

# **Selected anthropometric, physical and motor performance predictors of lower body explosive power in adolescents: the PAHL study**

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Dissertation submitted in fulfilment of the requirements for the degree *Magister Scientiae* in Sport Science at the Potchefstroom Campus of the North-West University

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# FOREWORD

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I would like to give thanks to the following special people in my life for always being there in any way uniquely contributing to make this all possible. All of my gratitude and admiration for all of your help, support and commitment to my hopes, dreams and aspirations. You were there always, and when I needed it most.

Firstly, thank you to my parents for making this all possible. Thank you for believing in me and giving me the freedom to pursue my interest and love. Thank you for all the seen and unseen you have done for me and poured into me. It took years of your sacrifice and love to get me where I am today. If it wasn't for you, I wouldn't have even made it to this starting point.

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To all of my friends and Potchefstroom family. Thank you for always having an open door and warm hearts. You always listened to me attentively, believed in me and encouraged me.

## Foreword

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To Kobie Enslin. As you know I always emphasize that words can be empty, that words can't be enough. It has got to be supported with actions. You have done this, and you have given your words life, love, meaning and colour. From the beginning you have stood by me in more ways than one, always being there. You were there in the hard times, and the not so hard times. You showed to me what was in your heart, and your words uplifted me. Thank you! My words may not be enough, but I aspire to give my words towards you meaning, love, life and colour forever more down our adventure together!

Then last but definitely not the least, my Beginning and my End. Thank you to my Heavenly Father Jahuah! Thank you for always keeping Your hand of guidance, Wisdom and blessings over me. Thank you for never letting go and removing your hand from me, for without your love nothing I would undertake would be a success, and therefore futile. For your love for me is forever more, and my heart and life belongs to you alone. This Masters degree is dedicated and offered to You and You alone...

***“He found him in a dessert land, and in the wasteland, a howling wilderness; He encircled Him, He instructed Him, He kept him as the apple of His eye.” – Deut 32:10***

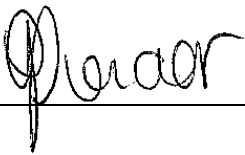
***“And Jesus increased in wisdom and stature, and in favour with God and man.”***

***– Luk 2:52***

# DECLARATION

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The co-authors of the two articles, which form part of this dissertation, Dr Cindy Pienaar (Supervisor) and Dr Ankebé Kruger (Co-supervisor) hereby gives permission to the candidate, Mr Koert van der Walt, to include the two articles as part of his Masters dissertation. The contribution (advisory and supportive) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this dissertation for examination purposes. Prof Andries Monyeki (co-author) contributed within reasonable limits to chapter 3 and Prof Ben Coetzee (Assistant supervisor) to chapters 2 and 4. This dissertation, therefore, serves as fulfilment of the requirements for the Magister Scientiae degree in Sport Science within the Physical Activity, Sport and Recreation Research Focus Area in the Faculty of Health Sciences at the North West University (Potchefstroom campus).



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Dr Cindy Pienaar

Supervisor and co-author



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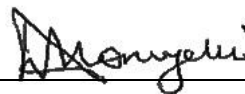
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Prof Andries Monyeki

Co-author

# SUMMARY

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## **Selected anthropometric, physical and motor performance predictors of lower body explosive power in adolescents: The PAHL study**

Lower body explosive power (LBEP) forms a critical component in any individual and team sport performance and it is therefore essential to develop a means of predicting LBEP in adolescents for early identification of future talent in various sporting codes. LBEP is frequently used by athletes during matches or competitions where explosive movements such as jumping, agility running and sprinting are required for successful performance. These movements are usually found in individual sports such as long jump and high jump as well as in team sports such as basketball, volleyball and soccer. To date not much literature is available on LBEP, especially with regard to LBEP prediction models. Furthermore, studies on adolescents are scarce and a LBEP prediction model has not yet been developed for a South African adolescent population. It is against this background that the objectives of this study were firstly, to develop a LBEP prediction model from various physical and motor performance components among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa; and secondly, to develop a LBEP prediction model from several anthropometric measurements among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.

Two hundred and fourteen ( $15.8 \pm 0.68$  years) 15-year-old adolescents (126 females, 88 males) from 6 surrounding schools within the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province of South Africa were purposefully selected from pre-acquired class lists took part in the study. Data was collected by means of various questionnaires as well as anthropometrical, physical and motor performance tests. For representation of LBEP a principal component factor analysis was done and the results indicated that the vertical jump test (VJT) was the best indicator of LBEP in the cohort of adolescents.

With regard to the anthropometrical related LBEP prediction model, the forward stepwise regression analysis yielded a correlation coefficient of  $R^2 = 0.69$ . The following variables contributed significantly ( $p \leq 0.001$ ) to the anthropometrical LBEP prediction model: stature (57%), muscle mass percentage (10%) and maturity age

## Summary

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(3%). The LBEP prediction model that was developed equated to  $LBEP (\text{vertical jump}) = -136.30 + 0.84(\text{stature}) + 0.7(\text{muscle mass percentage}) + 4.6(\text{maturity age})$ . Variables other than the variables that formed part of the study could explain the further 31% variance in the LBEP of the adolescents.

The physical and motor performance LBEP prediction model indicated that gender (39%) and 10 m speed (7%) contributed significantly ( $p \leq 0.001$ ) to the overall prediction of the LBEP of the adolescents. The LBEP prediction model delivered a stepwise forward regression analysis coefficient of  $R^2=0.458$  and a prediction formula  $LBEP = 68.21 + 9.82 (\text{gender}) - 18.33(10 \text{ m speed})$ . The remaining 56% of the variance in the results could be explained by other factors than the variables considered in the study.

In conclusion, to the best of the researchers' knowledge, this is the first study which has made an attempt at developing LBEP prediction models from the anthropometrical, physical and motor performance components of a cohort of adolescents of South Africa. The prediction models developed in the study will assist teachers sport scientists and sporting coaches who have limited resources available, to measure and calculate LBEP in adolescents, with the means to do so in South Africa. Further high quality studies are necessary to further improve and develop such prediction models for various age groups of adolescents in the greater South Africa.

**Keywords: Adolescent; Anaerobic power; Anthropometry; Explosive power; Horizontal jump; Motor and physical performance; Prediction model; Sprint; Standing broad jump test; Vertical jump**

# OPSOMMING

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## **Gekeurde antropometriese, fisieke en motoriese prestasie-voorspellers van laer liggaamseksplousiewe krag by adolessente: die PAHL studie**

Onderlyfeksplousiewe krag (OLEK: *Lower body explosive power* – LBEP) maak ’n kritieke komponent uit van alle individuele en spansportprestasie en dit is dus noodsaaklik om ’n wyse/metode te ontwikkel vir die voorspelling van OLEK by adolessente vir vroeë identifisering van toekomstige talent in verskeie sportsoorte. OLEK word dikwels tydens wedstryde of kompetisies deur atlete gebruik waarby eksplousiewe bewegings soos spring, vaardigheidshardloop en naelloop vir geslaagde prestasie vereis word. Hierdie bewegings word gewoonlik by individuele items soos verspring en hoogspring asook in spansport soos basketbal, vlugbal en sokker aangetref. Tot op hede bestaan daar nie veel literatuur oor OLEK nie, veral nie met betrekking tot OLEK-voorspellingsmodelle nie. Voorts is studies oor adolessente skaars en ’n OLEK-voorspellingsmodel is tot nog toe nie vir ’n Suid-Afrikaanse adolessentepopulasie ontwikkel nie. Dit is teen hierdie agtergrond dat die doelwitte van hierdie studie eerstens was om ’n geldige OLEK-voorspellingsmodel uit verskeie fisieke en motoriese prestasie-komponente te ontwikkel onder ’n groep adolessente wat in die Tlokwe plaaslike munisipaliteit van die Dr Kenneth Kaunda-distrik in die Noordwes Provinsie, Suid-Afrika, woonagtig is, en tweedens, om ’n geldige OLEK-voorspellingsmodel uit verskeie antropometriese metings onder ’n groep manlike en vroulike adolessente wat in die Tlokwe plaaslike munisipaliteit van die Dr Kenneth Kaunda-distrik in die Noordwes Provinsie, Suid-Afrika te ontwikkel.

Twee honderd en veertien ( $15.8 \pm 0.68$  jaar) 15-jaar oue adolessente (126 vroulik, 88 manlik) uit 6 skole in die omgewing van die Tlokwe plaaslike munisipaliteit van die Dr Kenneth Kaunda-distrik in die Noordwes Provinsie van Suid-Afrika wat doelbewus van vooraf verkreeë klaslyste geselekteer is, het aan die studie deelgeneem. Data is aan die hand van verskeie vraelyste asook antropometriese, fisieke en motorprestasie-toetse ingesamel. Ter verteenwoordiging van OLEK is ’n hoofkomponent faktoranalise uitgevoer en die resultate het aangedui dat die vertikalesprong-toets (VST) die beste aanduider van OLEK in die groep adolessente was.

Met betrekking tot die antropometries verwante OLEK-voorspellingsmodel, het die voorwaarts stapsgewyse regressie-analise 'n korrelasiekoëffisiënt van  $R^2 = 0.69$  opgelewer. Die volgende veranderlikes het betekenisvol bygedra ( $p \leq 0.001$ ) tot die antropometrie OLEK-voorspellingsmodel: lengte (57%), spiermassa-persentasie (10%) en volwassenheidsouderdom (3%). Die ontwikkelde OLEK-voorspellingsmodel gelykstaande aan OLEK (vertikalesprong-toets) =  $-136.30 + 0.84(\text{lengte}) + 0.7(\text{spiermassa-persentasie}) + 4.6(\text{volwassenheidsouderdom})$ . Veranderlikes, anders as dié wat deel van die studie uitgemaak het, kon die verdere 31%-variansie in die OLEK van die adolessente verklaar.

Die fisieke en motoriese OLEK-voorspellingsmodel het aangedui dat geslag (39%) en 10 m-spoed (7%) betekenisvol bygedra het ( $p \leq 0.001$ ) tot die algehele voorspelling van adolessente se OLEK. Die OLEK-voorspellingsmodel 'n stapsgewyse voorwaartse regressie-analisekoëffisiënt van  $R^2=0.458$  en 'n voorspellingsformule  $\text{OLEK} = 68.21 + 9.82(\text{geslag}) - 18.33(10 \text{ m-spoed})$  opgelewer. Die oorblywende 56% van die variansie in die resultate kon deur ander faktore as die veranderlikes wat in die studie oorweeg is, verklaar word.

Ten bevinding, na die beste wete van die navorsers is hierdie die eerste studie wat 'n poging aanwend om OLEK-voorspellingsmodelle uit die antropometrie, fisieke en motoriese prestasie-komponente van 'n groep adolessente van Suid-Afrika te ontwikkel. Die voorspellingsmodelle wat in die studie ontwikkel is, sal onderwysers, sportwetenskaplikes en sportafrigters wat in Suid-Afrika beperkte hulpbronne tot hul beskikking het, help om OLEK by adolessent deur middel van hierdie metodes te meet en te bereken met die bronne wat beskikbaar is. Bykomstige studies van hoë gehalte is nodig om sulke voorspellingsmodelle vir verskeie ouderdomsgroepe adolessente in die groter Suid-Afrika te verbeter en te ontwikkel.

**Sleutelwoorde: Adolessent; Anaerobiese krag; Antropometrie; Eksplosiewe krag; Horisontale sprong; Motor- en fisiese prestasie; Voorspellingsmodel; Naelloop; Staande breësprong-toets; Vertikale sprong.**

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# LIST OF ABBREVIATIONS

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%	Percentage
$\alpha$	Cronbach's alpha reliability coefficient
ASLRT	Active-straight-leg-raise-test
avg	average
b	intercept value
BJ	(Standing) Broad jump test
BMI	Body mass index
cm	centimetre
CMJ	Counter movement jump
DJ	Drop jump
$\text{g/mm}^2$	gram per square millimetre
HJT	Horizontal jump test
kg	kilogram
$\text{kg/cm}^2$	kilogram per square centimetre
$\text{kg/m}^2$	kilogram per square meter
km/h	kilometre per hour
LBEP	Lower body explosive power
m	meter
$\text{m}^2$	meter squared
m/s	meter per second
m/min	meter per minute
min/km	minute per kilometre

## List of abbreviations

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ml/kg/min	millilitre per kilogram per minute
mm	millimetre
Max	Maximum
Min	Minimum
MTIT	Modified-Thomas-Iliopsoas-test
MTQT	Modified-Thomas-Quadriceps-test
n	number of subjects in each subgroup
NWU	North-West University
p	statistical significance
PAHL Study	Physical Activity and Health Longitudinal Study
PCFA	Principal component factor analysis
PHV	Peak height velocity
PSLRT	Passive-straight-leg-raise-test
r	Pearson's correlation coefficient
R <sup>2</sup>	Standardized beta coefficient
rev/min	revolutions per minute
s (sec)	seconds
SEC	Series elastic component
SeJ	Sergeant jump
SL	Standing long jump test
SqJ	Squat jump
SRT	Sprint repeat test
SSC	Stretch-shortening cycle
steps/min	steps per minute
std	Standard deviation
StJ	Static jump
STJ	Standing triple jump
VJ	Vertical jump
VJT	Vertical jump test
VO <sub>2</sub>	Volumetrical oxygen uptake
VO <sub>2max</sub>	Maximal volumetrical oxygen uptake
W	Watt
watt/kg	watt per kg
WHR	Waist to hip ratio

# CHAPTER 1

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# 1

# INTRODUCTION

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- 1. PROBLEM STATEMENT**
  - 2. OBJECTIVES**
  - 3. HYPOTHESIS**
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## **1. PROBLEM STATEMENT**

Explosive power, or explosive muscular power during short-term exercise (Korff *et al.*, 2009:3737), is dependent on movement velocity, and is defined as the greatest rate of work achieved during a single, ballistic, resisted contraction (Saunders *et al.*, 2008:677). Performances in activities that require a single movement (such as throwing, jumping or striking) which produce high velocities at release or impact, will be directly influenced by the amount of explosive power produced (Newton & Kraemer, 1994:20). Various sports and athletic events (e.g. soccer, football, baseball, basketball, high jump, long jump and gymnastics) require sudden bursts of explosive power to accelerate, make rapid changes in direction (Newton & Kraemer, 1994:20) and for jumping (handball and volleyball) (Davis *et al.*, 2003:167; Hermassi *et al.*, 2011:125; Karahan, 2011:234; Cherif *et al.*, 2012:29 & 33). Any coach or sport scientist working with young sport participants that require lower body explosive power (LBEP) will therefore need to understand the components as well as the contribution of each of the components that determine the amount of lower body

explosive power that can be produced. Various anthropometric, physical and motor performance components related to the lower body explosive power of adolescents (12-19 years) have been identified (Armstrong *et al.*, 2001:119; Malina *et al.*, 2004b:555; Tomkinson, 2007:497; Baldari *et al.*, 2009:191).

