal phase, when compared to actual self-reported age at menarche status in adolescent girls which occur much later in the pubertal phase. Chapter one includes the introduction, problem statement, objectives, and hypotheses of the study as well as the structure of the thesis.

Chapter two consists of a literature review that focused on the relationship between menarche, anthropometric growth and physical- and motor fitness capabilities among adolescent girls. Firstly, terminology related to the current study was identified and defined. Secondly, the phenomena of

menarche and biological processes leading to reaching of menarche were described. Thereafter different ways of determining menarche and peak height velocity (PHV) were investigated and described. The literature review also reports on growth that took place relative to the onset of menarche. The effect of differential timing of menarche on longitudinal growth changes (stature, mass, arm span, sitting height, sitting height ratio, BMI) and differences between early and late developing girls were investigated. This was followed by an investigation of the effect of differential timing of menarche on longitudinal changes in physical- (muscle strength and cardio respiratory endurance) and motor fitness capabilities (speed, agility, hand-eye coordination, and explosive power). Next the possible interrelationship between changes in physical- and motor fitness capabilities and changes in anthropometric characteristics was investigated and described. Lastly the results of national and international cross-sectional-, longitudinal- and review studies applicable to the aims of this study, were investigated.

The literature review revealed that various changes in anthropometric characteristics and body composition occur with increasing age due to natural growth. Furthermore, it appears that the onset and especially the timing of the pubertal and menarcheal periods contribute to variation in girls' stature and mass development, while also significantly influencing biological changes such as the development of secondary sexual characteristics and body composition changes, such as breasts, wider hips, and higher fat percentage. Major hormonal changes also take place, which plays a contributory role in fat distribution in girls in preparing them for sexual reproduction.

Various cross-sectional and longitudinal studies have already been conducted that are relevant to this study and were described in the literature review. Results from these studies, focusing on girls' physical- and motor fitness capabilities, revealed significant differences between early- and late maturing girls with early developing girls initially showing advantages in muscle strength, anaerobic muscle strength and aerobic capacity. Researchers attributed this advantage to early maturing girls having more favorable anthropometric characteristics, including longer stature and limb lengths that are initially advantageous to them performing better in sport skills. However, early maturing girls also tend to be affected negatively by increased fat deposition from a younger age which in turn negatively affects their physical- and motor fitness capabilities. Consequently, with increasing age, late maturing girls tend to catch up with early maturing girls and surpass them in certain physical- and motor fitness capabilities due to them developing more favorable anthropometric profiles at a later age, after the onset of menarche at around 14-16 years of age. No significant differences were reported between early and late developing girls' speed, agility and

hand-eye coordination. All changes taking place during puberty are strongly influenced by maturation changes, especially menarche, which plays an important role in girls' sports skills.

Although the above studies convey information on growth, there were certain shortcomings regarding the aims of these studies in relation to the aims of this current study. The shortcomings include, among others, one-dimensional designs, where no interrelations between growth and physical and motor fitness were investigated. Furthermore, the effect of maturation and more specific the impact of menarche on girls' motor- and physical fitness capabilities was not investigated. In addition, only a small number of these studies were conducted within a South-African population. Lastly, most of these studies are also ten years and older, and hence, the relevance thereof on modern populations is debatable.

Methods used to determine menarcheal status include monitoring studies based on prospective or longitudinal methods (examined every 3-6 months), interviews, retrospective methods and the Status Quo method. Some of these methods are, however, costly and invade girls' privacy. Self-reporting of the onset period of menarche is also found to have limitations because the date is not well or correctly memorised by females. Consequently, researchers have started to develop equations based on growth parameters, to help predict maturity-offset in order to correct for these shortcomings.

Chapter 3 is presented in an article format with the title: "Two-year follow-up of differences in anthropometric growth between pre- and post-menarcheal girls: Implications for sport participation". The paper is prepared according to the guidelines of the *Journal of Cogent Social Sciences* and was submitted to this journal for potential publication. This article presents the results regarding differences in anthropometric growth including stature, arm span, mass, sitting height, sitting height ratio, leg length and BMI between pre- and post-menarcheal girls and the implications of these differences for sport participation. A convenience sample of high school girls (N=58) from one Quintile 5 high school, aged 13.51 ± 3.51 years at baseline, was used. The sample was further divided, based on the Status Quo method (have you reached menarche, Yes or No) into pre- (n=13) and post-menarche (n=45) sub-groups. The subjects were subjected to the test protocol over a longitudinal three-year school period (2011-2012), resulting in two-year follow-up measures of girls of differing menarcheal status between 13 and 16 years. Anthropometric characteristics were measured three times per year, four months apart over the three school years

(2010-2012), contributing to nine time-point measures. The protocol as developed by the International Society for the Advancement of Kinanthropometry (ISAK) was used for stature and body mass measurements. Basic statistics, an independent t-test and a repeated measures ANOVA with a post hoc Bonferonni correction were used, where $p < 0.05$ was used as a statistical significance. Effect sizes were calculated and interpreted according to Cohen's d-value cut-offs. Statistical significant differences were only found in the first year of the study between the groups (Grade 8 year, T1-T3), where after differences became mostly statistically insignificant only showing differences of 0.03cm (stature), 0.29cm (arm span), 2.61kg (mass), 0.54cm (sitting height), 0.08cm (leg length), 0.26% (sitting height ratio) and 1.04 (BMI) between the pre- and post-menarche girls during T9. Differences, however, were still of small practical significance up to the end of the second year (T1-T6). The conclusion drawn from these results is that the timing of the onset of menarche results in significant growth differences between early- and late maturing girls, although these differences are only temporary until all girls of the same chronological age have reached menarche. These differences in growth before all girls have reached menarche can affect sport performance at younger ages due to the physiological advantages of early maturing girls that is beneficial to sport participation. These early benefits however dissipate to where later maturing girls seem to have more ideal body compositions that in turn will benefit them more to excel in sport at a later age (14-15 years and older).

Chapter 4 is also presented in article format with the title: "Differences in strength and aerobic endurance between pre- and post-menarche girls during mid-adolescence: A two-year follow-up study". This article was prepared according to the guidelines of the *American Journal of Human Biology* and was submitted to this journal for potential publication. A longitudinal research design that spans over a three-year school period was used. A convenience sample ($N=58$) of high school girls aged, 13.51 ± 3.51 at baseline, were used. They were sub-divided into a pre- ($n=13$) and post menarche ($n=45$) group according to their menarcheal status, determined by using the Status Quo method, at baseline. Strength and cardio respiratory endurance were measured once a year, in February, resulting in three time-point measures (2010-2012). Physical fitness capabilities (muscle strength, cardio respiratory endurance) were measured according to the Australian Sport Search Protocol. Basic statistics, independent t-testing and a repeated measures ANOVA with a post hoc Bonferonni correction were used to describe and analyze the data where a $p < 0.05$ indicated statistical significance. Effect sizes were calculated to determine practical significance and was interpreted according to Cohen's d-value. The results showed that menarche status differently influenced the muscle strength and cardio respiratory endurance of pre- and post-menarche groups.

Post-menarche girls showed better muscle strength and pre-menarche girls better cardio respiratory endurance and relative $\dot{V}O_{2\max}$ ($p>0.05$) over the follow-up period. Differences between maturational groups ($p>0.05$) became smaller with increased age. Interaction effects were seen in absolute $\dot{V}O_{2\max}$ where post-menarche girls initially had a better absolute $\dot{V}O_{2\max}$ ($p>0.05$) although pre-menarche girls caught up and surpassed them at 15.51 years ($p>0.05$). It was concluded from the findings that the period at and immediately after reaching menarche is an unstable period of growth which have influences changes in girls' physical fitness capabilities. The results confirmed that the influences of somatic and biological growth on the strength and cardio respiratory endurance of girls with the same chronological age, will only be leveled out, one to two years after they all have reached menarche.