Previous studies have shown significant positive relationships between LBEP with body stature ( $r = 0.34 - 0.66$ ,  $p < 0.05$ ) (Armstrong *et al.*, 2001:118; Malina *et al.*, 2004b:560; Baldari *et al.*, 2009:192; Girard & Millet, 2009:1870), body weight ( $r = 0.34 - 0.71$ ,  $p < 0.05$ ) (Armstrong *et al.*, 2001:118; Malina *et al.*, 2004b:560; Baldari *et al.*, 2009:192; Castro-Piñero *et al.*, 2009:2307; Girard & Millet, 2009:1870) and fat-free mass ( $r = 0.60 - 0.67$ ,  $p < 0.05$ ) (Tomkinson, 2007:505; Baldari *et al.*, 2009:192). The correlation seen from fat-free mass is in regard to muscle mass as Kriemler *et al.* (2008:1751) reported that vertical jumping height values (a LBEP-related test) are dependent on adolescents' muscle mass. Fat mass, as calculated by the sum of skinfolds (SF) showed a significant negative correlation ( $r = -0.49 - 0.575$ ,  $p < 0.05$ ) with LBEP in adolescents (12 - 19 years) (Baldari *et al.*, 2009:192; Kapetanakis *et al.*, 2010:419; Milanese *et al.*, 2010:269; Moliner-Urdiales *et al.*, 2011:103). This last-mentioned finding was also accentuated by Kinnunen (2003:41-55) in a study on 7 - 18-year-old males and females in which LBEP negatively correlated with the triceps and the subscapular SF ( $r = -0.43$ ,  $p = 0.05$ ) in 12-year-old females compared to the findings that stature ( $r = 0.44$ ,  $p = 0.05$ ), abdominal SF ( $r = -0.36$ ,  $p = 0.05$ ) and the sum of the triceps and subscapular SF ( $r = -0.51$ ,  $p = 0.05$ ) correlated with the LBEP of 16-year-old females. However, Armstrong *et al.* (2001:118-119, 121) revealed that the addition of the sum of the triceps and subscapular SF, in a multilevel regression analysis as LBEP explanatories, rendered stature as a non-significant explanatory. With regard to males, Kinnunen (2003:41-55) reported a high negative correlation between LBEP and triceps ( $r = -0.49$ ,  $p = 0.05$ ) and abdominal SF ( $r = -0.43$ ,  $p = 0.05$ ) together with a positive correlation with biacromial width ( $r = 0.18$ ,  $p = 0.05$ ) in 14-year-olds. In the 18-year-old males the triceps and subscapular SF ( $r = -0.43$ ,  $p = 0.05$ ) as well as sitting height ( $r = 0.46$ ,  $p = 0.05$ ) were reported to be significant contributors (Kinnunen, 2003:41-55). Skinfolds are used as variables in calculating the fat percentage and fat mass of adolescents. An increase in fat mass is reported to impair adolescents' ability to reach high maximum LBEP values due to the increased load placed on the lower body musculature (Tomkinson, 2007:505; Baldari *et al.*, 2009:192; Kapetanakis *et al.*, 2010:419; Milanese *et al.*, 2010:269; Moliner-Urdiales *et al.*, 2011:103).

With regard to the influence of anthropometric components, research findings on the anthropometric components of height and body weight suggest that taller and leaner adolescents, that display greater height-to-weight ratios, would perform better in LBEP tests such as the vertical jump test (Nevill *et al.*, 2009:229). Another contributor to stature, the length of extremities, has been shown to contribute to and correlate strongly with LBEP ( $r = 0.588$ ,  $\alpha = 0.05$ ) (Stamm & Stamm, 2004:8).

Several physical and motor performance components have also been identified as contributors to LBEP. For example, higher elasticity of muscle-tendon units of the lower limbs (higher flexibility) is found to be associated with higher peak explosive power production during counter movement jumping activities (Witvrouw *et al.*, 2004:448), with low flexibility linked to poor speed performances (Nicholas, 1997:391). Various researchers have demonstrated that speed over short distances between 5 and 40 m correlates negatively and positively significantly ( $r = -0.48 - 0.63$ ;  $p < 0.05$ ) with LBEP (Nevill *et al.*, 2009:225; Milanese, 2010:273; Milojević & Stanković, 2010:111), which may indicate that flexibility contributes to the LBEP output of subjects. In contrast, Kinser *et al.* (2008:138) stated that changes in flexibility due to stretching may not have any effect on the LBEP output of subjects.

Two strength-related components, namely leg and handgrip strength have been highlighted as strong predictors of LBEP. In this regard, Temfemo *et al.* (2009:460) reported a significant positive correlation ( $r = 0.78 - 0.85$ ,  $p < 0.001$ ) between leg strength and LBEP (CMJ and SqJ) in 11 – 16-year-old Caucasian French adolescents. Significant correlations were reported between flexed arm hang time ( $r = 0.36$ ,  $p < 0.05$ ) (Milojević & Stanković, 2010:109) and handgrip strength ( $r = 0.72 - 0.83$ ,  $p = 0.01$ ) (Girard & Millet, 2009:1870) with LBEP in male adolescents. Similarly, Lennox *et al.* (2008:70–71) found positive correlations between LBEP, as measured by the standing long jump, and flexed arm hang ( $r = 0.34$ ,  $p \leq 0.05$ ) in female adolescents 15 years of age.

For all male and female adolescents, the direct and indirect influence of gender on LBEP values, whether through anthropometrical variables or physical and motor performance variables, is evident from literature. For anthropometrical variables the influence of gender is substantially noted in male adolescents as seen from an increase of 375% in maximal power delivery from 7.5 – 17.5 years compared to female adolescents' gain of 295% (Ronan *et al.*, 2003:121). Even at the same age level (12 years) in the study of Nevill *et al.* (2009:229) it was found that the higher muscle mass in male adolescents delivered a 9% higher LBEP jumping value than female adolescents. Malina *et al.* (2004a:114) stated that after maturation male adolescents see a 1.5 times increase in fat-free mass whereas female adolescents see a doubling in fat mass. This increase in female adolescent's fat mass impairs LBEP movements (Tomkinson, 2007:506; Lazzer *et al.*, 2009:227). The effect of maturity on the anaerobic power, necessary for LBEP, is not well understood and much investigated in the available literature (Malina *et al.*, 2004a:361). Nevertheless, a positive correlation can be found between anaerobic speed (40 m sprint) and LBEP in Greek male and female adolescents ( $n = 672$ ) aged 11 - 12 years ( $r = 0.573$ ;  $p < 0.001$ ) (Nevill *et al.*, 2009:225). This was verified in a later study by Milojevic and Stankovic (2010:111) in 123 14-year-old male adolescents. To further emphasize the confounding effect between gender, maturity (as seen in the increase in muscle mass) and motor performance variables, Figueiredo and E Silva (2010:608) found that in more mature adolescents an increase in vertical

jump performance is also accompanied by a higher increase in agility shuttle run and sprint values than is the case with less mature adolescents.

Despite the above-mentioned research findings with regard to the possible anthropometric, physical and motor performance predictors of LBEP in adolescents as well as the influence of gender on the LBEP, limited research exists between various ethnic groups in South African adolescents. It is in the light of the aforementioned research that the following research questions are posed. Firstly, is it possible to develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa? Secondly, is it possible to develop a LBEP prediction model from several anthropometric measurements among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa? Answers to these questions should provide coaches, sport-related professionals and sport scientists with information regarding the use of different anthropometric, physical and motor performance components to predict the LBEP scores of adolescents. Furthermore, the results of this study may also provide the last-mentioned group of people with an indirect way of identifying the adolescents that display high lower body explosive power values so that they can be directed to specific sports codes where lower body explosive power is a performance requirement.

## **2. OBJECTIVES**

The objectives of this study are to:

- Develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.
- Develop a LBEP prediction model from several anthropometric measurements among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.

## **3. HYPOTHESES**

The study is based on the following hypotheses:

- A LBEP prediction model can be developed by making use of speed, agility, explosive power, strength and flexibility measurements among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.

- A LBEP prediction model can be developed by making use of fat percentage, body mass, stature, muscle mass, length, breadth and girth measurements as well as maturity status among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.

#### **4. STRUCTURE OF THE DISSERTATION**

The dissertation is submitted in article format as approved by the Senate of the North-West University and is structured as follows:

- Chapter 1: Introduction: In accordance with the guidelines of the North-West University a bibliography is provided at the end of the chapter.
- Chapter 2: Literature review: Anthropometrical, physical and motor performance predictors of lower body explosive power (LBEP). In accordance with the guidelines of the North-West University a bibliography is provided at the end of the chapter.
- Chapter 3: Article 1: Physical and motor performance predictors of lower body explosive power (LBEP) among a cohort of male and female adolescents – the PAHL study. The article will be presented to *South African Journal for Research in Sport, Physical Education and Recreation* for publication, and will be written in Times New Roman 11 with 1.5 line spacing.
- Chapter 4: Article 2: An anthropometrical related lower body explosive power (LBEP) prediction model among a cohort of adolescents: The PAHL study. The article will be presented to *Human Movement Science* for publication, and will be written in Times New Roman 11 with 1.5 line spacing.
- Chapter 5: Summary, conclusions, limitations and recommendations.
- Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.
- Appendix B: Submission guidelines for authors.
- Appendix C: Letter from language editor.

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# CHAPTER 2

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# **2 LITERATURE REVIEW: ANTHROPOMETRICAL, PHYSICAL AND MOTOR PERFORMANCE PREDICTORS OF LOWER BODY EXPLOSIVE POWER (LBEP).**

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4.1.1 Relationship between age, gender and the LBEP of children and adolescents

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**Literature review: Anthropometric, physical and motor performance predictors of lower body explosive power (LBEP)**

## **1. INTRODUCTION**

Lower body explosive power (LBEP) refers to either the generation of explosive muscular power during short-term exercise (Korff *et al.*, 2009:3737) or explosive strength or the ability to increase force rapidly (Paja, 2011:12). LBEP is dependent on velocity which can be defined as the highest work rate achieved during a single, ballistic, resisted contraction (Saunders *et al.*, 2008:677). In sports such as soccer, football, gymnastics, baseball, basketball as well as in certain athletic events, sudden bursts of explosive power are crucial for acceleration, rapid change in direction and jumping (Newton & Kraemer, 1994:20). Numerous other sporting codes such as handball, volleyball, jazz ballet, taekwondo and tennis are all reliant on LBEP to a certain extent (Gorostiaga *et al.*, 1999:486; Bencke *et al.*, 2002:171; Davis *et al.*, 2003:167; Jovanović *et al.*, 2010:229; Ayed *et al.*, 2011:104; Hermassi *et al.*, 2011:125; Karahan, 2011:234; Kim *et al.*, 2011:135; Cherif *et al.*, 2012:29, 33). Therefore one can assume that participants will only be able to perform successfully in the last-mentioned sports or events if they are able to produce a certain amount of LBEP (Newton & Kraemer, 1994:20; Karahan & Cecilia, 2011:186).

LBEP is also dependent on various other factors such as physiological, psychological, social and environmental factors as well as the interaction between these factors (Nikolaïdis, 2011:342). For example, maximal short-term anaerobic power output, as an indicator of LBEP, has a moderate to large relationship with adolescents' body size, growth characteristics, training experience and lower-body morphology (Pearson *et al.*, 2006:280, Carvalho *et al.*, 2011:794-795). Consequently, adolescents will experience a short-term maturity-related variation in muscle power output (Carvalho *et al.*, 2011:794-795), partly due to a non-linear improvement in anaerobic energy supply during the adolescent growth spurt (Pearson *et al.*, 2006:280,285; Carvalho *et al.*, 2011:794-795 ). Due to these growth-related changes the trainability of LBEP will also be influenced by genetics and environmental factors (Pearson *et al.*, 2006:285; Chillón *et al.*, 2011:417). Most of the available literature regarding LBEP focused on adults, and literature searches regarding adolescents in a specific region of South Africa yielded no results. To date and to the author's knowledge a limited number of models have been developed for the prediction of LBEP by means of anthropometrical, physical and motor performance components of adolescents.

It is against this background that the literature review was undertaken. The purposes of this review were firstly, to describe the physiological models which underlie LBEP where after the different tests for LBEP measurement will be described. Secondly, age, gender anthropometrical, physical and motor performance

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factors which correlate and influence LBEP will be identified and discussed. Despite these factors, other miscellaneous factors possibly influencing LBEP or any anthropometrical, physical and motor performance factor will be discussed. Lastly, available prediction models relating to LBEP production will be reviewed.

Various search engines, namely Google, Google Scholar, Metacrawler, Sabinet Online, Science Direct and Scopus were used to identify and obtain the relevant literature sources. Databases, namely Academic Search Premier, ERIC, E-Journals, Google Books, Highwire, Medline, ProQuest, SACat, SAEPublications, Sage, Scirus and SportDiscuss were also used. The following keywords were used to conduct the searches: anthropometry, explosive power, anaerobic power, prediction model, motor performance, correlation, vertical jump, horizontal jump, peak power, sprint, agility, standing broad jump test, adolescents and children.

According to Malina *et al.* (2004a:8), the ages at which girls can be classified as adolescents are between 8 and 19 years, and for boys between 10 and 22 years. Participants between ages 12 and 19 years were used as the target population for purposes of this literature review. They represented the largest portion of available literature (on children and adolescents) which still complies with the definition of Malina *et al.* (2004a:8) (Armstrong *et al.*, 2001:119; Malina *et al.*, 2004b:555; Tomkinson, 2007:497; Baldari *et al.*, 2009:191). Despite adolescents being the target population, literature on children and young adults was also included in the literature review in order to represent the largest amount of information currently available.

Since the standing broad jump (BJ) and vertical jump (VJ) are generally used as determinants of LBEP, all studies referring to these measuring techniques were included in the literature review (Aragón-Vargas, 2000:215-216; Ruiz *et al.*, 2006:274; Williams, 2008:70; Nevill *et al.*, 2009:229; Ortega *et al.*, 2010:23; Jackson, 2011:1, 3 & 17; Malina *et al.*, 2011:32; Moresi *et al.*, 2011:81; Sauka *et al.*, 2011:36).

### **2. PHYSIOLOGICAL MODELS TO EXPLAIN EXPLOSIVE POWER PRODUCTION**

The production of LBEP is dependent on two distinctive factors, namely applying a greater force in a certain timeframe or applying a certain amount of force in a shorter timeframe (Mandy & Boyle, 2011:43), with the force delivery that needs to take place in a period of 0.3 - 0.8 seconds or less (Plisk, 2005; Paja, 2011:14 & 37). The amount of force released is calculated by means of tests such as the vertical jump test (VJT) (vertical displacement) or the standing long jump test (SL) (horizontal displacement) (Mandy & Boyle, 2011:43). The total displacement of the individual's body mass will give an indication of LBEP (Vanezis & Lees, 2005:1595; Jackson, 2011:3 & 17). The height and/or distance achieved during both these tests will be the result of a large amount of anaerobic energy released in a very short period of time (Bratić *et al.*, 2010:155).

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LBEP activities are usually reliant on the stretch-shortening cycle (SSC), which briefly can be described as a transfer of energy between ligaments, tendons and muscles (Arampatzis *et al.*, 2001:355). The following section will be dedicated to models that describe the SSC.

### 2.1 The mechanical model

In this proposed model, potential elastic energy is stored in the muscles due to rapid eccentric stretching (Potach & Chu 2008:414). The musculotendinous unit lengthens during the eccentric stretch, which in turn allows the series elastic component (SEC) to store elastic energy (Stemm & Jacobson, 2007:568; Williams, 2008:43). Following the eccentric muscle contraction, an immediate concentric muscle contraction occurs, which leads to the release of stored elastic energy and an increase in the amount of explosive power that can be generated (Vandyke, 2005:13; Potach & Chu 2008:414). The stored elastic energy will, however, dissipate as heat if the eccentric action is not immediately followed by a concentric muscle contraction (Potach, 2004:426; Potach & Chu, 2008:414).

### 2.2 The neurophysiological model

During LBEP-related activities, muscle spindle activity is stimulated by quick eccentric loading of the muscle, causing a rapid stretch which results in a quick, reflexive muscle action due to a signal sent from the muscle spindle through the spinal cord to the contracting muscle (Vandyke, 2005:13; Stemm & Jacobson, 2007:568; Potach & Chu, 2008:415).

The SSC utilises the potential energy stored as a result of the stimulation of the muscle spindles as well as the eccentric loading phase storing energy, and in turn enables a quick LBEP production during the concentric phase of a dynamic movement of the lower extremities (Potach, 2004:428; Stemm & Jacobson, 2007:568; Potach & Chu, 2008:415). The SSC involves the following three distinctive phases:

Phase I: The loading of the muscle by means of stretching and eccentric contraction resulting in the storage of potential elastic energy in the SEC (Kurokawa *et al.*, 2003:2313; Potach, 2004:428; Potach & Chu, 2008:415).

Phase II: The amortization phase refers to the time period elapsing from the end of phase I to the beginning of phase II, resulting in a delay between the eccentric and the following concentric phase (Potach, 2004:428; Vandyke, 2005:14; Potach & Chu, 2008:415-416; Williams, 2008:43). This phase is regarded as the most significant phase in power output production, and would lead to a loss of stored elastic energy in the form of dissipating heat if the phase was too timely (Vandyke, 2005:12 & 14; Potach, 2004:426; Potach & Chu, 2008:414).

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Phase III: This phase refers to the concentric phase during which a forceful contraction of the muscles occurs as a result of the stored elastic energy and stimulation of the muscle spindles which occur during phase I (Potach, 2004:428; Vandyke, 2005:14; Potach & Chu, 2008:416; Williams, 2008:43).

In summary, the above-mentioned models of the SCC best describe how LBEP is maximally produced. However, researchers are only able to determine the amount of LBEP by making use of different testing methods. The next section provides the reader with information concerning the different tests that can be executed to determine the amount of LBEP produced among different populations of subjects.

### **3. MEASUREMENT OF EXPLOSIVE POWER**

Various testing procedures have been developed to measure the LBEP of individuals (Bobbert *et al.*, 1987:332-333; Bobbert & Van Ingen Schenau, 1988:250; Hunter & Marshall, 2002:479; Cronin *et al.*, 2004:592; Markovic *et al.*, 2004:552; Moir *et al.*, 2004:227; Maulder & Cronin, 2005:76; Markovic & Jaric, 2007:1357; Mandy & Boyle, 2011:20 & 22). Population demographics on which the tests were used and the statistical significance found are represented per study as follows: Komi and Bosco (1978) used 16 male physical education students ( $24.0 \pm 1.4$  years), 16 male volleyball players ( $24.0 \pm 3.5$  years) and 25 female physical education students ( $20.6 \pm 1.2$  years); Bobbert *et al.* (1987) used a population of 10 male volleyball players ( $23 \pm 4$  years); Bobbert and Van Ingen Schenau (1988) also used 10 male volleyball players ( $23 \pm 3$  years); Hatze (1998) used 22 subjects of which 15 were male and 7 female (24.59 years); Aragón-Vargas (2000) used 52 college students ( $20.2 \pm 2.1$  years); Hunter and Marshall (2002) used 50 male players, primarily basketball and volleyball ( $24 \pm 4$  years); Cronin *et al.* (2004) used 25 experienced voluntary male individual and team sport players ( $23.4 \pm 4.6$  years); Markovic *et al.* (2004) used 93 male physical education college students ( $19.6 \pm 2.1$  years); Moir *et al.* (2004) used 10 male physical education college students ( $25.3 \pm 6.6$  years); Markovic and Jaric (2007) also used 159 male physical education college students (18 – 25 years); Hermassi *et al.* (2011) used 20 adolescent male handball players ( $17.1 \pm 0.8$  years); while Mandy and Boyle (2011) used 35 elite male youth soccer players (14 – 18 years). The following section will highlight some of the most widely used testing methods and protocols used by researchers.

#### **3.1 Counter movement jump (CMJ) / Vertical jump test (VJT)**

The execution of the VJT according to the methods of Harman *et al.* (2000) and Mandy and Boyle (2011:20) requires subjects to perform a minimum of two jumps with a 10-second rest period between each trial with the better of the two trials being used in the final analysis depending on the study needs. In the method of Komi and Bosco (1978:261), Bobbert and Van Ingen Schenau (1988:250) as well as Markovic *et al.* (2004:552) subjects were requested to keep their hands on their hips while performing a counter movement

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with their lower limbs. As variation of this technique, Moir *et al.* (2004:227) instructed their students to perform the jump from a maximum box height. The jump has also been performed without constraint such as a counter movement (Markovic & Jaric, 2007:1357; Mandy & Boyle, 2011:20). For VJT Hatze (1998:138) found a 3.55% relative average error. It has also been calculated that 97% of total power spent on maximal propulsion of the body is used solely for vertical propulsion (Hatze, 1998:138). An intraclass correlation coefficient of 0.93 - 0.98 was reported by Markovic *et al.* (2004:553) and by Moir *et al.* (2004:278). Markovic *et al.* (2004:553) also indicated an average intertrial correlation of 0.94 and a Cronbach's alpha reliability coefficient of 0.98. Hermassi *et al.* (2011:127) on his account found an intraclass correlation coefficient of 0.97 with a range from 0.93 to 0.98 in the 90% confidence interval. Markovic *et al.* (2004:553) and Moir *et al.* (2004:278) also displayed a variation coefficient of 2.4% - 2.8%. Aragón-Vargas (2000:221) found a reliability correlation coefficient of 0.994 and a reliability coefficient of determination of 0.987. A Pearson correlation of 0.861 with a significance level of smaller than 0.001 has been indicated in the study of Cronin *et al.* (2004:592). From these results it can be concluded that the VJT is accurate as an indicator of LBEP.

### **3.2 Sergeant jump (SeJ)**

The SeJ is performed using a counter movement with an arm swing as it was suggested in the original protocol of Sergeant (1921) (Markovic *et al.*, 2004:552). The final jumping height is calculated by subtracting the reaching height from the jumping height (Markovic *et al.*, 2004:552). The average intertrial correlation for the Sergeant jump was 0.90 and the intraclass correlation coefficient 0.96 (Markovic *et al.*, 2004:553). Markovic *et al.* (2004:553) also indicated a Cronbach's alpha reliability coefficient of 0.96 and a coefficient of variation of 3.0%. According to all indicators, the Sergeant jump has been accepted to be an accurate LBEP indicator.

In recent publications (Markovic *et al.*, 2004:552; Markovic & Jaric, 2007:1357; Moresi *et al.*, 2011:73-74) researchers have referred to the SeJ, the VJ and the CMJ as the same testing measurement.

### **3.3 Standing triple jump (STJ)**

In the execution of the standing triple jump, subjects are required to stand on a long jump mat and jump as far as possible by performing three jumps (Markovic *et al.*, 2004:552). The total distance from the starting position to the landing point where the heel makes contact to the ground is the measured distance (Markovic *et al.*, 2004:552). The average intertrial correlation for the standing triple jump is reported as being 0.83 (Markovic *et al.*, 2004:553). Markovic *et al.* (2004:553) also found an interclass correlation of 0.93, a Cronbach's alpha reliability coefficient of 0.93 and a coefficient of variation of 2.9%. For LBEP indication, the STJ has proven to be an accurate indicator.

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### **3.4 Standing long jump test (SL) / Horizontal jump test (HJT) / Broad jump test (BJ)**

This method requires subjects to jump as far as possible from a standing position (Markovic *et al.*, 2004:552). The distance is measured from the starting point to where contact occurs between the floor and the heel (Markovic *et al.*, 2004:552; Mandy & Boyle, 2011:22). The average intertrial correlation for the horizontal jump is indicated as 0.86 (Markovic *et al.*, 2004:553), and the intraclass correlation coefficient as 0.93 - 0.95 (Markovic *et al.*, 2004:553; Moresi *et al.*, 2011:79). In the study of Moresi *et al.* (2011:79) the coefficient of variation for the intraclass coefficient was calculated at 3.4%. Markovic *et al.* (2004:553) also indicated a Cronbach's alpha reliability coefficient of 0.95 and a variation coefficient of 2.4%. All indicators of the SL (HJT/ BJ) indicate that the measurement is accurate as a predictor of LBEP indication.

### **3.5 Modified Abalakow/Abalakov jump with arm swing**

This test is performed with a counter movement with an arm swing with a measuring tape attached to a specially constructed belt placed around the hips of the subject (Markovic *et al.*, 2004:552). The average intertrial correlation for the modified Abalakow/Abalakov jump with arm swing has been indicated as 0.81 (Markovic *et al.*, 2004:553). Markovic *et al.* (2004:553) also indicated an interclass correlation of 0.93, Cronbach's alpha reliability coefficient of 0.93 and the coefficient of variation of 4.6% (of which the largest value was found compared to other tests). The modified Abalakow /Abalokov jump with arm swing has been asserted to be an accurate indicator of LBEP.

### **3.6 Modified Abalakow/Abalakov jump with no arm swing**

This test is performed with a specially constructed belt and a measuring tape attached to it on the subject's waist (Markovic *et al.*, 2004:552). The testing method is performed from the counter movement jump position with no arm swing (Markovic *et al.*, 2004:552). The average intertrial correlation for the modified Abalakow/Abalokov jump with no arm swing has delivered 0.85 and an intraclass correlation coefficient of 0.94 (Markovic *et al.*, 2004:553). Markovic *et al.* (2004:553) also indicated the Cronbach's alpha reliability coefficient of 0.94 and a coefficient of variation of 4.1%. The modified Abalakow/Abalokov jump with no arm swing has been shown to be an accurate LBEP test.

### **3.7 Squat jump (SqJ)**

According to the method of Markovic *et al.* (2004:552) subjects are required to keep their hands on their hips while executing the jump without a counter movement from a semi squat position. The average intertrial correlation for the squat jump displayed a value of 0.91 (Markovic *et al.*, 2004:553). Markovic *et al.* (2004:553) also indicated an interclass correlation of 0.97, a Cronbach's alpha reliability coefficient of 0.97 and the coefficient of variation of 3.3%. Alemany *et al.* (2005:34) instructed subjects to squat at a self-selected depth prior to executing the jump. Hermassi *et al.* (2011:127) on their account found an interclass

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correlation coefficient of 0.96 with a range of 0.91 – 0.98 in the 90% confidence interval. In the study of Alemany *et al.* (2005) subjects were instructed to continue the jumping activity continuously until 30 repetitions were completed. Interclass coefficients of 3 different sessions for peak power were 0.96, 0.96 and 0.94 respectively (Alemany *et al.*, 2005:35). Coefficient of variations was 3.2% for peak power production (Alemany *et al.*, 2005:35). A Pearson correlation of 0.897 has been found in the study of Cronin *et al.* (2004:592) with a significance level of smaller than 0.001. The SqJ as an indicator of LBEP has proven to be accurate.

### **3.8 Drop jump (DJ)**

Various techniques to execute the DJ have been investigated by Bobbert *et al.* (1987:332). In the first technique the subject is requested to drop from a height of 20 cm and then rebound into a jump as quickly as possible (Bobbert *et al.*, 1987:332-333). In the second technique the subject is requested to drop from a height of 20 cm and then complete a larger downward movement before initiating the jump upwards (Bobbert *et al.*, 1987:332-333). The first technique is referred to as the bounce drop jump and the latter as the counter drop jump (Bobbert *et al.*, 1987:332). The drop jump has also been executed with the variations of heights from 20 – 100 cm while subjects were instructed to keep their hands on their hips (Komi & Bosco, 1978:261; Hunter & Marshall, 2002:479). With a level of significance smaller than 0.001, a Pearson correlation of 0.934 has been found in the study of Cronin *et al.* (2004:592). Therefore, the drop jump has been proven to be a sufficient LBEP test.

### **3.9 Static jumps (StJ)**

The StJ requires the subject to perform a jumping movement from a 3-second held, 90° bend knee as a starting point (Komi & Bosco, 1978:261; Moir *et al.*, 2004:227). Moir *et al.* (2004:278) indicated that the static jumps coefficient of variation is 2.4% with an interclass correlation of 0.91. The static jump has been proven to be an accurate LBEP indicator.

The above-mentioned testing methods have been investigated and found reliable by various researchers as indicators of LBEP (Bobbert *et al.*, 1987:332-333; Bobbert & Van Ingen Schenau, 1988:250; Hunter & Marshall, 2002:479; Markovic *et al.*, 2004:552; Moir *et al.*, 2004:227). These testing methods can be used to determine certain anthropometric, physical and motor performance components as contributors to LBEP (Armstrong *et al.*, 2001:121; Mandy & Boyle, 2011:43; Malina *et al.*, 2004a:361; Vescovi & McGuigan, 2008:101; Temfemo *et al.*, 2009:460). The following section will present a discussion of the influence of anthropometric, physical and motor performance variables on the LBEP of children and adolescents.

#### **4. FACTORS INFLUENCING THE LBEP OF CHILDREN AND ADOLESCENTS**

##### **4.1 Relationship between age, gender, anthropometric measurements and LBEP in children and adolescents.**

Various factors have been found to influence subjects' LBEP (Davis *et al.*, 2003:167). These factors have been thoroughly summarised and described according to each study in Table 1.

**Table 1: The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p)
Kinnunen (2003).	<p>Anthropometric measurements were referred to as structural-maturational variables which were taken on the left side of the body.</p> <p>These included: umbilical skinfold (SF), subscapular SF, triceps SF, calf girth, thigh girth, arm girth, radio-styilion (lower arm) length, acrom-radiale (upper arm) length, bicristal (hip) breadth, biacromial (shoulder) breadth, sitting height, standing height and weight.</p> <p>Descriptions and categorizing is as follows:</p> <p>Linear measurements:                      Standing height: With the subject against the wall, heels are placed together against the wall. Hands hang freely with the head in the Frankfurt plane.</p> <p>Sitting height: Subject begins seating position on 30 cm bench by leaning forward and sliding back against the wall upright. Feet are placed together in order for the thighs to be parallel to the floor with the head in the Frankfurt plane.</p>	<p>Male and female Caucasian adolescents, 7 – 18 years (n = 487)</p> <p>Males (n = 224)</p> <p>Females (n = 263)</p>	<p><b>Standing long jump:</b>                      In general (inclusive of gender and age):                      Weight: r = 0.75; p = 0.05                      Standing height: r = 0.82; p = 0.05                      Sitting height: r = 0.81; p = 0.05                      Biacromial breadth: r = 0.82; p = 0.05                      Bicristal breadth: r = 0.74; p = 0.05                      Acromion-radial length: r = 0.80; p = 0.05                      Radio-styilion length: r = 0.81; p = 0.05                      Arm girth: r = 0.67; p = 0.05                      Thigh girth: r = 0.67; p = 0.05                      Calf girth: r = 0.70; p = 0.05</p> <p><b>Males (in general):</b>                      Weight: r = 0.79; p = 0.05                      Standing height: r = 0.84; p = 0.05                      Sitting height: r = 0.84; p = 0.05                      Biacromial breadth: r = 0.85; p = 0.05                      Bicristal breadth: r = 0.81; p = 0.05                      Acromial-radial length: r = 0.82; p = 0.05                      Radio-styilion length: r = 0.83; p = 0.05                      Arm girth: r = 0.73; p = 0.05                      Thigh girth: r = 0.73; p = 0.05                      Calf girth: r = 0.75; p = 0.05</p>

cm = centimetre; SF = skinfold

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
Kinnunen (2003). (cont.).	<p>Acrom-radiale: The forearm is flexed 90° across the chest with the upper arm hanging free. A measurement is taken to the groove between the lateral condyle of the humerus and the head of the radius from the process of the acromion's lateral margin.</p> <p>Radio-styilion: a measurement is taken between the radius' styliod process tip and the groove between the lateral condyle of the radius and humerus.</p> <p>Breadth measurements: Bi-acromial breath: the acromion processes are palpated for with use of the index fingers. The sliding callipers' one end is placed just left of the left acromial process. The mobile end then is place just right of the right acromial process. The calliper is held up slightly with no pressure applied.</p> <p>Bi-cristal breadth: with palpitation the iliac crest is located whereby the calliper is placed firmly over the crests to depress fat over the bone.</p> <p>The sum of SF was calculated as the sum of the triceps, subscapular and umbilical SF.</p>	<p>Male and female Caucasian adolescents, 7 – 18 years (n = 487)</p> <p>Males (n = 224)</p> <p>Females (n = 263)</p>	<p><b>Females (in general):</b>                      Weight: r = 0.67; p = 0.05                      Standing height: r = 0.79; p = 0.05                      Sitting height: r = 0.77; p = 0.05                      Biacromial breadth: r = 0.77; p = 0.05                      Bicristal breadth: r = 0.71; p = 0.05                      Acromial-radial length: r = 0.77; p = 0.05                      Radio-styilion length: : r = 0.77; p = 0.05                      Arm girth: r = 0.54; p = 0.05                      Thigh girth: r = 0.61; p = 0.05                      Calf girth: r = 0.64; p = 0.05</p> <p><b>Female, 12 years: (highest 3 correlations)</b>                      Triceps SF: r = -0.395 to -0.42; p = 0.05                      Triceps + subscapular SF : r = -0.43; p = 0.05                      Sum of SF: r = -0.43; p = 0.05</p> <p><b>Females, 16 years: (highest 5 correlations)</b>                      Biacromial breadth: r = 0.47; p = 0.05                      Radio-styilion length: r = 0.45; p = 0.05                      Triceps SF: r = -0.50; p = 0.05                      Triceps + subscapular SF: r = -0.51; p = 0.05                      Sum of SF: r = 0.47; p = 0.05</p> <p><b>Males, 14 years: (highest 3 correlations)</b>                      Triceps SF: r = -0.49; p = 0.05                      Triceps + subscapular SF: r = -0.48; p = 0.05                      Sum of SF: r = -0.47; p = 0.05</p> <p><b>Males, 18 years: (highest 3 correlations)</b>                      Sitting height: r = 0.46; p = 0.05                      Biacromial breadth: r = 0.55; p = 0.05                      Triceps SF: r = -0.49; p = 0.05</p>