Chapter 5 is also presented in article format with the title: "Differences in motor fitness capabilities of pre- and post-menarche girls during mid-adolescence: A two-year follow-up study" and was prepared according to the guidelines of the *Annals of Human Biology* for consideration. A longitudinal research design that spans a two-year follow-up period was used. At baseline, a convenience sample ($N=58$) of high school girls aged 13.51 ± 3.51 years was used. The group were divided into a pre- ($n=13$) and post-menarche ($n=45$) group according to their menarche status during baseline by using the Status Quo method. Speed, agility, explosive power and hand-eye coordination were tested once annually, in February, according to the Australian Sport Search Protocol, resulting in three time-point measures (2010-2012). Differences between the maturity groups were mostly evident in strength tests. Only explosive upper body strength differed significantly between the groups, favoring post-menarche girls. Pre-menarche girls performed better in agility, and explosive leg strength and post-menarche girls in explosive upper body strength, hand-eye coordination and speed at 13.51 years. At 15.51 years no statistically significant between-group differences were found. Pre-menarche girls surpassed post-menarche girls in hand-eye coordination and 0-40 m speed and post menarche girls displayed higher leg strength scores after two years. Our results confirm that the effect of differential timing of the onset of menarche was small on speed, agility and hand-eye coordination capabilities of pre- and post-menarche girls, although strength differences were evident with post-menarche girls showing an advantage which can be ascribed to earlier maturation. The potential to excel in sport based on motor capabilities can therefore only be accurately determined a few years after all girls of the same chronological age have reached menarche.

Chapter 6 is also presented in article format with the title: “Classification agreement between self-reported age of menarche and calculated maturity offset in adolescent girls: A two-year follow-up study”. This article was prepared according to the guidelines of the *Journal of Human Biology* and will be submitted to this journal for possible publication. A longitudinal research design, including three school-years, that spans a two-year follow-up period, was used. A convenience sample (N=58) of high school girls aged, 13.51 ± 3.51 at baseline, was used. At baseline the group was divided into a pre- (n=13) and post menarche (n=45) group according to their menarche status determined by the Status Quo method. A maturity-offset prediction equation was used to predict the groups’ amount of years from PHV. This equation includes specific anthropometric measurements that were collected during the first measurements in February of each year. An independent t-test, cross tabulation and ROC Curve statistics were used to analyze the data. Results derived from the equation were then compared to the known onset of menarche status of the group that were used to divide the group into early and late developers, in order to determine the ability of the equation to predict the maturity offset of girls that can help to classify them as early, average or late developing girls. Post-menarche girls displayed higher maturity offset values closer to 0, indicating that the equation is able to correctly classify girls in maturity groups although maturity offset results were not accurate in terms of amount of years from PHV. Differences between maturational groups were also not significant with regard to maturity offset scores. The level of agreement between the two methods was not of such a nature that it can be recommended for determining maturity-offset but does have the potential to classify girls into maturity groups. The results also revealed that the maturity-offset equation were more accurate when it was used on girls who are within 2 years pre- or post-PHV indicating that the equation does have the potential to be used, if used within the correct timeframe. Maturity-offset as calculated by the equation as used in this study based on age and growth characteristics is considered to be less suitable for use in all populations. However, our results suggest that these equations have the potential to be used to broadly categorize girls earlier than when actual menarche occurs, into earlier and later maturational groups for research as well as practical purposes. From our findings, it is also recommended that such equations need to be adjusted for specific population groups.

7.2 CONCLUSIONS

The results of the study were used to test the set hypotheses and to draw final conclusions.

7.2.1 Hypothesis 1

Hypothesis 1 states that adolescent girls of differing menarcheal status will significantly differ in height, mass, sitting height, ratio, arm span, leg length and BMI over a two-year follow-up period.

Differences between pre- and post-menarche groups were the highest in Grade8 at the age of 13.51 years. Early maturing girls (post-menarche) were taller and heavier at 13.51 years of age and had longer body segments including arm span sitting height, sitting height ratio and leg length ($p < 0.05$). Differences between pre- and post-menarche girls, at 13.51 years, were significant in stature, mass and sitting height and borderline significant for arm span and BMI. These differences were mostly leveled out by the age of 16 years, showing no significant differences between the groups. The results did however show various significant 4-monthly growth changes in the anthropometric variables. These changes in pre- and post-menarche girls over the two-year follow-up period (13.51-16.25 years) were also statistically significant ($p < 0.05$) in all anthropometric characteristics measured. Post-menarche girls were however still taller and heavier with a longer sitting height by the end of the study, although differences were insignificant between groups.

Based on these findings, Hypothesis one, is therefore **partially accepted** as there were significant differences at a younger age between girls of different menarcheal status, although these differences became insignificant with increased age.

7.2.2 Hypothesis 2

Hypothesis 2 states that adolescent girls of differing menarcheal status will significantly differ in muscle strength and cardiovascular endurance over a two-year period of follow-up, with post-menarche girls outperforming pre-menarche girls.

Differences between pre- and post-menarche groups were statistically insignificant although of small to medium practical significance during Grade8 (T1) at the age of 13.51 years. These differences became even smaller with increased age during T2 and T3. Post-menarche girls outperformed the pre-menarche girls in the muscle strength test and absolute $\dot{V}O_{2\max}$ with pre-menarche girls performing better in aerobic capacity and relative $\dot{V}O_{2\max}$ at 13.51 years (T1). By the age of 16.25 years the post-menarche group increased their advantage in the strength test from

T2 to T3 with the pre-menarche girls outperforming the post-menarche group in aerobic capacity as well as absolute- and relative $\dot{V}O_{2\max}$. Pre-menarche girls had the most significant changes in muscle strength and absolute $\dot{V}O_{2\max}$, with post menarche girls showing more significant changes in aerobic capacity and relative $\dot{V}O_{2\max}$ from T1 to T3.

Based on these results hypothesis two is **rejected** regarding significant differences between pre- and post-menarche girls' muscle strength and aerobic capacity. The last part of this hypothesis states that post-menarche girls will outperform pre-menarche girls. In this regard the hypothesis is **partially accepted** as post-menarche girls outperformed the pre-menarche group only in muscle strength.

7.2.3 Hypothesis 3

Hypothesis three states that adolescent girls of differing menarcheal status will differ significantly in speed, agility, hand-eye coordination and power over a two-year period of follow-up, with post-menarche girls outperforming pre-menarche girls.

During baseline (T1), at the age of 13.51 years, the only significant difference between pre- and post-menarche girls' motor fitness capabilities was found in explosive upper body strength in favor of the post-menarche group. No further noteworthy differences were found during baseline. Post menarche girls outperformed the pre-menarche girls in 0-10m- and 0-40m speed ($p>0.05$) and the pre-menarche girls performed better in explosive leg strength, agility and hand-eye coordination during baseline measurements ($p>0.05$) (T1). At the age of 16.25 years (T3) no statistically significant difference was found in any of the motor fitness capabilities between pre- and post-menarche girls. During T3 post menarche girls performed better in explosive upper body strength, explosive leg strength and 0-10m speed with pre-menarche girls performing better in agility, 0-40 m speed and hand-eye coordination ($p>0.05$).

Based on these results hypothesis 3 is **rejected** as no significant differences between girls of differing menarcheal status were found over the follow-up period. The hypothesis is **partially accepted** for the last part which states that post-menarche girls will outperform the pre-menarche girls in all motor fitness capabilities. They only did so in explosive upper body strength, explosive leg strength and 0-10 m speed although differences between groups were insignificant.

7.2.4 Hypothesis 4

Hypothesis 4 states that the ability of a calculated maturity-offset equation to classify maturity status early in the pubertal phase, will be accurate when compared to actual self-reported age of menarche status.

The results of the maturity-offset equation were compared with actual menarche-groups (pre- and post-menarche) by means of three different statistical analyses. All three methods showed that a large percentage of the girls were misclassified. Therefore, it is concluded that the level of agreement between the two methods is inadequate more than two years post-PHV. The equation's ability to accurately predict maturity-offset (years from PHV) is inadequate but does have the probability of classifying girls into maturational groups correctly.