° = degrees; SF = skinfold

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
Kinnunen (2003). (cont.).	<p>Circumferences:</p> <p>Biceps: With the arm hanging freely it is measured at the maximum bulge of the biceps muscle.</p> <p>Thigh: With the right foot supporting the subject's weight and the left foot on the bench in order for the thigh to be held parallel to the surface. Measurement is taken between the proximal and distal ends of the femur.</p> <p>Calf: Measure the maximum bulge of the calf with the lower extremity in position during the thigh measurement.</p> <p>SF: Triceps: Measurement was done on a position mid-way between the proximal and distal end of the humerus with the arm hanging freely at the side.</p> <p>Subscapular: From the scapula one inch below the inferior angle the measurement is taken from a line.</p> <p>Umbilicus: Measurement is taken approximately to the left of the umbilicus at one inch.</p>	<p>Male and female Caucasian adolescents, 7 – 18 years (n = 487)</p> <p>Males (n = 224)</p> <p>Females (n = 263)</p>	
Malina <i>et al.</i> (2004b).	<p>Standard techniques were used to the nearest 0.1 cm and 0.1 kg respectively to measure height and weight.</p> <p>Pubic hair development was assessed with the criteria of Tanner.</p>	<p>Male soccer players, 13.2 – 15.1 years (n = 69)</p> <p>(n = 39, born in 1984)</p> <p>(n = 30, born in 1985)</p>	<p><b>Vertical jump:</b> Height: Standardized beta R<sup>2</sup> coefficients = 0.368; thus r = 0.607/-0.607 Adjusted R<sup>2</sup> = 0.41; thus r = 0.64/-0.64</p>

cm = centimetre; kg = kilogram; SF = skinfold; R<sup>2</sup> = Standardized beta coefficients

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
Stamm and Stamm (2004).	<p>For measuring SF, the methods of Knussmaan were used. Lower extremity length was measured via the method of K.S. Jatsuta. In total 49 measurements were taken of which 11 were SF. From these SF relative mass of subcutaneous adipose tissue was calculated to bring the total to 51 measurements and calculations.</p> <p>Length measurements were: horizontal arm spread, lower limb length, upper limb length, lower body length, upper body length, trunk length, abdomen length, sternum length, head-neck length, xiphoidal length, suprasternal height and body height.</p>	Female adolescent volleyball players, 13 - 16 years (n = 46)	<p><b>Highest jump and reach standing:</b>                      Age: r = 0.383; p = 0.05                      Height: r = 0.863; p = 0.05                      Lower body length: r = 0.588; p = 0.05                      Upper limb length: r = 0.766; p = 0.05                      Lower limb length: r = 0.713; p = 0.05                      Horizontal arm span: r = 0.796; p = 0.05                      Biacromial breadth: r = 0.620; p = 0.05                      Pelvis breadth: r = 0.659; p = 0.05</p>
Baldari <i>et al.</i> (2009).	<p>For measuring SF a Harpenden calliper (St Albans, UK) were measured on the right side of the body to the nearest 0.2 mm.</p> <p>A two-SF measurement for children to youths was used to estimate percentage body fat. Body weight was measured with a digital scale with an accuracy of 0.1 kg while standing height was measured to the nearest 0.1 cm with a stadiometer (St Albans, UK).</p> <p>Using the method of Tanner puberty was assessed of the subjects.</p>	Male soccer adolescents and children, 10 - 14 years (n = 51)	<p><b>Standing long jump:</b>                      Age: r = 0.66; p &lt; 0.05                      Stature: r = 0.67; p &lt; 0.05                      Weight: r = 0.34; p &lt; 0.05                      Fat free mass: r = 0.60; p &lt; 0.05                      Body fat %: r = -0.49; p &lt; 0.05</p>
Girard and Millet (2009).	<p>The status of maturation was assessed via the method of Tanner.</p> <p>No further descriptions were given.</p>	Male junior tennis players, 13.6 ± 1.4 years (n = 12)	<p><b>CMJ:</b>                      Age: r = 0.65; p &lt; 0.05                      Height: r = 0.66; p &lt; 0.05                      Weight: r = 0.71; p &lt; 0.01</p>

cm = centimetre; CMJ = counter movement jump; mm = millimetre; kg = kilogram; SF = skinfold

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
<p>Temfemo <i>et al.</i> (2009).</p>	<p>Fat mass (fat percentage), leg muscle volume, lean body mass, body mass, body mass index, leg length and standing height were the initial anthropometric measurements.</p> <p>Following the techniques of the International Biological Program the following measurements were taken: calf SF thickness, quadriceps SF thickness, supra iliac SF, subscapular SF, tricipital SF, bicipital SF, ankle circumference, intercondylar distance, maximum calf circumference, under kneecap circumference, middle-thigh circumference, upper-thigh circumference, leg length, body mass and height.</p> <p>All SF measurements were taken with a Harpenden SF Calier (Baty International, Sussex, UK) on the body's right side. For fat percentage the formula of Siri was used. Lean body mass was acquired subtracting fat body mass from total body mass. Leg muscle volume was assessed with the method of Jones and Pearson from where it was compared to a truncated one. Subjects with a body mass index (BMI) of 18.9 – 29.9 were only accepted for this study.</p>	<p>Male adolescents and children, 6 – 13 years (n = 96)</p>	<p><b>Single standing long jump:</b>  <math>\Sigma</math> of four SF (triceps, biceps, subscapular and suprailiac):                      r = -0.226; p &lt; 0.001</p>

SF = Skinfold

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
Milanese <i>et al.</i> (2010).	<p>Measurements were used via the methods of Lohman <i>et al.</i> (1988).</p> <p>Subjects were weighed to the nearest 0.1 kg using a certified electronic scale (Tanita electronic scale BWB-800 MA (Wunder SA.BI. Sr1)). A Harpenden portable stadiometer (Holtain Ltd., Crymych, Pembs. UK) was used for height measurement. BMI was calculated as kg/m<sup>2</sup> and girth was taken at the waist and hip.</p> <p>The following procedure was followed for SF measurement according to Norton and Olds. At each site 2 measurements were taken with the average calculated thereof. For values differing greater than 2 mm a 3<sup>rd</sup> measurement was taken. The 2 closest values were then used for the average calculation. Measurements were done with a Harpenden calliper (Gima, Modena, Italy). These SF were the triceps SF, subscapular SF, chest SF, abdominal SF and frontal thigh SF thickness.</p>	<p>Male and female adolescents, 6 – 12 years (n = 152):</p> <p>Males (n = 103) Females (n = 49)</p> <p>Male, 10 – 12 years; (n = 37) Female, 10 – 12 years; (n = 17)</p>	<p><b>Standing long jump:</b></p> <p><b>Females, 12 years:</b> Σ of SF (triceps, subscapular, chest, abdominal and frontal thigh): r = -0.575; p = 0.016</p>

Σ = The total summation; BMI = Body mass index; kg = kilogram; mm = millimetre; SF = skinfold

**Table 1 (cont.): The relationship between certain anthropometric measurements and LBEP results in adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlation (r) to LBEP and their level of significance (p).
Moliner-Urdiales <i>et al.</i> (2011).	<p>Using the criteria of Tanner the pubertal status was used.</p> <p>SF measurements were followed in the HELENA-CSS as described in Nagy <i>et al.</i> BMI was calculated as body mass (kg) divided by height squared (m<sup>2</sup>).</p> <p>SF thickness was measured on the left side to the nearest 0.2 mm on the left side at the medial calf, thigh, suprailiac, subscapular, triceps and biceps. A Holtian Caliper (Crymmych, UK) was used. For total body fat the sum of six SF were used.</p> <p>Waist circumference was measured to the nearest 1 mm at the natural narrowest part of the waist.</p>	<p>Male and female Spanish adolescents, 12.5 – 17.5 years; (n = 363)</p> <p>Males (n = 177) Females (n = 186)</p>	<p><b>Standing broad jump:</b></p> <p>∑ of six SF (biceps, triceps, subscapular, suprailiac, thigh and medial calf): semipartial r = -0.239; R<sup>2</sup> = 0.105, thus r = 0.324/-0.324 (females)</p> <p>∑ of six SF (biceps, triceps, subscapular, suprailiac, thigh and medial calf): semi partial r = -0.447; R<sup>2</sup> = 0.340, thus r = 0.583/-0.583 (males)</p>

∑ = The total summation; kg = kilogram; mm = millimetre; m<sup>2</sup> = metre squared; R<sup>2</sup> = Standardized beta coefficients

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### 4.1.1 Relationship between age, gender and the LBEP of children and adolescents

An increase in age from childhood to adulthood is accompanied by various morphological and physiological changes which are all related to changes in LBEP performance (Malina *et al.*, 2004a:361; Stamm & Stamm, 2004:10; Baldari *et al.*, 2009:192; Castro-Piñero *et al.*, 2009:2307; Girard & Millet, 2009:1870; Ayed *et al.*, 2011:104). In this regard, Ronan *et al.* (2003:121) indicated that 57% of the variance in maximal anaerobic LBEP output among adolescent boys could be explained by the age of these subjects. However, it is not only the chronological age of a subject that must be considered when evaluating LBEP but also the biological age which usually also gives an indication of growth development (Ayed *et al.*, 2011:104). Quatman *et al.* (2005:5) found that gender affected the take-off force for the VJT as they progressed through their maturational development. It became evident that male adolescents increased their take-off force necessary for the VJT despite an increase in their body weight, whereas female adolescents' take-off force decreased (Quatman *et al.*, 2005:5).

### 4.1.2 Relationship between body weight, gender and the LBEP of children and adolescents.

During adolescents' growth and maturation, an increase in age is evident in accordance with an increase in body weight which translates to an increase in LBEP (VJ) (Almuzaini, 2007:331). Female adolescents tend to be heavier than male adolescents, particularly during the age of 12 – 14 years as a result of growth (Günay *et al.*, 2011:206). In general both male and female adolescents' body weight ( $r = 0.67 - 0.71$ ;  $p < 0.05$ ) (Baldari *et al.*, 2009:192; Girard & Millet, 2009:1870) and fat-free mass ( $r = 0.60$ ;  $p < 0.05$ ) (Baldari *et al.*, 2009:192) positively correlate with LBEP (CMJ and SL). Weight-bearing muscular fitness tests, i.e. the vertical and standing broad jump requiring LBEP, can contrarily be negatively influenced by a higher body mass (Tomkinson, 2007:505; Shang *et al.*, 2010:5, Chillón *et al.*, 2011:420). In support of this statement Malina *et al.* (1995:227) stated that the leanest 5% of a Flemish national sample of female children and adolescents between 7 and 17 years of age performed the best in the vertical jump test. Contradictory to these findings, Kapetanakis *et al.* (2010:419) reported that body weight plays no role in LBEP jumps ( $r = -0.001$ ,  $p = 0.990$ ), but only serves as an indicator of body fat. In summary, an increased body weight due to fat mass did not contribute to improved LBEP (Tomkinson, 2007:506; Lazzer *et al.*, 2009:227), whereas when body weight increased as a result of higher muscle mass the result was a significantly increased LBEP (Mandy & Boyle, 2011:42).

### 4.1.3 Relationship between muscle mass, gender and LBEP of children and adolescents.

In general it is accepted that male adolescents have a higher fat free mass (Kriemler *et al.*, 2008:1752) and female adolescents have a higher fat mass as a result of maturation (Kriemler *et al.*, 2008:1752; Temfemo *et al.*, 2009:460). These differences in mass contribution serve as the main reason for the variation in LBEP between male and female adolescents. The next sections will therefore be dedicated to a discussion on these

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two mass-related aspects. Female adolescents do not experience the same increase in muscle mass or a corresponding increase in LBEP during the adolescent growth spurt compared to male adolescents, mainly due to a smaller increase in testosterone production (Bratić *et al.*, 2010:155). An increase in fat free mass, inclusive of muscle mass, positively influences the absolute anaerobic power output during LBEP movements (Malina *et al.*, 2004a:258; Tomkinson, 2007:505; Lazzer *et al.*, 2009:227), whereas an increase in body mass due to an increase in fat mass negatively influences anaerobic power output during LBEP movements (Lazzer *et al.*, 2009:227; Tomkinson, 2007:506). Furthermore, research suggests that male adolescents with a leaner ectomorphic physique, representative of lesser muscle mass, performed worse when compared to their normal weight peers in LBEP tests (Ferrar *et al.*, 2010:118). In another study, 52% of the variation in anaerobic peak power production during a 30-second cycle ergometer test could be attributed to muscle mass differences in a group of 14 – 16-year-old male basketball players (Carvalho *et al.*, 2011:793).

According to Mandy and Boyle (2011:42) an adolescent with a higher muscle mass to body weight ratio would produce more powerful propulsion during the execution of LBEP movements. It has also been established that a lesser weight-to-height ratio (not BMI) or greater height-to-weight ratio [(height-weight<sup>0.29</sup>)<sup>1.02</sup>] amongst 9 – 16-year-old female adolescents are associated with optimal performances in body weight activities utilizing LBEP in activities such as jumping (Stamm & Stamm, 2004:7; Nevill *et al.*, 2009:229-230; Malina *et al.*, 2011:39). Amongst a group of male adolescents it was found that a greater lean body mass and greater muscle mass contributes to the attainment of greater anaerobic power (Mikulic, 2011:147). The increase in muscle mass observed during growth in especially male adolescents (Castro-Piñero *et al.*, 2009:2306-2307) has a significant effect on the performance of LBEP movements (Malina *et al.*, 2004a:258; Tomkinson, 2007:505; Travill, 2007:285; Alberga, 2008:3; Lazzer *et al.*, 2009:227). In relation to gender, male adolescents experience an increase of 375% in maximal power delivery from the age of 7.5 – 17.5 years (Ronan *et al.*, 2003:121). A significant increase of 295% is also seen in female adolescents at similar age gaps but is less than those observed in their male counterparts (Ronan *et al.*, 2003:121). With the emphasis on age, Nevill *et al.* (2009:229) found that male adolescents' LBEP was 9% higher than that of female adolescents at the age of 12 years due to males' marked increase in muscle mass. In contrast to the above-mentioned, only Wu *et al.* (2003:192) found that muscle mass had a poor correlation with LBEP jumping activities in adult females (19.7 ± 0.96 years). Tomkinson (2007:505) clearly distinguishes that an increase in fat mass impairs LBEP jumping values whereas an increase in muscle mass should increase LBEP jumping values in children and adolescents from 6 to 19 years of age.