The hypothesis is therefore **partially accepted** based on under-average ability of the equation to accurately predict maturity offset.

7.3 General findings

This thesis examined differences in growth, body composition, physical- and motor fitness capabilities in girls with different maturity status, where the onset of menarche was used as a marker for early or late pubertal development. The feasibility of a mathematical equation to determine the age from PHV (maturity-offset) as a possible substitute for information about maturation in the place of menarcheal status, that occur late in the pubertal process, to place girls in early or late development categories before the onset of menarche, has also been investigated. The following are general findings and recommendations that arise from the results of the thesis.

- The findings were mostly consistent with previous findings. Only small differences were found between pre- and post-menarche groups although differences were of practical significance. The reason for these small differences that were found in this study can be due to girls reaching menarche at younger ages and that differences between early and late maturing girls are already, to a certain extent, being eliminated. Muscles strength and explosive muscle strength differed the most between pre- and post- menarche girls and speed and agility the least throughout the study.
- The results confirmed that although there were mean differences in the motor capabilities of girls of differing maturity status, based on their menarche status during mid- to late adolescence, these differences were only of small practical significance with regard to

agility and speed at the mean age of 13.51 years. Differences were also larger at a younger age (13.51 years) but declined with increased age. Performance based on mean values, in the motor tests of pre-menarche girls, were approximately two years behind that of the post-menarche girls during the period 13-16 years of age. Based on these findings it can be concluded that the motor capabilities of girls, once they have reached menarche, will only be comparable with other girls of the same chronological age who have reached menarche earlier, one to two years later when the influences of puberty on their fitness performance can be considered to have been leveled out. It is therefore recommended that the motor- and physical performance of girls should only be compared, one to two years after they all have reached menarche. Talent identification (TID) processes should consequently only take place beyond 14-years of age as it was found that differences between early and late maturity girls became insignificant at this age.

- The findings confirm that age at menarche is a significant marker of strength and endurance differences between girls especially at the age of 13 years. Early maturing girls showed overall larger increases in muscle strength and consequently having an advantage in strength activities throughout the study. Late maturing girls on the other hand, had an overall advantage in cardio respiratory endurance between 13.51 and 15.51 years of age. These strength and endurance differences can play a role in sport selection and consequently participation in sport, as early maturing girls will initially be preferred for selection in sport teams due to their initial advantage in strength and endurance. This can also lead to the sporting potential of late maturing girls being overlooked that may cause them losing interest in sport or dropping out of participation in sport and physical activity.
- The most significant differences between maturity groups were evident in the strength tests where the post-menarche group outperformed the pre-menarche group. Differences in strength also became larger with increased age. These findings highlight the importance of teachers, coaches, therapists and all other professions working with girls within their primary school years (Grade 4-7) to have background knowledge on growth and maturation and the effects thereof on girls of similar chronological age but differing maturity status, in order to use this knowledge in situations where growth and maturation may have an influence. It is recommended that this knowledge should be incorporated into the planning and development of programs where growth, maturation and strength may play a role.

- It is furthermore also important to educate girls before and during the reaching of pubertal milestones, of the effects of puberty including the onset of menarche on their bodies, and subsequently regarding changes in their physical- and motor fitness capabilities and the influence of these expected changes on sport performances. Girls also need to be provided with coping strategies to deal with these changes.
- As changing physique, physical- and motor capabilities influence sport skill development, it is recommended that knowledge on these changes should be implemented in designing physical activity and training programs for girls. Furthermore, talent identification and selection should be done by people who have the necessary knowledge of growth and maturation of girls during the mid-adolescent period, as early and late maturation may differently affect girls' physical- and motor fitness capabilities. It can lead to ineffective talent selection if these factors are not taken into consideration. Differences in maturation must therefore be taken into account in the TID process. A greater awareness of growth changes that are associated with differing timing of the onset of menarche and the impact of these factors on girls' sport performance is therefore also important to be emphasized among sports coaches and teachers.
- Knowledge of the menarche status of girls can assist coaches with determining earlier and late developers. It is however a late process during puberty and also invading the privacy of girls to ask them about their menarch status. This thesis therefore studied the possibility of using an easy, non-invasive method where an equation can be used that are based on interactions of age, sex, stature, mass and sitting height, that can assist coaches to determine developmental differences that result in earlier or later development. It was found that such an equation is only accurate in predicting girls' maturity status at a younger age, before or close after reaching PHV, although also only to a small degree. The accuracy of such an equation also declined with increasing age as girls move further away from PHV. It was concluded that the equation was not as accurate when it was used on a different population as for whom it was originally standardized. It is therefore recommended that maturity-offset equations should be used with caution, and that it should be adjusted for each specific population based on the growth characteristics of that specific population. Such equations should also only be used closer to the PHV period. Lastly, it is recommended that the results from equations developed on different population to yours should rather only be used as a tool to broadly categorize girls into different maturity

groups and not to determine their actual maturity offset (age from PHV). This should also duly be done at ages close to their PHV.

7.4 Limitations and Recommendations

Although the study design had various strengths such as the longitudinal analysis of the data, limitations still occurred. The researcher, however strived to optimize the reliability as well as the validity of the results. It is therefore important to outline the limitations that possibly may have affected the results, and which should be taken into account when planning future research projects with similar assumptions. These limitations include:

7.4.1 The study was conducted during the first three years of high school between the ages of 13- and 16 years of age. The study, therefore, took place during the late pubertal stage during which a high percentage of girls have already reached menarche. Consequently, most changes due to the effects associated with reaching menarche and differences between early and late developing girls were already leveled out to a large extent. The effects of menarche on growth and motor- and physical fitness could therefore not be investigated to its fullest extent during this period. Accordingly, it is suggested that future studies, although practically difficult to perform, especially in the South African school system, where children move to different schools when they enter the secondary schooling period, should be carried out over a longer age period (11-17 years) to be able to fully investigate the influences of the pubertal phase.

7.4.2 The study was based on a sample of convenience that included only one school in the Northwest Province of South Africa. The participants also included mainly caucasian females that also limit the generalizability of the results. It is therefore recommended that the selection of subjects for future similar studies should make use of randomly selected samples and also females representing different Provinces and ethnic groups for improved generalization of the results to same aged South African females.

7.4.3 Since the study design was longitudinal in nature, the loss of subjects to follow-up was high (38%), which could have affected the results. Although difficult to control for, it is recommended that future studies in this regard should plan for drop-out that can influence the power of study findings. Although studies of this nature include many follow-up measurements of growth, it is recommended that arrangements should be made with subjects who have completed baseline measurements to still be able to measure them, during the follow-up testing, or when they missed

the testing or, even when they have changed schools. Although largely out of control of the researcher it is recommended that group sizes at the start of studies should be large enough in order to be able to account for a large drop-out percentage and still be large enough to have statistical power.

7.4.4 Although the study was of longitudinal nature it only stretched over a three-year period from the start of the girls' High School year. This limits the strength of the study, due to the findings that showed that some girls have reached menarche as early as 10-years of age which signifies a substantial period of the pubertal phase that was not covered in this study during which significant growth and maturation occurred in girls and from which more accurate conclusions could have been made. It is therefore recommended that future studies should focus more on girls who are the nearest and furthest away from menarche, thus those who fall on the extreme ends of the normal distribution curve regarding the age of onset of menarche, for comparison purposes. This can possibly lead to more clear findings regarding possible differences in growth and motor- and physical fitness capabilities of early and late maturing girls.

7.4.5 Although outside the researcher's control, environmental conditions, such as weather conditions were not always identical over the course of the study and could possibly have influenced the outcome of the results, especially the field tests. It is recommended that tests should be performed as far as possible within a controlled environment and in similar circumstances to previous years.