#### 4.1.4 Relationship between fat mass, gender and LBEP of children and adolescents

It is well known that fat mass increases during maturation of adolescents, particularly among female adolescents due to an increase in estrogenic levels (Guyton & Hall, 2006:1018; Kriemler *et al.*, 2008:1752; Temfemo *et al.*, 2009:460). It is evident from research that LBEP weight-bearing tests are negatively influenced by a higher body mass (Chillón *et al.*, 2011:425) as a result of a higher fat mass. Fat mass as calculated by the sum of SF, is considered to be “dead weight” which leads to an increase in movement resistance through extra load bearing and impairs anaerobic power output during LBEP movements (Milanese *et al.*, 2010:269; Moliner-Urdiales *et al.*, 2011:103). This fact is substantiated by research findings which indicated that children and adolescents (6 – 18 years old) that were overweight due to an increased fat mass performed significantly worse ( $p \leq 0.05$ ) in LBEP tests (standing broad jump/SL and VJ) compared to their normal weight counterparts (Kamtsios, 2008:34; Ferrar *et al.*, 2010:118). Alberga (2008:52) further stated that after weight loss in previously overweight adolescents, a loss in fat mass was the only factor that determined an increase in vertical jumping heights. An increase in fat mass, as calculated by various SF, correlated significantly negative ( $r = -0.524$ ;  $p < 0.05$ ) with LBEP (VJT) values in 13 – 16-year-old females (Stamm & Stamm, 2004:6-8). Furthermore, significant negative correlations were found between the triceps ( $r = -0.49$ ,  $p = 0.05$ ) and the abdominal SF ( $r = -0.43$ ,  $p = 0.05$ ) with LBEP (SL) results in 14-year-old adolescent males (Kinnunen, 2003:41-55 & 107). The same researchers furthermore reported significant negative correlations ( $r = -0.43$ ,  $p = 0.05$ ) between triceps and subscapular SF as well as LBEP (SL) results in 12-year-old female adolescents whereas the sum of the triceps and subscapular SF showed the highest significant negative correlation ( $r = -0.51$ ,  $p = 0.05$ ) with LBEP (SL) results among 16-year-old female adolescents (Kinnunen, 2003:41-55, 104-105). Among 18-year-old males the triceps and subscapular SF displayed significant, negative correlations ( $r = -0.43$ ,  $p = 0.05$ ) with LBEP (SL) (Kinnunen, 2003:41-55, 108). In another study the triceps, subscapular, supriliac, abdominal and medial calf SF showed significant negative correlations ( $p = 0.05$ ) with standing long jump in 7 – 18-year-old South-African boys of the Cape region (Travill, 2011:121)

#### 4.1.5 Relationship between breadth indicators, gender and LBEP of children and adolescents

A significant, positive correlation ( $p = 0.05$ ) was observed between biacromial breadth and LBEP (SL) in male ( $r = 0.55 - 0.85$ ) (Kinnunen, 2003:44-55) and female adolescents ( $r = 0.47 - 0.77$ ) (Kinnunen, 2003:46-52). Another breadth measurement, bicristal breadth, was reported to have a significant positive correlation with female adolescents ( $r = 0.71$ ;  $p = 0.05$ ) (Kinnunen, 2003:46-52) and male adolescents ( $r = 0.81$ ;  $p = 0.05$ ) (Kinnunen, 2003:44-55). Stamm and Stamm (2004:8 & 13) also found that biacromial breadth ( $r = 0.620$ ;  $p < 0.05$ ) together with pelvis breadth showed a strong positive correlation ( $r = 0.659$ ;  $p < 0.05$ ) with LBEP among competitive female adolescents between 13 and 16 years of age. The relationship between the breadth sizes of different body sites and LBEP test results can possibly be attributed to the fact that increased

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mechanical loading of certain skeletal sites result in bone gain and consequently an increase in bone breadths of the areas targeted (Nelson & Bouxsein, 2001:202; Gruodytė & Jürimäe, 2011:5). In this regard, Gruodytė and Jürimäe (2011:6) suggested that female adolescents who participated in sports or weight-bearing activities prior to menarche might lead to more beneficial bone health i.e. a higher bone mineral density (Gruodytė & Jürimäe, 2011:6). It can therefore be assumed that an increase in bone density and bone mass will increase measurements in bone breadth. Other researchers also revealed that male and female European adolescents who obtained lower scores in LBEP tests due to low strength levels showed low total and lower limbs bone mineral content (Gracia-Marco *et al.*, 2011:2677).

### **4.1.6 Relationship between limb length, stature, gender and LBEP of children and adolescents**

Various length indicators are also indicators or contributors of body stature, whereas shorter limb lengths also seem to correlate positively with lower LBEP (VJT) test scores and vice versa. In this regard Stamm and Stamm (2004:8 & 13) found lower body limb length to correlate significantly positive ( $r = 0.713$ ;  $p < 0.05$ ) with LBEP (VJT) in 13 - 16-year-old female volleyball players. Furthermore, research showed that taller and leaner adolescent females (11-16 years) who displayed lower height-to-weight ratios, performed better in LBEP (VJ and SL) tests than heavier or shorter adolescents (Stamm & Stamm, 2004:7; Nevill *et al.*, 2009:229-230; Malina *et al.*, 2011:39). Acromial height, has also been identified as a LBEP test predictor in 7 – 13-year-old boys (Travill, 2011:116 & 121). A significant positive correlation ( $r = 0.61 - 0.86$ ;  $p < 0.05$ ) was also reported between body stature and LBEP (VJ, SL and SqJ) test results in 13 – 16-year-old females and 10 – 15-year-old males (Malina *et al.*, 2004b:560; Stamm & Stamm, 2004:8; Baldari *et al.*, 2009:192; Girard & Millet, 2009:1870). Kinnunen (2003:44 & 46) established that sitting height correlated significantly positive ( $p = 0.05$ ) with LBEP (SL) of male adolescents and children ( $r = 0.84$ ), and female adolescents and children ( $r = 0.77$ ). As contributors to body stature, Stamm and Stamm (2004:12) found lower stature results ( $r = 0.588$ ;  $p = 0.05$ ) and upper limb length ( $r = 0.766$ ;  $p = 0.05$ ) to correlate significantly positive with LBEP (SL). Another limb length-related measurement, namely horizontal arm span, also seems to correlate significantly positive ( $r = 0.796$ ;  $p < 0.05$ ) with LBEP (VJ) test results in 13 – 16-year-old female volleyball players (Stamm & Stamm, 2004:8 & 13). According to Kinnunen (2003:44), male adolescents and children's radio-stylion length correlated significantly positive with LBEP (SL) ( $r = 0.83$ ;  $p = 0.05$ ) while female adolescents and children's radio-stylion length also correlated significantly positive with LBEP (SL) ( $r = 0.45 - 0.75$ ;  $p = 0.05$ ) (Kinnunen, 2003:46-52). For acromial-radial length, male adolescents and children's lengths correlated significantly positive ( $r = 0.82$ ;  $p = 0.05$ ) (Kinnunen, 2003:44) with LBEP (SL) with similar results seen in female adolescents and children's lengths ( $r = 0.77$ ;  $p = 0.05$ ) (Kinnunen, 2003:46).

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### **4.1.7 Relationship between girth, gender and LBEP of children and adolescents**

Increase in adolescent's musculature as a result of maturation is evident in the increase in their girth measurements. According to Kinnunen (2003:44) male adolescent and children's LBEP (SL) showed a positively significant ( $p = 0.05$ ) correlation with the girth measurements of the arm ( $r = 0.73$ ), thigh ( $r = 0.73$ ) and calf ( $r = 0.75$ ). The same tendency was noted in female adolescents and children with their LBEP (SL) values correlating significantly ( $p = 0.05$ ) with girth measurements of the arm ( $r = 0.54$ ), thigh ( $r = 0.61$ ) and calf ( $r = 0.64$ ) (Kinnunen, 2003:46). The larger correlations evident from males when compared with females might be as a result from male adolescents' larger muscular mass as reviewed earlier.

The above-mentioned discussion clearly demonstrates that various anthropometric measurements may influence the LBEP test results of adolescents. However, various physical and motor performance variables also seem to influence adolescents' LBEP values. Therefore the following section will be dedicated to a discussion of the physical and motor performance variables that may possibly influence subjects' LBEP.

### **4.2 Relationship between certain physical and motor performance components and LBEP in children and adolescents**

For the purpose of the following discussion the various physical and motor performance factors which correlate with and influence LBEP have been summarised in Table 2.

**Table 2: Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Lennox <i>et al.</i> (2008).	<p>A fitnessgram was done with additional physical fitness tests. These tests are:</p> <p>PACER: A 20 m multistage shuttle run with a progressive pace increase. The number of 20 m laps completed is recorded when the subject cannot complete a lap in the required time.</p> <p>Curl-ups: A test measure for abdominal strength and endurance. The aim was completion of the maximum correct repetitions done at a pace of 1 curl-up every 3 seconds. To ensure correct execution an age-appropriate measuring strip was used.</p> <p>Trunk lift: In a prone position the trunk is lifted as high as possible with their eyes focused in line with an object with their eyes on the floor. The position is held with the measurement (cm) taken from the floor to the chin.</p> <p>Push-ups: The maximum repetitions had to be done at a rate of 1 every 3 seconds with the torso touching the floor.</p> <p>Pull-ups: The execution should be done with the chin above the bar according to the method of Meredith and Welk (1999).</p> <p>Flexed arm hang: The time is recorded for as long as the subjects hang bent arm with their chin above the bar.</p> <p>Back saver sit-and-reach: Each leg's flexibility is measured separately in unison with the lower back.</p>	<p>Male and female adolescents, 15 years (n = 318)</p> <p>School 1: (n = 252) Male adolescents (n = 116) Female adolescents (n = 136)</p> <p>School 2: (n = 66) Male adolescents (n = 21) Female adolescents (n = 45)</p>	<p><b>Standing long jump:</b> <b>Female adolescents:</b> Arm hang: r = 0.34; p ≤ 0.05</p>

cm = centimetre; m = metre

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Lennox <i>et al.</i> (2008). (cont.)	<p>Sitting against the sit-and-reach box with the sole of the right foot flat on the left foot flat on the floor with the knee bent. Arms forward with hands over each other and palms facing down the subjects stretch 4 times as far forward as possible. During the 4<sup>th</sup> attempt the position is held for 1 second. The longest distance is recorded.</p> <p>Left and right hand grip strength: It was measured with a Lafayette-hand grip dynamometer. Measuring in kg the dynamometer was held parallel with the leg in which the subject had to squeeze it as hard as possible.</p>	<p>Male and female adolescents, 15 years (n = 318)</p> <p>School 1: (n = 252) Male adolescents (n = 116) Female adolescents (n = 136)</p> <p>School 2: (n = 66) Male adolescents (n = 21) Female adolescents (n = 45)</p>	
Vescovi and McGuigan (2008).	<p>A standardized warm-up was done for 10 – 15 minutes with the performance tests performed in a single session. Thereafter a 3-minute rest was given between trials and 6 – 7-minute rest between tests.</p> <p>Linear sprinting: It was measured over a distance of 36.6 m with infrared timing gates (Brower Timing, Utah) at positions of 9.1, 18.3, 27.4 and 36.6 m. Subjects began in an upright position when ready.</p> <p>CMJ height was determined with an electronic timing map (Just Jump System, Probotics Inc.).</p> <p>Agility was measured by making use of a modified version of the Illinois and pro-agility tests. For the Illinois test, two of the four 9.1 m sprints were left out. Sprinting 9.1 m from the start position to the 2<sup>nd</sup> corner from which the subjects turned around back down through the centre cone lines.</p>	<p>Female high school soccer players, 15.1 ± 1.6 years (n = 83)</p> <p>Female college soccer players and young adults, 19.9 ± 0.9 years (n = 51)</p> <p>Female college lacrosse players and young adults, 19.7 ± 1.1 years (n = 79)</p>	<p><b>Counter movement jump:</b> <b>High school soccer players:</b> 9.1m sprint: r = -0.491; p &lt; 0.0001 18.3m sprint: r = -0.564; p &lt; 0.0001 27.4m sprint: r = -0.580; p &lt; 0.0001 36.6m sprint: r = -0.575; p &lt; 0.0001</p> <p><b>College soccer players:</b> 9.1 m sprint: r = -0.658; p &lt; 0.0001 18.3 m sprint: r = -0.758; p &lt; 0.0001 27.4 m sprint: r = -0.767; p &lt; 0.0001 36.6 m sprint: r = -0.788; p &lt; 0.0001</p> <p><b>College lacrosse players:</b> 9.1 m sprint: r = -0.685; p &lt; 0.0001 18.3 m sprint: r = -0.757; p &lt; 0.0001 27.4 m sprint: r = -0.759; p &lt; 0.0001 36.6 m sprint: r = -0.747; p &lt; 0.0001</p>

m = metre

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Vescovi and McGuigan (2008). (cont.)	From there a last direction change was done at the 3 <sup>rd</sup> cone in order to finish with a 9.1 m sprint across the line. For the pro-agility test a flying start was done at the centre cone to the other end 9.1 m further in order to touch the ground. A directional change would be done back with a sprint for which the ground was touched once again from where another directional change would be done again with a sprint of 4.6 m to the finish line.	<p>Female high school soccer players, 15.1 ± 1.6 years (n = 83)</p> <p>Female college soccer players and young adults, 19.9 ± 0.9 years (n = 51)</p> <p>Female college lacrosse players and young adults, 19.7 ± 1.1 years (n = 79)</p>	
Girard and Millet (2009).	<p>A standardized warm-up was done for 15 min, where after a series of tests were repeated 3 times for two separate days.</p> <p>Sprinting: Distances (5, 10 and 20 m) were measured with 2 photocells connected with an electronic timer (Globus, Treviso Italy). Subjects would stand with feet side by side in a tennis-ready position.</p> <p>Jumps: The SJ was performed with a 1-second delay. Other jumps were the CMJ and DJ.</p> <p>Bounds: A multi-rebound jump was done 6 times to the highest maximum height. Subjects were requested to keep their knees stiff with minimal contact time.</p> <p>Grip strength was measured in both hands using a handgrip dynamometer (Captels, St. Mathieu de Treviers, France).</p> <p>Plantar flexor's maximum voluntary torque from contraction was measured with a dynamometric pedal (Captels, St. Mathieu de Treviers, France).</p>	Male junior tennis players, 13.6 ± 1.4 years (n = 12)	<p><b>Counter movement jump:</b> 5 m: r = -0.83; p &lt; 0.001 10 m: r = -0.89; p &lt; 0.001 20 m: r = -0.95; p &lt; 0.001 Grip strength in the dominant hand: r = 0.83; p &lt; 0.001 Grip strength in the non-dominant hand: r = 0.72; p &lt; 0.01</p>

CMJ = Counter movement jump; DJ = Drop jump; m = metre; min = minute(s)