7.4.6 The longitudinal nature of the study contributed to the exposure of the subjects to the same physical- and motor fitness tests, three times over the three-year period. Motivation, to do their best but also boredom with the tests could possibly have impacted the performance of the tests, thus affecting the results. It is therefore recommended that researchers of future studies make sure that the subjects understand the importance of the research and encourage them to always do their best while performing the tests.

APPENDIX A

Author Guidelines: Journal Cogent Social Science

Journal of Research on Adolescence

The Official Journal of the Society for Research on Adolescence

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Editorial Scope

JRA seeks to publish innovative and rigorous research that advances understanding of adolescent development. The journal considers manuscripts from the wide range of topics relevant to adolescent development, using rigorous quantitative or qualitative methodologies, and considering samples during the second decade of life (though samples of university students aged about 18-20 years need a strong justification that the sample is not one of convenience). Manuscripts should advance understanding of adolescent development, rather than merely study a phenomenon with an adolescent sample, and should therefore be grounded in developmental theory and prior developmental research. There are no exclusions of particular methodologies, though studies including a diverse and representative sample, with valid and multiple information sources, and/or with best practice quantitative or qualitative analysis strategies are preferred. Manuscripts should

clearly articulate the advances in understanding adolescent development and the applications for improving the lives of adolescents.

Audience

Scientists, educators, and practitioners interested in adolescent development, including clinical, social, and developmental psychologists, sociologists, social workers, and those specializing in human development and family studies.

Online publication from 2016

Effective with the 2016 volume, the Journal of Research on Adolescence will be published in an online-only format. This transition will reduce the environmental impact caused by the production and distribution of printed journal copies and will allow the journal to expand the number of journal pages, include color images, and reach out to a broader scientific and lay audience. Published articles will continue to be disseminated quickly through the journal's broad network of indexing services and discoverable through popular search engines such as Google. All color images will now be reproduced digitally and published free of charge.

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Manuscript Submission

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Types of Manuscripts

The Journal of Research on Adolescence considers only original manuscripts in formats described below. Inquiries concerning alternative formats should be addressed to the Editor prior to submission. All submissions are expected to be no more than 40 manuscript pages, including tables, references, and figures (but excluding appendices). Authors are strongly encouraged to

submit concise and focused papers in the 25-30 page range. All manuscripts must be written in English and strictly adhere to APA Style (6th edition).

Empirical articles comprise the majority of works appearing in the journal. To be accepted, empirical articles must be judged as being high in scientific quality, contributing to the empirical base of adolescent development, and having important theoretical, practical, and/or interdisciplinary implications.

Brief reports are reserved for short cutting-edge empirical papers that are no longer than 4000 words in length (approximately 15 pages, including ALL text, tables, footnotes, appendices). Manuscripts in this format should advance understanding in an area through noteworthy but concisely reported findings, new methodologies, extensions of prior research across populations, or informative replication efforts. For manuscripts that require longer descriptions of methods and results, authors should use the empirical article format.

Reviews focus on synthesizing existing knowledge on adolescent development in ways that solidify and advance understanding. Meta-analyses of previous empirical research are especially encouraged, but narrative reviews of research, theoretical syntheses, historic reviews, or other types of reviews are welcome.

Special sections will be considered. Before preparing a submission for a special section, submitters should email

APPENDIX B

Author Guidelines: American Journal of Human Biology

AUTHOR GUIDELINES

SECTIONS

1. Submission
2. Aims and Scope
3. Manuscript Categories and Requirements
4. Preparing the Submission
5. Editorial Policies and Ethical Considerations
6. Author Licensing
7. Publication Process After Acceptance
8. Post-Publication
9. Journal Contact Details

1. SUBMISSION

Authors should kindly note that submission implies that the content has not been published or submitted for publication elsewhere except as a brief abstract in the proceedings of a scientific meeting or symposium.

Once the submission materials have been prepared in accordance with the Author Guidelines, manuscripts should be submitted online via the journal online editorial system. If you do not have online access, contact the journal at AJHB@anthro.umass.edu before submission.

By submitting a manuscript to or reviewing for this publication, your name, email address, and affiliation, and other contact details the publication might require, will be used for the regular operations of the publication, including, when necessary, sharing with the publisher (Wiley) and partners for production and publication. The publication and the publisher recognize the importance of protecting the personal information collected from users in the operation of these services, and have practices in place to ensure that steps are taken to maintain the security, integrity, and privacy of the personal data collected and processed. You can learn more at <https://authorservices.wiley.com/statements/data-protection-policy.html>.

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2. AIMS AND SCOPE

The American Journal of Human Biology is the official journal of the Human Biology Association. *The American Journal of Human Biology* is a bimonthly, peer-reviewed, internationally circulated journal that publishes reports of original research, theoretical articles, timely reviews, and brief

communications in the interdisciplinary field of human biology. As the official journal of the Human Biology Association, the Journal also publishes abstracts of research presented at its annual scientific meeting and book reviews relevant to the field.

The Journal seeks scholarly manuscripts that address all aspects of human biology, health, and disease, particularly those that stress comparative, developmental, ecological, or evolutionary perspectives. The transdisciplinary areas covered in the Journal include, but are not limited to, epidemiology, genetic variation, population biology and demography, physiology, anatomy, nutrition, growth and aging, physical performance, physical activity and fitness, ecology, and evolution, along with their interactions. The Journal publishes basic, applied, and methodologically oriented research from all areas, including measurement, analytical techniques and strategies, and computer applications in human biology.

Like many other biologically oriented disciplines, the field of human biology has undergone considerable growth and diversification in recent years, and the expansion of the aims and scope of the Journal is a reflection of this growth and membership diversification.

The Journal is committed to prompt review, and priority publication is given to manuscripts with novel or timely findings, and to manuscripts of unusual interest.

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3. MANUSCRIPT CATEGORIES AND REQUIREMENTS

Research reports should be prepared as one of two types: Short Reports or Original Research Articles. In addition, the Journal regularly solicits Feature Articles from noted experts on timely topics.

Short Reports: Short reports are presentations of original research findings of a focused nature. They should not exceed 1,500 words or text, inclusive of abstract, and include no more than 2 tables or figures and no more than 15 references. Short reports will be given expedited review in order to maintain the shortest possible time to decision and publication.

Original Research Articles: Original articles include presentation of results from more complex research designs and those with more important theoretical or methodological content or implications. While there are no standard limitations on the length of original articles, authors are cautioned to be concise in their presentations and to employ tables and figures only as necessary.

Feature Articles: Feature articles may be solicited on topics of current interest from noted experts. Since it is hoped that these articles will prove useful as teaching materials, authors are encouraged to include clear illustrations and extensive bibliographies. The format of feature

articles need not follow the standard organization for research reports, described below, but may be adapted to the content at hand.

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4. PREPARING THE SUBMISSION

Parts of the Manuscript

The manuscript should be submitted in separate files: main text file; figures; supporting information (if needed).

Main Text File

The text file should be presented in the following order:

- i. A short informative title that contains the major key words. The title should not contain abbreviations (see Wiley's best practice SEO tips);
- ii. A short running title of less than 48 characters;
- iii. The full names of the authors;
- iv. Each author's institutional affiliation where the work was conducted, with a footnote for the author's present address if different from where the work was conducted;
- v. Abstract and keywords;
- vi. Main text;
- vii. Acknowledgements;
- viii. Author Contributions
- ix. References;
- x. Tables (each table complete with title and footnotes);
- xi. Figure Legends;
- xii. Appendices (if relevant).

Figures and supporting information should be supplied as separate files. Footnotes are not to be used except for tables and figures.

Authorship

Please refer to the journal's authorship policy the Editorial Policies and Ethical Considerations section for details on eligibility for author listing.

Acknowledgments

Contributions from anyone who does not meet the criteria for authorship should be listed, with permission from the contributor, in an Acknowledgments section. Financial and material support should also be mentioned. Thanks to anonymous reviewers are not appropriate.

Conflict of Interest Statement

Authors will be asked to provide a conflict of interest statement during the submission process. For details on what to include in this section, see the section ‘Conflict of Interest’ in the Editorial Policies and Ethical Considerations section below. Submitting authors should ensure they liaise with all co-authors to confirm agreement with the final statement.

Abstract

Please provide an abstract of 250 words or fewer containing the major keywords summarizing the article.

The abstract should include the following sections:

- Objectives: A succinct statement of the goal(s) of the research.
- Methods: A brief description of the study design, materials, subjects, data collection, and statistical or other analysis methods used.
- Results: A brief description of the principal findings.
- Conclusions: A brief statement of the conclusions drawn relative to the objectives of the study.

Keywords

Please provide three to five keywords.

Main Text

- The Journal uses US spelling; however, authors may submit using either option, as spelling of accepted papers is converted during the production process.
- Articles may range from approximately 2,500 to 6,000 words.

References

As of 2017, the references of the journal should be prepared according to the *Publication Manual of the American Psychological Association* (APA) (6th edition). This means in text citations should follow the author-date method whereby the author's last name and the year of publication for the source should appear in the text, for example, (Jones, 1998). Use of et al. is determined by the number of authors and whether it is the first time a reference has been cited in the paper.

Specifically, articles with one or two authors include all names in every in-text citation; articles with three, four, or five authors include all names in the first in-text citation but are abbreviated to the first author name plus et al. upon subsequent citations; and articles with six or more authors are abbreviated to the first author name plus et al. for all in-text citations.

The complete reference list should appear alphabetically by name at the end of the paper. Please note that for journal articles, issue numbers are not included unless each issue in the volume begins with page 1, and a DOI should be provided for all references where available (though it is not required). For more information about APA referencing style, please refer to the APA FAQ.

Reference examples follow:

Journal article

Phelps, L. (1996). Discriminative validity of the WRAML with ADHD and LD children. *Psychology in the Schools*, 33, 5-12.

Book Edition

Bradley-Johnson, S. (1994). Psychoeducational assessment of students who are visually impaired or blind: Infancy through high school (2nd ed.). Austin, TX: Pro-ed.

Footnotes

Footnotes should be placed as a list at the end of the paper only, not at the foot of each page. They should be kept to a minimum. Keep footnotes brief; they should contain only short comments tangential to the main argument of the paper and should not include references. They should be numbered in the list and referred to in the text with consecutive, superscript Arabic numerals.

Tables

Please ensure that each table is referred to in the main text of the manuscript. Tables should be self-contained and complement, not duplicate, information contained in the text. They should be supplied as editable files, not pasted as images. Legends should be concise but comprehensive – the table, legend, and footnotes must be understandable without reference to the text. All abbreviations must be defined in footnotes. Footnote symbols: †, ‡, §, ¶, should be used (in that order) and *, **, *** should be reserved for P-values. Statistical measures such as SD or SEM should be identified in the headings.

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Legends should be concise but comprehensive – the figure and its legend must be understandable without reference to the text. Include definitions of any symbols used and define/explain all abbreviations and units of measurement.

Figures

Although authors are encouraged to send the highest-quality figures possible, for peer-review purposes, a wide variety of formats, sizes, and resolutions are accepted. [Click here](#) for the basic figure requirements for figures submitted with manuscripts for initial peer review, as well as the more detailed post-acceptance figure requirements.

Figures submitted in color may be reproduced in color online free of charge. Please note, however, that it is preferable that line figures (e.g., graphs and charts) be supplied in black and white so that they are legible if printed by a reader in black and white.

Additional Files

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Appendices will be published after the references. For submission they should be supplied as separate files but referred to in the text.

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Supporting information is information that is not essential to the article, but provides greater depth and background. It is hosted online and appears without editing or typesetting. It may include tables, figures, videos, datasets, etc.

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Note: if data, scripts, or other artefacts used to generate the analyses presented in the paper are available via a publicly available data repository, authors should include a reference to the location of the material within their paper.

General Style Points

The following points provide general advice on formatting and style.

- **Abbreviations:** In general, terms should not be abbreviated unless they are used repeatedly and the abbreviation is helpful to the reader. Initially, use the word in full, followed by the abbreviation in parentheses. Thereafter use the abbreviation only.
- **Units of measurement:** Measurements should be given in SI or SI-derived units. Visit the Bureau International des Poids et Mesures (BIPM) website for more information about SI units.
- **Numbers:** numbers under 10 are spelt out, except for: measurements with a unit (8mmol/l); age (6 weeks old), or lists with other numbers (11 dogs, 9 cats, 4 gerbils).
- **Trade Names:** Chemical substances should be referred to by the generic name only. Trade names should not be used. Drugs should be referred to by their generic names. If proprietary drugs

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5. EDITORIAL POLICIES AND ETHICAL CONSIDERATIONS

Peer Review and Acceptance

The acceptance criteria for all papers are the quality and originality of the research and its significance to journal readership. Papers will only be sent to review if the Editor-in-Chief determines that the paper meets the appropriate quality and relevance requirements.

Wiley's policy on the confidentiality of the review process is available here.

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The journal encourages authors to share the data and other artefacts supporting the results in the paper by archiving it in an appropriate public repository. Authors should include a data accessibility statement, including a link to the repository they have used, in order that this statement can be published alongside their paper.

Human Studies and Subjects

For manuscripts reporting medical studies that involve human participants, a statement identifying the ethics committee that approved the study and confirmation that the study conforms to recognized standards is required, for example: Declaration of Helsinki; US Federal Policy for the

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Participant anonymity should be preserved. Photographs need to be cropped sufficiently to prevent human subjects being recognized (or an eye bar should be used). Images and information from individual participants will only be published where the authors have obtained the individual's free prior informed consent. Authors do not need to provide a copy of the consent form to the publisher; however, in signing the author license to publish, authors are required to confirm that consent has been obtained. Wiley has a standard patient consent form available for use.

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- UK authors should conform to UK legislation under the Animals (Scientific Procedures) Act 1986 Amendment Regulations (SI 2012/3039).
- European authors outside the UK should conform to Directive 2010/63/EU.

Clinical Trial Registration

The journal requires that clinical trials are prospectively registered in a publicly accessible database and clinical trial registration numbers should be included in all papers that report their results. Authors are asked to include the name of the trial register and the clinical trial registration number at the end of the abstract. If the trial is not registered, or was registered retrospectively, the reasons for this should be explained.

Research Reporting Guidelines

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- The Gold Standard Publication Checklist from Hooijmans and colleagues
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Upon its first use in the title, abstract, and text, the common name of a species should be followed by the scientific name (genus, species, and authority) in parentheses. For well-known species, however, scientific names may be omitted from article titles. If no common name exists in English, only the scientific name should be used.

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Nucleotide sequence data can be submitted in electronic form to any of the three major collaborative databases: DDBJ, EMBL, or GenBank. It is only necessary to submit to one database as data are exchanged between DDBJ, EMBL, and GenBank on a daily basis. The suggested wording for referring to accession-number information is: 'These sequence data have been

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- EMBL Nucleotide Archive: ebi.ac.uk/ena
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<Author Guidelines updated June 20, 2018>

APPENDIX C

Author Guidelines: Annals of Human Biology

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APPENDIX D

Author Guidelines: Journal of Human Biology

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- Contents
- Submissions
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- General
- References
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- Addendum
- Submissions
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The second page should contain the abstract of the paper (500 words maximum). The abstract should give a summary of the article and not be merely descriptive of it. For example, state the results and the conclusions; do not use such phrases as "The results are discussed in terms of

epidemiology.” The prereview made by the editors is based solely on the abstract and title; therefore the abstract should be exhaustive and informative.