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Korff <i>et al.</i> (2009).	Subjects were asked to hop at their own preferred frequency without shoes with each subject's hands on their iliac crests. Thereafter 3 vertical counter movement jumps were done. Each method was standardised with a verbal description, demonstration and 2-3 practice trials.	Male and female adolescents, 11 – 18 years (n = 73)  Group 1: 11 – 13 years (n = 43)  Group 2: 16 – 18 years (n = 30)	<b>Peak power (Counter movement jump):</b> Leg stiffness: r = 0.70; p < 0.001
Nevill <i>et al.</i> (2009).	An array of 5 tests was done of which 2 trials were given to each test. These tests were:  Aerobic endurance (20 m multistage shuttle run test): In groups of 5, subjects were to run between lines 20 m apart in time with a record signal from a CD player. From a starting speed of 8.5 km/h an increase of 0.5 km/h were given for each signal. The test was terminated with the subject not being able to complete 3 consecutive signals at the required speeds.  Anaerobic speed (40 m sprint): Starting with the preferred foot at the starting line the subject started in an upright position.  VJ: The best trial of 2 was recorded with a jump meter fitted to the waist (T.K.K. 5106 JUMP MD; Takei Scientific Instruments, Tokyo, Japan).  Sit and reach test: Sitting on the ground floor, the subjects' bare feet were placed against a box. Leaning forward over the top of the box the arms and knees had to be kept straight. Two trials were done.	Greek male and female adolescents (n = 672)  Males, 12.2 ± 0.7 years (n = 348)  Females, 12.2 ± 0.5 years (n = 324)	<b>Vertical jump:</b> 40 m sprint: r = 0.573; p < 0.001

km/h = kilometre per hour ; m = meter

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Nevill <i>et al.</i> (2009). (cont.)	Hand grip test: Measurements were taken with a calibrated hand dynamometer (TAKEL, Tokyo, Japan). Subjects had to squeeze the device with maximal force with both hands in 2 trials. In order to control for variations in hand size the handle length were adjusted.	Greek male and female adolescents (n = 672)  Males, 12.2 ± 0.7 years (n = 348)  Females, 12.2 ± 0.5 years (n = 324)	
Temfemo <i>et al.</i> (2009).	After a week-long performance experiment had been done to familiarize the subjects, the 2 <sup>nd</sup> week was utilized for performance testing of the SqJ, CMJ and rebound jump.  For each test 3 tests were performed with a 2-min resting period. The jumps were evaluated with an electronic apparatus, the Psion, which was connected by a cable to a resistive platform (Ergojump Bosco System; Junghans GMBH, Schramberg, Germany).	French Caucasian adolescents, 11- 16 years (n = 479)  Male (n = 240)  Female (n = 239)	<b>Counter movement jump:</b> Average power output: r = 0.84 (male) Average power output: r = 0.84 (female)
Dumke <i>et al.</i> (2010).	Testing was done on separate days but concurrently whereas on day 1 all muscular testing was done.  With knees bent subjects first had to perform on a force plate a maximally isometric plantar flexion. Subjects, while seated in a chair, placed on the force plate the balls of their feet with knees and ankles at 90°. For measuring the maximal isometric force, all subjects sat with an oscillation device placed on their knees with knees and ankles at 90°. Concerning their maximal isometric plantar flexion force subjects were loaded from 5 – 40% in incremental succession of 5%. To measure the lower leg oscillation through the force plate, each load was tapped with a 10 kg weight.	Male adolescent and young adults, 21 ± 2.7 years (n = 12)	<b>Counter movement jump peak force production:</b> VO <sub>2</sub> at stage 2: r = 0.66; p = 0.02 (through incremental treadmill test) VO <sub>2</sub> at stage 3: r = 0.70; p = 0.01 VO <sub>2</sub> at stage 4: r = 0.58; p = 0.04

° = degrees; % = percentage; CMJ = Counter movement jump; kg = kilogram; min = minute(s); SqJ = Standing broad jump ; VO<sub>2</sub> = Volumetrical Oxygen Uptake

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Dumke <i>et al.</i> (2010). (cont.)	<p>Subjects were requested to perform the CMJ with a minimum of 2 trials and a rest period of 2 minutes between trials. Measurements were taken with a bar held across their shoulders (LPTs; Celesco Transducer Products. PT5A-150, Chatsworth, CA, USA).</p> <p>Squat testing was done isometrically maximal for 3 seconds in a power rack against a bar on a force plate (AMTI, BP6001200).</p> <p>A discontinuous incremental test was executed on a treadmill (Trackmaster, JAS Fitness Systems). The increment started at 187.6 m/min at 1% grade. After 3 min, subjects stepped off for 20 seconds in order for a lactate sample to be taken. For each 3-minute stage thereafter the speed was increased at 26.8 m/min until 321.6 m/min was reached or the subjects had reached their ventilator threshold. If 321.6 m/min (19.35 km/h or 3.06 min/km) was reached the grade was increased 0.5% with no lactate samples taken.</p>	Male adolescent and young adults, 21 ± 2.7 years (n = 12)	
Jovanović <i>et al.</i> (2010).	After adequate warming up and stretching was done during the morning, 9 sets of standardized motoric tests were done for explosive strength, agility and speed. All tests were explained and illustrated with emphasis placed on the correct technique. These tests were: the running 20 and 40 m, Sergeant test, throwing medicine ball from a lying position, longitudinal jump from the spot, triple jump from the spot, T-test, envelope-test and 6 angular directional tests.	Female jazz ballet dancers, 12 – 15 years (n = 21)	<p><b>Longitudinal jump from the spot:</b> Running 20 m: r = 0.657; p = 0.01 Running 40 m: r = 0.622; p = 0.01</p> <p><b>Sergeant test:</b> Running 20 m: r = 0.473; p = 0.05 Running 40 m: r = 0.564; p = 0.01</p> <p>T-test: r = 0.641; p = 0.01</p>

% = percentage; km/h = kilometre per hour; m/min = meter per min; m = meter; min = minute(s); min/km = minutes/kilometre

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Milanese <i>et al.</i> (2010).	<p>Subjects attending summer camp were measured over 3 years in June/July.</p> <p>The standing long jump was used as part of motor fitness tests. For the 30 m dash subjects assumed an upright position. Three trials were performed with the score being averaged.</p>	<p>Male and female adolescents, 6 – 12 years (n = 152)</p> <p>Male, 10 – 12 years (n = 37)</p> <p>Female, 10 – 12 years (n = 17)</p>	<p><b>Standing long jump:</b></p> <p><b>Males, 12 years:</b> Velocity (30 m): r = 0.630; p &lt; 0.001</p> <p><b>Females, 12 years:</b> Velocity (30 m): r = 0.600; p = 0.011</p>
Milojević and Stanković (2010).	<p>Subjects attending their 1<sup>st</sup> year of high school were subjected to 11 motor ability tests, where after it was repeated for their 2<sup>nd</sup> year under the same conditions. These tests were: the standing long jump, push-ups, the pull up hang, 20 m running with a high start, 4x5 m with a high running start, hand tapping, hyperextensions, the one leg stand on a balance beam, coordination with a baton, the 3-medicine-ball slalom and the backward polygon.</p>	<p>Male adolescents, 14 – 15 years (n = 123)</p>	<p><b>Standing long jump:</b> 20 m run with a high start: r = -0.48; p = 0.00 Endurance in the hanging position: r = 0.36; p = 0.00</p>

m = metre

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Mandy and Boyle (2011).	<p>A 5-min warm-up was done after which subjects were sent to rotate through 5 different testing stations in 2 groups. These 5 tests were:</p> <p>Arrowhead agility drill: it was completed twice; one to each side. Standing in a 2-point position, the player ran as fast as possible to a middle flag (10 m away), around to a side flag (5 m away), around to the furthest flag (5 m away) and back around to the beginning (15 m away).</p> <p>Linear sprint: The subject stood with one foot on or behind the starting line with a two-point stance. Speed times were measured at 5, 10, 20 and 40 m with timing lights (Newtest, Stockholm, Sweden).</p> <p>VJ: The height reached was calculated as the difference between the gross jump height (measured as the maximum distance reached of the preferred hand's distal third metatarsal) from their standing reach.</p> <p>Broad jump: Two boxes were connected, with a non-slip surface from the front of the platform of the force plate. Calculation of the distance was done as the displacement of the posterior of the heels from the starting line.</p>	Elite male youth soccer players, 15 – 18 years (n = 75)	<p><b>Vertical jump height:</b>            10 m sprint: r = -0.36; p ≤ 0.05            20 m sprint: r = -0.42; p ≤ 0.05            40 m sprint: r = -0.38; p ≤ 0.05            Arrow head agility, right: r = -0.42; p ≤ 0.05            Predicted VO<sub>2</sub>max: r = -0.39; p ≤ 0.05</p> <p><b>Broad jump distance:</b>            10 m sprint: r = -0.54; p ≤ 0.05            20 m sprint: r = -0.67; p ≤ 0.05            40 m sprint: r = -0.72; p ≤ 0.05            Arrow head agility, right: r = -0.36; p ≤ 0.05            Arrow head agility, left: r = -0.48; p ≤ 0.05</p>

m = meter; min = minute(s); VO<sub>2max</sub> = Maximum Volumetric Oxygen Uptake

**Table 2 (cont.): Physical and motor performance factors summary table of adolescents.**

Study	Methodology	Gender, status, age and number of participants.	Results: factors correlated (r) to LBEP with their level of significance (p).
Moresi <i>et al.</i> (2011).	Self-administered (jogging, exercise bike pedalling) warm-up was done for 5 minutes. Thereafter familiarization jumps was done for the array of test jumps. Three trials were completed of the following jumps: SL, reactive long jump from a 0.45 box, and a DJ from the same box. These jumps were first demonstrated where subjects were allowed as many practice trials preferred, for familiarisation.	Female junior level sprinters and horizontal jumpers, 16.4 ± 1.1 years (n = 8)	(Standing long jump components in relation to the best sprinting times arranged from average to best accordingly) Average horizontal power: r = -0.866* to -0.887** Peak horizontal power: r = -0.810* to -0.865* Peak horizontal force: r = -0.791* to -0.860* Horizontal take-off velocity: r = -0.770* to -0.835* Average horizontal force: r = -0.803* to -0.804* Vertical take-off velocity: r = -0.643 to -0.723* Average vertical power: r = -0.727* to -0.750* * p = 0.05; ** p = 0.01
Hermassi <i>et al.</i> (2011).	Two familiarization trials were done in the two weeks prior to the testing period. Testing of the CMJ and SJ was done on the same day 3 days after the last competition date. Calculations were done on the force platform (Quattro Jump, version 1.04; Kistler Instrumente AG, Winterthur, Switzerland).  For the agility T-test the same directives of the T-test were followed with the intercone distances being altered. This resulted in an increase to 36.56 m from 20 m. The best trial's time was recorded.  For 5 m sprinting 2 trials were performed on a tartan surface with a minimum of a 5-minute rest with the fastest trial being recorded.	Male handball adolescents, 17.1 ± 0.8 (n = 20)	<b>Counter movement jump:</b> Agility T-test: r = -0.66; p < 0.01

CMJ = Counter movement jump; DJ = Drop jump; m = meter; SqJ = Squat jump; SL = Standing long jump test

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### 4.2.1 Speed

LBEP's high take-off speeds tend to correlate with the attainment of high LBEP values; therefore high take-off speeds during jump activities may positively influence adolescents' standing broad jump performances (Mandy & Boyle, 2011:9; Papadopoulos *et al.*, 2011:441). In this regard various researchers have reported significant, negative correlations ( $r = -0.28 - -0.72$ ;  $p < 0.05$ ) between 5 and 40 m sprinting times and LBEP (SL, BJ and VJ) (Milojević & Stanković, 2010:109 & 111; Mandy & Boyle, 2011:43; Moresi *et al.*, 2011:80-81). Furthermore, Mandy and Boyle (2011:40, 43) also showed that LBEP, as measured in the BJ, explained 52% of the variance in 40 m, 45% of the variance in 20 m, 29% of the variance in 10 m and 10-20% of the variance in 5 m sprinting times of 75 elite male u15-u17 soccer players. Thus sprinting and LBEP jumping abilities are closely related (Hermassi *et al.*, 2011:131; Stamm *et al.*, 2011:385). In terms of explosive power jumps, HJT tend to have a stronger positive relationship with speed than VJ (Maulder & Cronin, 2005:78). Seeing that the body is propelled in both horizontal and vertical planes during acceleration in sprinting, it is logical that forces applied in a horizontal plane would be large force contributors to speed and agility (Mandy & Boyle, 2011:45; Moresi *et al.*, 2011:74).

### 4.2.2 Agility

Agility can be defined as a change of direction speed that relies on preplanned movement and consists of a rapid rebound or change of direction which is influenced by the amount of LBEP produced (Gabbett & Benton, 2009:212). Most sport scientists would rather classify agility as any movement, not only preplanned movement, involving a rapid change and/or changes of direction (Gabbett & Benton, 2009:212). LBEP as measured in the VJ has a strong association with agility in elite male u15-u17 soccer players ( $n = 75$ ) and 20 male adolescent handball players ( $r = -0.66$ ,  $p < 0.01$ ) (Hermassi *et al.*, 2011:127 & 131; Mandy & Boyle, 2011:44), and correlates significantly with the agility T-test results of 21 female jazz ballet dancers (12 - 15 years) ( $r = 0.641$ ,  $p = 0.01$ ) (Jovanović, 2010:231). Therefore a greater amount of force or power applied during the onset of a movement will result in a greater vertical jump height and a shorter agility time (Paja, 2011:9). In conclusion, Mandy and Boyle (2011:30 & 44) found that the BJ correlated significantly ( $p < 0.05$ ) with the arrowhead agility test to the left ( $r = -0.48$ ) and right ( $r = -0.36$ ), while VJ correlated significantly with the arrowhead agility test to the right ( $r = -0.42$ ) in male adolescents.

Table 2 represented a concise summary of the physical and motor performance predictors of LBEP in adolescents as indicated by literature. From the total of 13 studies, three found agility test to correlate significantly with agility. Factors such as grip strength correlated significantly with LBEP in a singular study,  $VO_2$  correlated significantly with LBEP in two studies while speed and speed variants correlated significantly with LBEP in eight of the 13 studies. In the following section other possible factors; such as external factors, strength, technique and training, stiffness and flexibility, physiological factors; influencing LBEP will be

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discussed. Factors such as leg stiffness had been found to correlate significantly in one of the studies with LBEP, while power or force measurements reflective of strength had been found to correlate significantly with LBEP in two of the 13 studies.

### **4.3 The influence of various other physical factors on the LBEP of adolescents**

Performance in team sports which requires LBEP is influenced by a combination of environmental, social, psychological and physiological factors (Nikolaïdis, 2011:342). According to Escarti and Guzman (1999:84), experience, verbal persuasion, strength and other physiological factors influence LBEP execution performance. The following section will discuss the influence of some of these factors and their influence on LBEP.

#### **4.3.1 Strength**

Strength measurement, irrespective of whether from handgrip strength, flexed arm hang or leg strength, is reflective of LBEP, and correlates significantly positive with LBEP. Temfemo *et al.* (2009:460) concluded that a strong positive correlation existed between LBEP (CMJ) and maximal leg strength in 11 – 16-year-old boys ( $r = 0.85$ ) and girls ( $r = 0.78$ ). For 15-year-old South African girls, a positive relationship was found between LBEP, as measured by SL, and the flexed arm hang time ( $r = 0.34$ ,  $p \leq 0.05$ ) (Lennox *et al.*, 2008:70). Also in the study of Milojević and Stanković (2010:109), flexed arm hang time as a strength component ( $r = 0.36$ ,  $p < 0.00$ ) (SL) and handgrip strength ( $r = 0.72 - 0.83$ ,  $p = 0.001 - 0.01$ ) (CMJ) (Girard & Millet, 2009:1870) correlated positively with LBEP in boys (13 – 15 years of age).

#### **4.3.2 Stiffness and flexibility**

In all sporting programs exercise is always preceded with various types of stretching. The inclusion of static stretches in a flexibility and explosive strength program did not affect 22 female athlete's LBEP ( $11.3 \pm 2.6$  years) (Kinser *et al.*, 2007:137-138; Behm & Chaouachi, 2011:2647) or enhance the LBEP movements of 60 male basketball and volleyball players ( $24 \pm 4$  years) (Hunter & Marshall, 2002:486; Behm & Chaouachi, 2011:2647). In contrast, Behm and Chaouachi (2011:2647) found that static stretching may result in the production of more LBEP due to a better ability to store potential elastic energy. In this regard, Witvrouw *et al.* (2004:104) also found that a higher elasticity of muscle-tendon units in the lower limbs is associated with higher LBEP production during jumping activities. In contrast, decreased stiffness of the SEC will lead to a decreased LBEP production during jumping (Cornwell *et al.*, 2002:432). In support of the previous statement, leg stiffness has a significantly positive correlation ( $r = 0.70$ ,  $p < 0.001$ ) with peak explosive power production during LBEP (VJ) jumping activities of 16 – 18-year-old Australian adolescents (Korff *et al.*,

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2009:3739), and can be regarded as an important factor for achieving better performances in sports which require LBEP (Hobara *et al.*, 2011:2115).