On the third page of the manuscript you should start the actual text. The text should contain the following sections: an introduction (untitled) outlining the background of your topic and stating your purpose in writing the present article; the materials and methods (the study population, statistical methods, measurement methods, etc.); the results; and a discussion, followed by a perspectives section, if needed. After the main text of your article, you should include a complete list of Literature Cited. In the text, you should cite references by author and date. In the Literature Cited section references should be in alphabetical order by author. The Literature Cited should include all references cited in the text, figure captions, and tables. Please do not pad your list with papers you do not cite. Following the Literature Cited section are the tables and the figure captions.

References

Each reference in the Literature Cited section should be complete. For journal articles this means that you should include the names of the first three authors (and then “et al.” to indicate more than three authors), date, title of article, journal title (abbreviated according to Index Medicus, or spelled out completely if the journal is not listed in the Index), volume number, and inclusive page numbers.

Example: Smith, J. 2008. Distribution of haplogroups in Indian populations. *Hum. Biol.* 90:115.

For chapters in a book you must list the names of the first three authors, date, title of chapter, title of book, editors of book, publisher and its location (city and state if in the United States; city and country otherwise), volume number if necessary, and inclusive page numbers.

Example : Jones, M. 2008. Overview. In *Distribution of Haplogroups in India*, J. Smith and N. Brown, eds. Detroit, MI: Wayne State University Press, 122.

If you are referencing an entire book, include the names of the first three authors (or editors), date, title, and publisher and its location.

Example : Smith, J., and N. Brown, eds. *Distribution of Haplogroups in India*. Detroit, MI: Wayne State University Press.

Other types of references (technical reports, dissertations, etc.) should always include as much information as possible: the names of the first three authors (sometimes the author might be a corporation or an organization), date, title, publishing organization and its location, number of report, name of university and its location, series designation, etc. Articles appearing in conference proceedings should be treated as chapters in a book; that is, you should list the names of the first three authors, date, title of article, title of conference proceedings book (not the name of the conference, where it was held, and on what date), editors of the proceedings, publisher (probably the organization that sponsored the conference) and its location, and volume and page numbers.

Tables

You should place the tables after the Literature Cited section. Each table should be placed on a separate page, double-spaced, in Human Biology style. Use the table function in Word if at all possible (if you cannot use the table function, then use tabs between entries to make the columns; do not insert a series of spaces). Do not use vertical or slant rules. Keep in mind that the table should not contain more columns of data than will fit on a printed page turned sideways. The tables should be numbered sequentially in the order they are to appear. Make sure that each table is cited in the text in sequential order. Each column should have a heading, and all units should be clearly marked (% , cm, etc.).

Figures and Figure Captions

After the tables should be a list of figure captions. Because the figure captions are typeset, they should not be part of the actual illustrations. They should be placed on a separate page as you would the text, that is, double-spaced. You do not have to use a separate page for each caption. All illustrations should be numbered sequentially. Keys and other internal matter should be lettered on the figure, or if possible, included in the figure caption.

Photographs should be supplied as high-resolution TIF or JPG files. Resolution should be approximately 300 dpi at actual printed size (i.e., the size when printed in the journal).

The ideal format for figures, charts, and graphs is a "vector" format (i.e., Adobe Illustrator .AI or .EPS files, or a vector .PDF file), as this allows the most flexibility for re-sizing as required for the journal, and the best possible quality when printing. If a vector format is not available, then please send a high-resolution TIF or JPG. Please make sure that legends, axis labels, and other text elements are of sufficient size to be readable when re-sized to fit the journal layout.

Reviewed Books

Books produced by North American and international publishers should be sent for review to Ripan Malhi, Department of Anthropology, 607 S Matthews Ave., M/C 148, Urbana, IL 61801.

Addendum

It is the style of Human Biology to use the Human Gene Mapping Workshop nomenclature for genetic systems. This nomenclature system and its terminology are explained by Shows et al. in their article “Guidelines for Human Gene Nomenclature: An International System for Human Gene Nomenclature (ISGN, 1987)” [Cytogenet. Cell Genet. 46:1128 (1987)]. In addition, the abbreviations for specific alleles, enzymes, markers, etc. are given by McAlpine et al. [“Report of the Nomenclature Committee and the 1989 Catalog of Mapped Genes,” Cytogenet. Cell Genet. 51:1366 (1989)]. It is also the style of the journal to use metric units. In addition, symbols, diacritical marks, and other unusual characters should be clearly marked on the manuscript. Also be sure to distinguish between the number “1,” the letter “l,” and the letter “I” if you are using a sans serif typeface.

APPENDIX E

Ethical Documentation and Informed Consent forms



18 Januarie 2009

Ingeligte toestemming vir deelname aan sportprojek

Beste ouers,

Mnr. Oosthuizen het toestemming verleen dat die Graad 8 leerders van Gimmies aan hierdie projek kan deelneem. Die Noordwes Universiteit (NWU) se Skool vir Biokinetika, Rekreasie en Sportwetenskap bied aan alle Graad 8 leerders die geleentheid om kosteloos talentidentifiseringstoetse af te lê ten einde die onderbou van elke kind se liggamsamestelling, motoriese, fisieke en sportpsigologiese samestelling te kan bepaal. Hieruit kan elke deelnemer se moontlike potensiaal in sekere sportsoorte vasgestel word. Die toetsprotokol sal bestaan uit 11 fisieke (wat 4 groei metings insluit) en motoriese toetse asook 'n sportpsigologiese en algemene sportdeelname vraelys om sodoende 'n fisieke sowel as 'n sportpsigologiese profiel van elke deelnemer te kan saamstel. Na afloop van die toetsings (nadat die resultate verwerk is), sal elke deelnemer 'n verslag ontvang met betrekking tot die resultate wat hy/sy behaal het gedurende die toetsings. Aangesien die ouderdomstydperk waarin u kind tans verkeer, gekenmerk word aan geweldige groeiveranderinge wat veral die fisieke profiel van 'n kind (positief maar ook negatief) kan beïnvloed, sal die toetse weer in Graad 9 en 10 herhaal word ten einde hierdie effek op die kinders se ontwikkeling en sportdeelnameprofiel te monitor en aan die kind te kan verduidelik.

Die toetsings sal tydens skoolure op 25 Januarie (drie graad 8 klasse) of 26 Januarie (drie graad 8 klasse) in klasverband plaasvind by die Hoë Prestasie Sportinstituut (HPI) van die NWU (aan die oorkant van Gimmies en onder toesig van die skool). Kinders moet asseblief op die betrokke dag in sportdrag geklee wees. Deelname is vrywillig. Die kind en die skool kan egter net voordele uit deelname aan die projek verkry, en ons vra gevolglik dat u toestemming sal verleen vir u kind tot deelname. Voltooi asseblief die vorm en stuur asseblief dadelik saam met u kind terug skool toe.

Hiermee verleen ek, ouer van.....(naam van kind) toestemming dat hy/sy aan die sportprojek kan deelneem.

Handtekening van ouer: _____

Handtekening van kind: _____

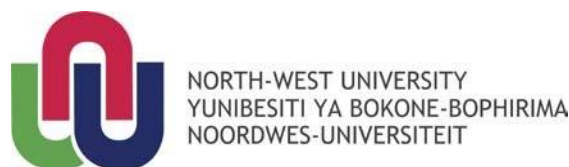
Enige navrae kan gerig word aan:

Prof. Anita Pienaar (Kinderkinetikus) 018 299 1796

Dr. Ankebé Kruger (Sportwetenskaplike) 018 299 1793

Me. Ri-Ellen Kemp (Sportwetenskaplike) 018 299 2856

Mnr. Barry Gerber (Kinderkinetikus) 018 299 1773



Private Bag X6001, Potchefstroom

• South Africa 2520

• **Tel: (018) 99-4900**

• **Faks: (018) 299-4910**

Web: <http://www.nwu.ac.za>

• **Institutional Research Ethics
Regulatory Committee**

Tel +27 18 299 4849

Email Ethics@nwu.ac.za

• **ETHICS APPROVAL CERTIFICATE OF FULL SINGLE APPLICATION**

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: Growth and sport psychological characteristics of talented adolescent boys and girls – A 3 year longitudinal study.															
Project Leader: Prof AE Pienaar Student: BP Gerber															
Ethics number:	N	W	U	-	0	0	1	9	9	-	1	5	-	A	1
	Institution				Project Number				Year		Status				
	Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation														
Approval date: 2016-02-22					Expiry date: 2017-02-21					Risk		Minimal			

Further conditions of the approval (if any):

- x Translation of the informed consent document to the languages applicable to the study participants should be submitted to the HREC (if applicable).
- x Any research at governmental or private institutions, permission must still be obtained from relevant authorities and provided to the HREC. Ethics approval is required BEFORE approval can be obtained from these authorities.
- x Any further information and any report templates is obtainable from Carolien van Zyl at Carolien.VanZyl@nwu.ac.za.