### 4.3.3 Physiological factors

LBEP production is partly genetically determined among adolescents (Chillón *et al.*, 2011:417). In addition, differences in maturation need to be considered (Ayed *et al.*, 2011:104), especially with regard to skeletal and neuromuscular maturation (Carvalho *et al.*, 2011:794). The muscle characteristics or morphology of a person are regarded by several researchers to be the most important factor in determining LBEP production (Vanezis & Lees, 2005:1601-1602; Carvalho *et al.*, 2011:794). In this regard, longer muscle fascicles can for example generate greater shortening velocities and thus deliver greater mechanical powers than shorter fascicles (Arampatzis *et al.*, 2006:3346). Variations in muscle characteristics may also include a higher ratio of fast-twitch muscle fibres (type IIb/x) (Ackland & De Ridder, 2003:93; Majumdar & Robergs, 2011:490), and a tendon unit with an insertion that gives a greater mechanical advantage (Ackland & De Ridder, 2003:93). Continued training or participation in physical activities may in the long run cause type IIa muscle fibres (moderate fatigue resistance) to convert to type IIb/x (low fatigue resistance) fibres in adolescents (Majumdar & Robergs, 2011:490). These last-mentioned muscle characteristics may enable a person to execute more rapid and forceful muscle contractions so that more LBEP is generated, especially during jumping activities. However, muscle fibre size is also greatly affected by age, increasing by 15-20 times from birth to young adulthood (Majumdar & Robergs, 2011:491).

The neuromuscular system also contributes to the production of LBEP by the activation of more muscle motor units and the recruitment of a higher number of muscle fibres during contraction of the targeted muscle (Aerenhouts *et al.*, 2007:107; Majumdar & Robergs, 2011:491). Adolescents will usually also experience an increase in the efficiency of contractile activity during maturation (De Ste Croix *et al.*, 2001:147), which will allow them to shorten the transfer phase between the eccentric and concentric muscle contractions when jumping (Gollhofer, 2003:334).

### 4.3.4 Technique and training experience

The technique used to execute a jump might have an influence on the LBEP produced. In this regard, jumps executed while performing an arm swing delivered better LBEP results than jumps without an arm swing (Vanezis & Lees, 2005:1601-1602). The reason for this is that an arm swing leads to an increase in hip torque production during especially the latter half of the jump's propulsion phase (Hara *et al.*, 2008:647). Another technical-related factor that needs to be considered is the depth of the eccentric bending action, or greater counter movement, that each subject self-selects during execution of counter movement jumps (Mandy & Boyle, 2011:9, Paja, 2011:24-25). An increase in the counter movement speed of the afore-mentioned action

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will also affect the jumping performance (Mandy & Boyle, 2011:9). The speed of movement will undoubtedly influence the amount of potential elastic energy stored during phase I of the SSC (Papadopoulos, 2011:441). Higher movement speeds will lead to the storage of more potential elastic energy and will ultimately give rise to higher jumping heights. Access to sporting facilities including appropriate opportunities for physical activity, which includes LBEP activities, could possibly influence LBEP (Chillón *et al.*, 2011:417).

Given the previously stated factors correlating with LBEP, some researchers have to a certain extent determined the contributions of these factors to LBEP. Other researchers in their respective studies have determined LBEP's percentage possible contributions on its account to various other factors. Prediction models of LBEP as well as models and equations for factors contributing to LBEP, and LBEP contributing to certain factors will be discussed in the following section.

### **5. PREDICTION MODELS/EQUATIONS OF LBEP IN CHILDREN AND ADOLESCENTS**

Table 3 represents a summary of the prediction models or equations explaining LBEP in children and adolescents. The table also includes models and/or equations where LBEP is responsible for the explanation for a certain percentage of other factors.

**Table 3: Summary of models and contributions of LBEP in relation to other factors and vice versa**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	Results: the contribution of LBEP to other factors.
Malina <i>et al.</i> (1995).	<p>An array of anthropometric-related dimensions was measured. First stature and body weight was taken. Skinfold measurement included: the medial calf, subscapular, suprailiac, biceps and triceps with a Harpenden calliper. Fat was estimated from the sum of these aforementioned SF.</p> <p>The fitness test for the battery included:                      The flamingo stand: With a preferred foot on the longitudinal axis (50 cm long, 4 cm high, 3 cm wide) of the beam the subject had to maintain balance for 1 minute. The other foot was held by the hand when bent backwards on that side of the body. Scoring was given on the number of times the foot left the beam to maintain their balance, thus the lower the score the better.</p> <p>Plate tapping: Scoring was measured as the total number of taps attained in one 20-second trial. This was done in an upright position with two 20-cm in diameter plates, 60 cm apart.</p> <p>Sit and reach: In 2 trials the farthest distance reached was recorded. A reach was executed in a seated position with knees extended with feet against a vertical support placed firmly.</p> <p>Arm pull: The subject pulled to their maximum abilities with their preferred arm against the dynamometer. While in a standing position the non-preferred arm held a fixed vertical support.</p>	Flemish female children and adolescent national sample group, 7 – 17 years (n = 6 700)	Leaner female adolescents of which 5% in total generate higher LBEP due to lesser fat mass affects.	

cm = centimeter

**Table 3 (cont.): Summary of models and contributions of LBEP in relation to other factors and vice versa.**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	Results: the contribution of LBEP to other factors.
Malina <i>et al.</i> (1995). (cont.)	<p>Bent (flexed) arm hang: With only 1 trial, the subjects had to hang as long as possible keeping their eyes above the horizontal bar with their arms flexed.</p> <p>Leg lifts: With only 1 trial the subjects had to complete as many repetitions in 20 seconds as possible. One repetition was executed in a supine position where both legs were raised to a vertical position and lowered to the floor as many times as possible.</p> <p>50 m shuttle run: With both feet crossing the line in only 1 trial the subjects had to run as quick as possible 5 times between the 50 m lines.</p> <p>Pulse recovery after 1 minute step test: Stepping on and off a 40 cm bench at a rate of 30 steps/min the pulse rate was recorded directly before and after the test, as well as at 1 and 2 minutes of rest afterwards. The scoring was the sum of the 1 and 2-minute pulse rates.</p> <p>Submaximal power output: The subjects pedalled on an electromagnetically braked bicycle ergometer at 60 rev/min. Each of the 3 stages lasted 3 minutes where the initial load was set at 1 watt/kg body weight whereas the 2<sup>nd</sup> and 3<sup>rd</sup> stages were set at 2 and 3 watt/kg body weight distinctively.</p>	Flemish female children and adolescent national sample group, 7 – 17 years (n = 6 700)		

cm = centimeter; m = meter; rev/min = revolutions per minute; SF = skinfold; steps/min = steps per minute; watt/kg = watt per kilogram

**Table 3 (cont.): Summary of models and contributions of LBEP in relation to other factors and vice versa**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	Results: the contribution of LBEP to other factors.
Kinnunen (2003).	<p>Adolescents were divided into groups for the purpose of analysis on the SL in relation to numerous anthropometric measurements:</p> <p>7-year-old females 12-year-old females 16-year-old females 7-year-old males 14-year-old males 18-year-old males</p> <p>Refer to Kinnunen (2003) in Table 1 for anthropometric-related descriptions.</p>	<p>Male and female Caucasian adolescents, 7 – 18 years</p> <p>Males (n = 224) Females (n = 263)</p>	<p>12-year-old females: Triceps and subscapular SF: b = -.309; R<sup>2</sup> = .095</p> <p>16-year-old females: Sum of SF: b = -.381; R<sup>2</sup> = .124 Standing height: b = -.171; R<sup>2</sup> = .153</p> <p>14-year-old males: Triceps SF: b = -.292; R<sup>2</sup> = .174 Biacromial breadth: b = -.310; R<sup>2</sup> = .235 Umbilical (abdominal) SF: b = -.278; R<sup>2</sup> = .259</p> <p>18-year-old males: Triceps and subscapular SF: b = -.375; R<sup>2</sup> = .108 Sitting height: b = -.298; R<sup>2</sup> = .194</p>	
Ronan <i>et al.</i> (2003).	<p>Adolescents were divided into 11 cohorts of with whom tests were done twice, with a time increment of 3.8±0.4 years in between.</p> <p>Anthropometric measurements were measured including lean leg volume, leg length, body mass and their respective ages.</p>	<p>Male and female children and adolescents, 7.5 – 17.5 years</p> <p>Males (n = 109) Females (n = 100)</p>	<p>57% age explanation.</p>	

SL = Standing long jump test

R<sup>2</sup> = Standardized beta coefficient

**Table 3 (cont.): Summary of models and contributions of LBEP in relation to other factors and vice versa.**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	Results: the contribution of LBEP to other factors.
Stamm and Stamm (2004).	<p>Subjects were divided into 6 groups. Groups were tested on 9 validated motor performance physical tests.</p> <p>See Table 1 for anthropometric-related descriptions.</p> <p>The motor performance physical test was: Two VJ variations of 1 standing and 1 with a running approach. Heights attained were calculated from subtracting their standing outstretched positions with the 2 different heights attained. The other tests included a 20 m shuttle run, a sit-up test, a flexibility test through bending forward in a sitting position, zigzag run test and the medicine ball throw test.</p>	Female volleyball adolescent players, 13 - 16 years (n = 46)	<p>Weight and height explain <math>R^2=0.75</math> for LBEP.</p> <p>Lower limb length, horizontal arms span, upper leg circumference and a chest SF explain <math>R^2=0.89</math> of LBEP.</p>	
Carvalho <i>et al.</i> (2011).	All anthropometric measurements were taken, following standardized procedures of Lohman <i>et al.</i> Stature and sitting height was measured to the nearest 0.1 cm with a portable stadiometer (Harpender model 98.603, Holtain Ltd, Croswell, UK). With a portable balance (Seca model 770, Hanover, MD, USA) to the nearest 0.1 kg body mass was measured. Total thigh volume was calculated by means of measuring the partial lengths between each circumference location. These locations were the gluteal furrow (maximum), mid-thigh (maximum) and the minimum circumference above the knee.	Male basketball players, 14.0 – 16.0 years (n = 94)	52% anaerobic peak power production contribution in male adolescents.	

% = percentage; cm = centimeter; kg = kilogram; m = meter; LBEP = Lower body explosive power;  $R^2$  = Standardized beta coefficient

VJ = Vertical jump

**Table 3 (cont.): Summary of models and contributions of LBEP in relation to other factors and vice versa**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	Results: the contribution of LBEP to other factors.
Carvalho <i>et al.</i> (2011). (cont.)	<p>A standardized warm-up was done where after a 30 sec Wingate anaerobic test was done. The test was started at a speed of 60 rev/min with a resistance of 0.075 kg per body mass which was applied as soon as the necessary speed was attained. Subjects had to remain seated at all times applying maximum effort.</p> <p>The Bangsbo sprint test and line drill test was used to measure the running-based maximal short-term performance in field conditions. For the line drill test, subjects had to run 4 consecutive shuttle run sprints of 5.8, 14.0, 22.2 and 28.0 m for a total of 140 m. The Bangsbo test was executed by running a 35 m sprint 7 times with a jog/walk rest period of 25 seconds in between.</p>	Male basketball players, 14.0 – 16.0 years (n = 94)		
Mandy and Boyle (2011).	<p>Refer to Table 2 for physical and motor performance-related descriptions</p> <p>With minimal movement, body weight was measured on a force plate. Clothes' weight was taken into account. Height was measured with the aid of an imperial tape and a fixed wall. Subjects had to maintain contact with their back to the wall and to stand as tall as possible. For SF, 3 measurements were taken and were defined as follows: Abdominal: A vertical fold 2 cm to the right of the umbilicus.</p>	Elite male youth soccer players, 15 – 18 years (n = 75)		<p>52% of the variance in 40 m time. 45% of the variance in 20 m time. 29% of the variance in 10 m time. 10-20% in 5 m sprinting time. 97% of the total amount of power spent results in maximal propulsion during the LBEP VJ.</p>

cm = centimeter; kg = kilogram; LBEP = Lower body explosive power; m = meter; VJ = Vertical jump; rev/min = revolutions per minute  
sec = second(s)

**Table 3 (cont.): Summary of models and contributions of LBEP in relation to other factors and vice versa**

Study	Methodology	Gender, status, age and number of participants.	Results: factor contribution/explanation to or affecting LBEP.	LBEP contribution to factor.
Mandy and Boyle (2011). (cont.).	<p>Suprailiac: measured in the anterior axillary line immediately superior to the iliac crest with the fold a diagonal fold in line with the natural angle of the iliac crest.</p> <p>Thigh: On the anterior midline of the thigh a vertical fold is taken midway between the proximal border of the patella and the inguinal crease (hip).</p> <p>Lean mass and fat mass was subsequently calculated.</p>	Elite male youth soccer players, 15 – 18 years (n = 75)		
Travill (2011).	<p>The physical and motor performance was done via 5 tests. A summary and definition were given and done on a standardized method researched by the author from Corbin and Linsey. These 5 tests were the: sit-and-reach test, hand grip dynamometer, standing long jump test, 50 m-sprint test and 3-minute step test.</p> <p>The anthropometric measurements were: biepicondylar-femur (left and right), biepicondylar-humerus (left and right), biiliac breadth, biacromial breadth, medial calf SF, abdominal SF, suprailiac SF, subscapular SF, triceps SF, relaxed forearm girth, tensed arm girth (left and right), relaxed arm girth, calf girth, hip girth, waist girth, chest girth, upper extremity length, lower extremity length, dactylion height, acromiale height, trunk height, sitting height, height and mass. Body fat and body density was subsequently calculated.</p>	Male children and adolescents, 7 – 18 years (n = 360)	<p>Acromial height, medial SF and chest girth combination in 38.6% explanation for male adolescents younger than 13 years Left upper arm contracted girth, upper limb length and abdominal SF combination in 42% explanation for male adolescents older than 13 years of age.</p> <p>Age contributes 9% more for 12-year-old male adolescents than for same age female adolescents.</p>	

% = percentage; m = meter; SF = skinfold

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The use of models or singular tests to predict aerobic performance in adults (Stickland *et al.*, 2003; Akay *et al.*, 2011; Rocznio *et al.*, 2012) and adolescents have been successfully applied (Akalan *et al.*, 2008; Roberts *et al.*, 2009; Jacks *et al.*, 2012). Currently, most researchers have focussed more on determining the percentage contribution of predictors for LBEP performances in adolescents, rather than compiling a full LBEP prediction model (Davis *et al.*, 2003:172; Carvalho *et al.*, 2011:793; Travill, 2011:116-117). As mentioned earlier, this literature overview primarily focused on the anthropometric, physical and motor performance components that influence adolescents' LBEP.

With regard to age and anthropometric-related contributors to LBEP, muscle mass has demonstrated a contribution of 52% to anaerobic peak power production during a 30-second ergometer cycle test in 14 – 16-year-old ( $n = 94$ ) male basketball players (Carvalho *et al.*, 2011:793). A study on Flemish female adolescents (7 – 17 years) ( $n = 6\ 700$ ) revealed that female children and adolescents that outperformed their peers in LBEP- (SL and VJ) related tests had lower fat mass values (Malina *et al.*, 1995:227). This supports the notion that a smaller fat mass and an increase in muscle mass in relation to body weight contributes to LBEP production (Malina & Katzmarzyk, 2006:304). Age alone may explain as much as 57% of the maximal power produced in male adolescents (Ronan *et al.*, 2003:121).