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:

- x The project leader (principle investigator) must report in the prescribed format to the NWU-IRERC and HREC:
 - annually (or as otherwise requested) on the progress of the project, and upon completion 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. – Annually a number of projects may be randomly selected for an external audit.
- x 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 HREC and 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.
- x 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.
- x In the interest of ethical responsibility the NWU-IRERC and HREC retains the right to:
 - request access to any information or data at any time during the course or after completion of the project;
 - to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process.
 - 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

Linda du Plessis

Digitally signed by Linda du Plessis
DN: cn=Linda du Plessis, o=NWU, ou=Vaal Triangle Campus,
email=linda.duplessis@nwu.ac.za,

• Plessis c=ZA

Date: 2016.03.15 11:48:27 +02'00'

Prof Linda du Plessis
Chair NWU Institutional Research Ethics Regulatory Committee (IRERC)

APPENDIX F

Test Scoring Sheet

TOETSPROTOKOL

ALGEMENE INLIGTING	Proefpersoon nr:							
Naam en van:								
Geboortedatum:	D	D	M	M	J	J	J	J
Ras:	B		S		L		I	
Skool:								
TOETSPROTOKOL	DATUM:		DATUM:		DATUM:			
Massa:	kg		kg		kg			
Lengte:	cm		cm		cm			
Sithoogte:	cm		cm		cm			
Armspan:	cm		cm		cm			
Basketbalgooi (m):	1				2			
Krieketbalgooi (m):								
Vangtoets (n):	R /10				L /10			
Vertikale sprong (cm):	Staan							
	Spring		1		2			
Ratsheid (sek):	1				2			
Spoed (sek):	0-10m				0-40m			
	1				1			
	2				2			
Beep (n):								

APPENDIX G

Proof of Submission of Paper for Possible Publication

----- Original message -----

From: Marvin Nercua <em@editorialmanager.com>

Date: 2018/11/16 12:28 (GMT+02:00)

To: Barend Gerber <gerber.barry@gmail.com>

Subject: Cogent Social Sciences | Your submission COGENTSOCSCI-2018-0380

Ref: COGENTSOCSCI-2018-0380

Two year follow-up of differences in anthropometric growth of pre- and post menarcheal girls:
Implications for sport participation
Cogent Social Sciences

Dear Mr. Barend Gerber,

Thank you for submitting 'Two year follow-up of differences in anthropometric growth of pre- and post menarcheal girls: Implications for sport participation' to Cogent Social Sciences. As you know, Cogent Social Sciences has a Freedom APC model, which allows you to select the amount you can afford when you submit. We have now considered your request for a waiver and as South Africa is not categorized by the World Bank as a low-income country, unfortunately you do not meet our eligibility criteria and we are unable to grant your waiver on this occasion.

If, however, you are able to pay an APC of \$675 to support sustainable open access publishing, representing a 50% discount from the recommended APC, please get back to us by 23rd November 2018.

Best regards,

Lesny Hernandez

On behalf of

Marvin Nercua - Journal Editorial Office

On behalf of Cogent Social Sciences

Taylor & Francis Group

4 Park Square | Milton Park | Abingdon | Oxon | OX14 4RN | UK

Web: www.cogentoa.com

e-mail: socialsciences@cogentoa.com

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In compliance with data protection regulations, please contact the publication office if you would like to have your personal information removed from the database.

American Journal of Human Biology - Manuscript number AJHB-19-0032

Inbox



AJHB Editorial Office <onbehalf@manuscriptcentral.com> Wed, Jan 30,
3:38 PM (23
hours ago)

to me, Anita.Pienaar, Ankebe.Kruger

30-Jan-2019

Dear Mr. Gerber,

Your manuscript entitled "Differences in strength and aerobic endurance in pre- and post-menarche girls during mid-adolescence: A two-year follow-up study" 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-19-0032. Please mention this number in all future correspondence regarding this submission.

If you believe you have been listed as a co-author in error, you have not provided the written permission that is required for assignment of the Contribution to the formal corresponding author, or have any other concerns, please contact the Editorial Office immediately at AJHB@anthro.umass.edu . You may also reply to this e-mail, preferably leaving the subject line intact.

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 the top right corner of the site.

Thank you for submitting your manuscript to the American Journal of Human Biology.

Sincerely,

American Journal of Human Biology Editorial Office

Annals of Human Biology - Manuscript ID TAHB-2019-0025

Inbox



Annals of Human Biology <onbehalf@manuscriptcentral.com> Thu, Jan 31, 4:44 PM

to me

31-Jan-2019

Dear Mr. Gerber:

Your manuscript entitled "Differences in motor fitness capabilities of pre- and post-menarche girls during mid-adolescence: A two-year follow-up study" has been successfully submitted online and is presently being given full consideration for publication in Annals of Human Biology.

Your manuscript ID is TAHB-2019-0025.

Please mention the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your postal address or e-mail address, please log in to ScholarOne Manuscripts at <https://mc.manuscriptcentral.com/tahb> and edit your user information as appropriate.

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- paper is not under consideration elsewhere;
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Thank you for submitting your manuscript to Annals of Human Biology.

Yours sincerely,
Rachel Deevey

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APPENDIX H

Description of test Items

- ISAK (International Standards for Anthropometric Assessment) (Stewart *et al.*, 2011)
- Canadian Sport for Life protocol (Simmons, 2000)
- “Sport Search Program” (Australian Sports Commission, 1995)
- Topendsports, 2012

Anthropometric measurements

- 1. ISAK (International Standards for Anthropometric Assessment) (Stewart *et al.*, 2006)**
- 2. Canadian Sport for Life (CS4L) (Simmons, 2000)**

The protocol as developed by the International Society for the Advancement of Kinanthropometry (ISAK) was used for stature and body mass measurements (Stewart, Marfell-Jones, Old & de Ridder, 2011). Sitting height was determined by a modified method (Simmons, 2000) and arm span according to the Canadian Sports for Life protocol (Balyi & Way, 2010). All researchers were trained level 2 Kinanthropometrists (theory and practical training), ranging from honours students to senior researchers in Kinderkinetics and Sport Science. Furthermore, these researchers were equipped with all necessary skills and knowledge beforehand to perform these measurements. All measurements were taken behind enclosed spaces to ensure the privacy of the participants and were taken by researchers of the same gender as those of the participants. Participants had to wear minimal clothing during measurements.

Stature and Sitting height

Stature and Sitting height was measured to the nearest 0.1cm by means of a portable Harpenden stadiometer (Harpenden Holtain Ltd, Crymych, UK). Stature was measured with the subject standing, facing forward, with the heels, back and head against the stadiometer and with feet standing together. The head was held in the Frankfort position by the examiner, and the measurement was taken after the subject had inhaled deeply, to the nearest 0.1 cm. Two measurements were taken, of which an average value was used (Stewart *et al.*, 2011). Inter-measurement reliability for stature was calculated as 0.98. Sitting height was measured by having the subject sit flat on the stadiometer with the back against the stadiometer and knees bent at about 90 degrees. The head of the subject was held in the Frankfort position by the examiner, and the measurement was taken to the nearest 0.1 cm while the subject had to inhale deeply (Simmons, 2000).

Mass

Mass was measured by means of an electronically calibrated scale (Omro BF 511). The subject stood upright with weight evenly distributed over the scale with the arms at the sides of the body. The subject had to look straight forward while standing without shoes and as little clothing as possible and the measurement was then taken to the nearest 0.1 kg (Stewart *et al.*, 2011).

Arm span

Arm span was measured by attaching a tape measure horizontally against a wall at about shoulder height of the subject with the starting point of the tape in a corner of a wall. The subject stood upright, with the front of the body and the toes against the wall. The arms had to be extended horizontally, with the palms facing the wall and the head turned to the left. The measurement was taken to the nearest 0.1 cm (Balyi & Way, 2010).

Leg length

Leg length was calculated by subtracting the sitting height value from the stature value. Sitting height ratio was calculated by using the following formula: Height/sitting height x 100.

BMI

The body mass index (BMI) is a statistically developed equation developed by Adolphe Quetelet in the 1900's for evaluating body mass and is not related to gender and age. BMI was calculated by applying the following equation: Body mass in kilograms divided by height in meters squared or, $BMI = x \text{ KG} / (y \text{ M} * y \text{ M})$ (x=body mass in KG, y=height in M).

Sport Search Program ”(Australian Sports Commission, 1995)

The Australian Sport Search Program protocol, commonly used in Australia for sports talent identification in children of 12 years and older was used (Australian Sport Commission 1996). The test protocol involves ten tests consisting of four anthropometric (length, mass, sitting height and arm span) and six physical and motor tests (beep test, basketball throw, 40m speed test, 10m agility test, vertical jump and throw-and-catch-test). All motor tests were conducted according to this protocol. In addition, girls of 0-10m speed were also tested.

Physical fitness capabilities

Aerobic endurance

The multistage Beep-test was used to test aerobic endurance (Australian Sports Commission, 1996). This is a 20-meter running test with a progressive increase in intensity/speed each time a new level is reached after a one minute duration. Subjects are instructed to run to the opposite side and place one foot behind the by the time the next beep sounds and wait for the beep to start running again back and forth. Subjects continues running for as long as possible until they can no

longer keep up with the intensity and did not reach the line two consecutive times before the beep sounded. The result of the beep-test is noted as the total "shuttles" and levels completed (Australian Sports Commission, 1996). Absolute and relative $\dot{V}O_2\text{max}$ were calculated from these scores. Absolute $\dot{V}O_2\text{max}$ (maximal oxygen uptake per minute measured in ml/kg/min taking a person's body weight into consideration) was calculated by using the equation $\dot{V}O_2\text{max} = 41.76799 + (0.49261 \times \text{PACER}) - (0.00290 \times \text{PACER}^2) - (0.61613 \times \text{BMI}) + (0.34787 \times \text{Gender} \times \text{Age})$ (Matsuzaka, 2004). Relative $\dot{V}O_2\text{max}$ (maximal oxygen uptake per minute) was calculated in ml/min without taking body weight into consideration.

Motor fitness capabilities

Basketball throw

The basketball throw is designed to measure upper body strength. The subject sits with the buttocks, back and head resting against a wall, with the legs horizontally on the floor in front of the body. The subject uses a two-handed chest pass to push the ball (size 7 ball) in a horizontal direction as far forward as possible. The measurement is taken to the nearest 5cm. Each subject is allowed two trials and the best trial is recorded (Australian Sports Commission 1996).

10m and 40m speed test

Anaerobic ability was measured using the Fusion Sport Smart Speed System (Fusion Sport Pty Ltd, 2009) developed in Brisbane, Australia. All subjects underwent a thorough warm-up session beforehand. The test included 4 speed lights, namely 0m, 5 m, 10m and 40m. Only the time of 0-10m and 0-40m were used. The test is performed from a standing position from where the subject had to accelerate to the last measuring speed light. The better of two attempts is recorded and expressed in seconds to the nearest 0.01 second. The subject receives two attempts, with two minutes of rest between efforts.

10m agility test

The 10m agility test is completed between markers placed five metres apart on a hard surface. The subject starts standing behind one line with the front foot on the line. On command "go" the subject runs as fast as possible to the other line, pivots, while both feet must touch behind the line, and returns to the starting line. This constitutes one cycle, with five required in total. Two attempts are given, with 2 minutes of rest in between, and the best effort is then scored with a calibrated

stopwatch and expressed in seconds to the nearest 0.01 second (Australian Sports Commission 1996).

Vertical jump

The vertical jump test is a test of explosive leg strength. The subject has to stand upright and stretch as high as possible against a wall while the feet remain flat on the ground. The distance (reaching height) is taken to the nearest 1cm. The subject then goes into a crouch position with the preferred hand raised vertically, and the non-preferred hand held by the side (not allowed to swing arms for momentum) and jumps upward and touches the wall at the highest point possible. The “vertical jump height” is recorded to the nearest 1cm. The subject receives two attempts, with approximately 30 seconds of rest in between attempts, and the best result is recorded in centimetres. Lastly, the reaching height is subtracted from the vertical jump height to obtain the vertical jump distance (Australian Sports Commission 1996).

Throw-and-catch test

The throw and catch test for accuracy consists of 20 underhand tosses, where ten throws are first thrown and caught with the dominant hand followed with ten throws with the non-dominant hand. The subject is instructed to throw a tennis ball with the preferred hand towards the target (circle target, 30cm diameter) that is 2.5m away and attempt to catch the ball with the same hand. Practice trials are allowed until the subjects demonstrate that they understand the instructions. The ball must be thrown underarm and is not allowed to bounce before being caught. Each trial is only successful if the ball hits the target and the subject catches the ball cleanly (not trapped) (Australian Sports Commission 1996).

Topendsports, 2012

Strength

The cricket ball throw for distance was used to test upper-body shoulder and chest strength. During the cricket ball throw test, the subject had a 10m run-up to throw a cricket ball (224mm, 156 grams) as far as possible. During the run-up before the throwing action, the subject was not allowed to touch or cross the starting line from where the measurement was taken. Each subject received two attempts, and the best attempt was recorded in meters (Topendsport, 2012).

APPENDIX I

Proof of Language Editing



Antoinette Bisschoff
71 Esselen Street,
Potchefstroom
Tel: 018 293 3046
Cell: 082 878 5183
Language@dlts.co.za
CC No: 1995/017794/23

Monday, 29 April 2019

To whom it may concern

**1. RE: CONFIRMATION OF LANGUAGE EDIT, TYPOGRAPHY AND
TECHNICAL PRECISION**

The PhD dissertation of Barry Gerber was edited for language, typography and technical precision. The referencing and sources were not checked as per request.

Final, last minute corrections remain the responsibility of the author.



**2. ANTOINETTE BISSCHOFF BA LANGUAGES (UPE – NOW NMU);
MBA (PU FOR CHE – NOW NWU); TRANSLATION AND LINGUISTIC
STUDIES (NWU)**

Officially approved language editor of the NWU since 1998
Member of SA Translators Institute (no. 100181)

Director: CME Terblanche - BA (Pol Sc), BA Hons (Eng), MA (Eng), TEFL
22 Strydom Street
Baillie Park, 2531
Tel 082 821 3083
cumlaudelanguage@gmail.com

DECLARATION OF LANGUAGE EDITING

I, Christina Maria Etrechia Terblanche, hereby declare that I edited the
research chapter titled:

**LITERATURE REVIEW: RELATIONSHIPS BETWEEN MENARCHE,
ANTHROPOMETRIC GROWTH AND PHYSICAL AND MOTOR FITNESS
CAPABILITIES**

for **Barry Gerber** for the purpose of inclusion as a chapter of a
postgraduate study. Changes were indicated in track changes and
implementation was left up to the author.

Regards,



CME Terblanche

Cum Laude Language Practitioners (CC)

South African Translators Institute accr nr: 1001066

Full member of the Professional Editors Guild