According to the contribution model for LBEP by means of the vertical jump test, Stamm and Stamm (2004:17) found that 56.25% ( $R^2 = 0.75$ ) of the variance in LBEP (VJ) could be explained by the age, body weight and height of female adolescent volleyball players (13 – 16 years of age). Their second model obtained an even higher prediction power ( $R^2=0.89$ ) by including lower limb lengths, horizontal arm span, upper leg circumferences and chest SF as possible predictors of LBEP (Stamm & Stamm, 2004:17). A similar contribution model of Travill (2011:117) reported that 42% of the variance in LBEP (SL) could be explained by a left contracted upper arm girth, upper limb length and abdominal SF in 13 – 18-year-old adolescent males. Furthermore Travill (2011:116) found that a combination of acromial height, medial SF and chest girth explained 38.6% of the variance in LBEP in adolescent boys and children under the age of 13. Kinnunen (2003:66) formally finalised a prediction model for LBEP (SL) from various anthropometric components tested, although no physical and motor performance data was ever considered as part of the study. Each predictor was assigned an own intercept (b) value as found in other prediction models, including an  $R^2$  value or percentage contribution to LBEP (Kinnunen, 2003:66). The smallest contribution was found from the combination of triceps and subscapular SF (9.5%) in 12-year-old females, while the largest contribution was found to be the umbilical (abdominal) SF (25.9%) in 14-year-old male adolescents.

From the discussed literature it is evident that only one model was found from which the LBEP of adolescents can be predicted although only making use of the anthropometric values of the specified

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population group. Furthermore, some of the available literature only identified and investigated a small number of factors which may possibly influence the LBEP of adolescents. It is therefore necessary for more extensive models to be developed that include a wider variety of possible factors for the accurate prediction of adolescents' LBEP. The above discussion clearly demonstrates numerous factors that need to be considered when developing such a prediction model. LBEP prediction models for adolescents will allow coaches and sport scientist to indirectly identify young adolescents who may possibly have the LBEP capabilities required to excel in a variety of sports.

### **6. CONCLUSION AND RECOMMENDATIONS**

LBEP production is seen as a very important aspect for performance in certain team and individual sports of which it has become clear from the discussion above that LBEP is influenced by various anthropometrical, physical and motor performance variables. The physiological principle of the SSC best explains the production of explosive power which is necessary in the production of LBEP, and comprises of both the mechanical model and the neurophysiological model.

To measure maximal LBEP production, researchers have devised variations of certain jumping techniques. Some measurements are done to calculate LBEP and others to validate LBEP performance. As for these tests, none of them to our knowledge have been specifically verified for adolescents. The VJT (in similarity to the SeJ) and the HJT are the two best tests for measuring LBEP in adolescents. Both jumping techniques addresses the vertical approach in LBEP movements and also the horizontal approach in LBEP movements. Both of these tests are more natural in movement due to the counter movement as can be seen in different types of sports or individual item movements.

The review served the purpose of identifying factors influencing LBEP. Factors such as age and gender were identified with numerous other anthropometric factors which included body weight, muscle mass, fat mass, breadth indicators, limb length and girth. Physical and motor performance factors identified consisted of speed, agility, strength, stiffness and flexibility. Referring to almost all of the above-mentioned components; age, muscle mass, breadths, limb lengths, girth, speed, agility, strength, stiffness and flexibility; have been found to have a positive influence, and thus a positive correlation, with maximal LBEP production. Very few factors, i.e. fat mass as well as stiffness and flexibility, have shown to possibly decrease the maximal LBEP attained. Body weight's influence on LBEP has been shown to be influenced positively by muscle mass and negatively by fat mass. From the reviewed literature certain anthropometrical and anthropometrical-related variables have been found to be more profound as indicators of LBEP values, with variables such as age, weight, height, biacromial breadth, triceps SF, biceps SF, subscapular SF, suprailiac SF, frontal thigh SF and

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fat mass or percentage as calculated in various forms of the sum of SF showing greater influential power to LBEP production. For physical and motor performance variables the following indicators have been identified as being markedly more profound LBEP value indicators: arm hang, sprinting velocities, muscle power output and agility time.

Other categorical factors which could influence LBEP, but remained outside the scope of this literature review were physiological factors, technique and training experience. For most of the factors a consensus can be reached on the power of their influence on LBEP. Factors such as stiffness and flexibility remain unclear as studies have concluded opposing results in their findings. Speed as a factor has produced significant correlations in numerous studies although results varied between positive and negative correlations. It is clear that a lower speed test time, indicating a better result, will yield a negative correlation with higher LBEP values. In certain studies positive correlations were found which might be attributable to analytical techniques used or the manner of reporting. Thorough and conclusive research is needed in order to address this issue. For categorical factors, such as external factors, influences on LBEP are recognized but to what extent and in what manner is not defined in this literature review. Conclusive studies regarding these factors are suggested to complement future literature reviews such as this review.

Very few studies have been conducted with the aim of developing LBEP prediction models for adolescents, with most researchers reporting on the correlations of various factors to LBEP values. Of all the available literature only four authors quantified various predictors' percentage contribution (as contribution models) to LBEP and only one author has compiled a full prediction model for LBEP values from anthropometric variables.

Of the previously mentioned, the contributing predictors to LBEP tend to be the strongest of Ronan *et al.* (2003) and Travill (2011). Ronan *et al.* (2003) stated that age's contribution to LBEP production was 57%. In the study of Travill (2011) whereby the relationship between the characteristics of anthropometrics and physical fitness was established, two models through a stepwise regression analysis, were quantified and established for their contribution to LBEP production.

From the available contribution and prediction models the largest contributors to LBEP were the combination of lower limb length, horizontal arm span, upper leg circumference and chest SF's 89% contribution to LBEP for 13 - 16-year-old female volleyball adolescents. Two other strong contribution and prediction models explaining predictors' contribution to LBEP was a weight and height combination of 75% for the same aforementioned adolescent group as well as the triceps (17.4%), biacromial breadth (23.5%) and umbilical SF (25.9%) combination of 66.8% in 14-year-old males. Although these variables have shown to be possible

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contributors of LBEP, only one contribution model has been developed for a certain male population of 13 years and younger or older than 13 years for South African adolescents. Due to the limited available literature, studies were included with doubtful quality. Further research with regard to certain predictors as well as the development of LBEP prediction models for South African adolescents is much needed. Filling these voids with more current studies will contribute significantly to predicting LBEP of adolescents in rural South Africa where limited instruments and resources are available for talent identification and sports development.

Certain shortcomings were, however, identified in the review of the current available literature. From the above-mentioned findings it is clear that LBEP contributors, especially applicable to adolescents, are lacking in the literature. The same is true for specific reference to adolescents in South Africa. Numerous studies' age groups did not pertain only to adolescents, but also to children or young adults. In some studies, numerous data were collectively gathered, processed and described and this resulted in adolescents of 18 years in the upper scope of adolescence, to be represented in averages of data from older spectrums of subjects. Some of these collective groups included subjects as old as 25 years. The same scenario can be stated of adolescents in the younger spectrum. This is evident from the cut-off ages that vary in different studies on adolescents. It would therefore be recommended that future studies need to be done exclusively on adolescents, or to report statistical data and analysis on more specific age groups only, i.e. 18-year-olds, 19-year-olds and so forth.

Nevertheless, the findings from the review highlights the importance and need for a well-researched prediction model for the LBEP of adolescents with special attention needed for a South African-based study in an adolescent South African population.

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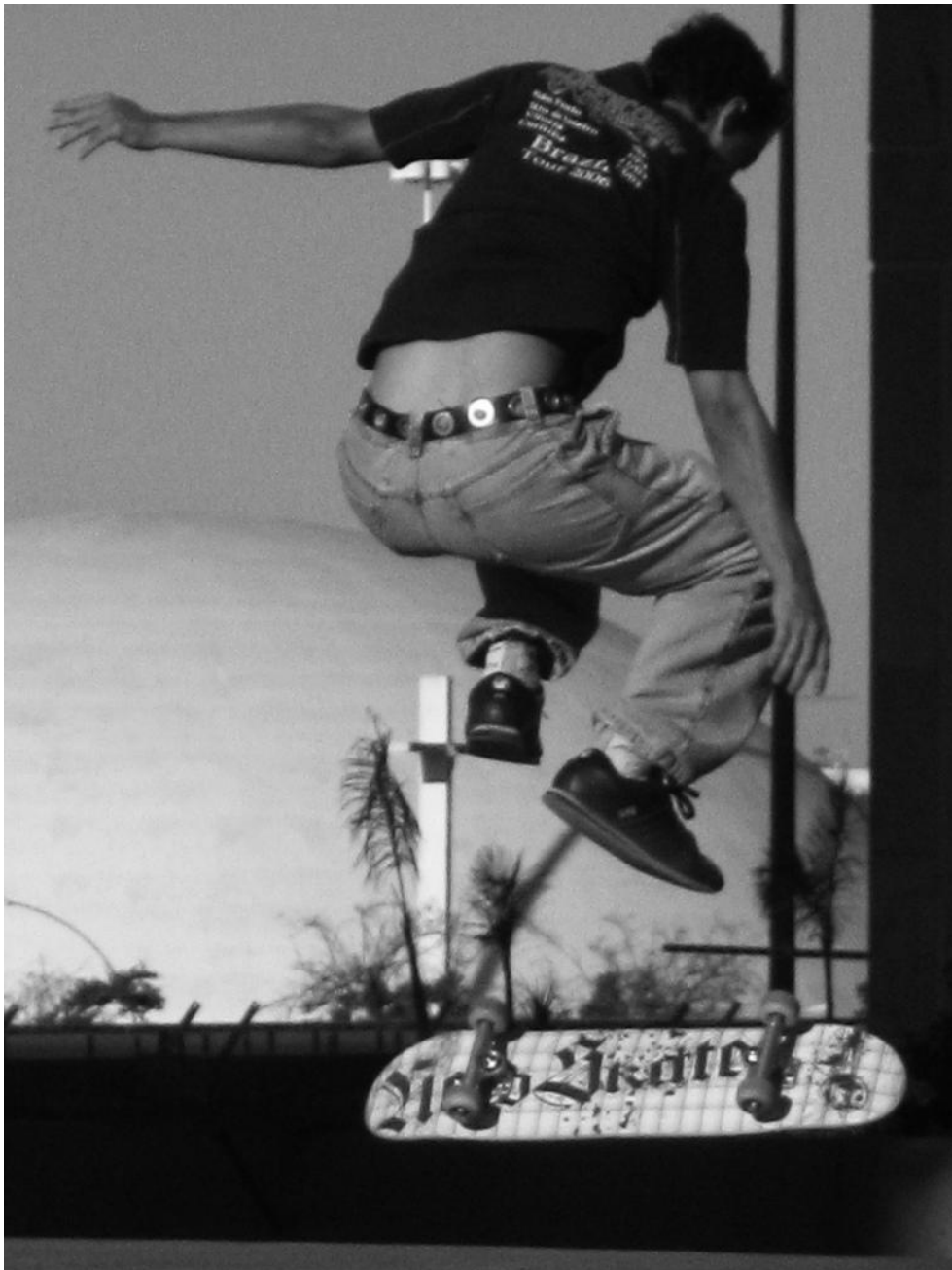
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# CHAPTER 3

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**3**

**PHYSICAL AND MOTOR  
PERFORMANCE  
PREDICTORS OF LOWER  
BODY EXPLOSIVE POWER  
(LBEP) AMONG A COHORT  
OF MALE AND FEMALE  
ADOLESCENTS – THE PAHL  
STUDY**

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**TITLE:** PHYSICAL AND MOTOR PERFORMANCE PREDICTORS OF LOWER BODY EXPLOSIVE POWER (LBEP) AMONG A COHORT OF MALE AND FEMALE ADOLESCENTS – the PAHL STUDY.

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**PHYSICAL AND MOTOR PERFORMANCE PREDICTORS OF LOWER BODY EXPLOSIVE POWER (LBEP) AMONG A COHORT OF MALE AND FEMALE ADOLESCENTS – the PAHL STUDY**

**FISIEKE EN MOTORIESE PRESTASIEVOORSPELLERS VAN ONDERLYF EKSPLOSIWE KRAAG IN 'N GROEP MANLIKE EN VROULIKE ADOLESSENTE– “die PAHL”-STUDIE**

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**ABSTRACT**

*The aim of this study was to develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa. Two hundred and fourteen 15-year-old adolescents (88 males and 126 females with a mean age of  $15.8 \pm 0.68$  years) from 6 schools, of which 2 were from the Potchefstroom city area and 4 from the Ikageng area, were measured over a 7-day period. Various questionnaires were completed beforehand where after the physical and motor performance components were tested of which 7 were physical and 14 motor performance components. Forward stepwise regression analyses indicated that gender and 10 m speed formed a significant and component-derived prediction model of LBEP values in 15-year-old adolescents. For gender a contribution of ( $R^2=0.39$ ) 39% was calculated and for 10 m speed a contribution of ( $R^2=0.07$ ) 7%. The results indicate that 46% ( $R^2=0.46$ ) of the LBEP can be predicted by making use of the adolescents' speed and gender. Variables other than physical and motor performance components are responsible for 54% of LBEP prediction in adolescents.*

**Key words:** Explosive power; Motor and physical performance; Prediction model, Adolescent.

## INTRODUCTION

Lower body explosive power (LBEP) is dependent on the velocity of a movement and can be defined as the greatest rate of work achieved during a single, ballistic, resisted contraction (Saunders *et al.*, 2008). Therefore explosive power produced will influence performance in activities that require high velocity at release or impact (Newton & Kraemer, 1994:20). Performing in sports such as basketball, volleyball and handball are all dependent on LBEP activities such as jumping, sprinting, striking and agility (Karahan & Cecilia, 2011).

Several researchers have identified certain physical and motor performance components as possible contributors to LBEP jumping in children and adolescents (Witvrouw *et al.*, 2004; Kinser *et al.*, 2008; Nevill *et al.*, 2009; Milanese, 2010; Milojević & Stanković, 2010). These variables might include arm hang time (Lennox *et al.*, 2008; Milojević & Stanković, 2010), grip strength (Girard & Millet, 2009), leg stiffness (Korff *et al.*, 2009), agility T-test (Jovanović *et al.*, 2010; Hermassi *et al.*, 2011), VO<sub>2</sub> (Dumke *et al.*, 2010), arrow head agility test and predicted VO<sub>2max</sub> (Mandy & Boyle, 2011). Contribution to higher LBEP production, as demonstrated by a higher counter movement jumping height is due to the result of greater elasticity of the muscle-tendon units of the lower limbs (higher flexibility) (Witvrouw *et al.*, 2004). A decreased stiffness of the muscle component is occasionally described in conjunction with increased flexibility (Morsé *et al.*, 2008). Contradictory to some of the previously mentioned findings a decreased stiffness of the series elastic component (SEC) had led to a 7.4% decrease ( $p < 0.05$ ) in LBEP output of adults (Cornwell *et al.*, 2002). Furthermore, Korff and co-workers (2009) found a significantly positive correlation ( $r = 0.70$ ,  $p < 0.001$ ) between leg stiffness and peak LBEP production jumping activities among adolescents. Similarly, Kinser *et al.* (2008) stated that flexibility-induced changes, due to stretching, may have no effect on the LBEP output production of children and adolescents. In addition, low flexibility scores in adults have been associated with poor speed performances (Nicholas, 1997).

Various researchers found that LBEP for children and adolescents correlates significantly negative with speed over short distances between 5 and 40 m (Nevill *et al.*, 2009; Milanese, 2010; Milojević & Stanković, 2010). Reports suggest that motor and physical performance components such as handgrip strength in 13- to 15-year-old male adolescents ( $r = 0.72 - 0.83$ ,  $p = 0.001 - 0.01$ ) (Girard & Millet, 2009), leg strength in 11- to 16-year-old male ( $r = 0.85$ ) and female adolescents ( $r = 0.78$ ) (Temfemo *et al.*, 2009) as well as flexed arm hang in 15-year-old South African female adolescents ( $r = 0.34$ ,  $p \leq 0.05$ ) (Lennox *et al.*, 2008:70) and in 14- to 15-year-old adolescents ( $r = 0.36$ ,  $p < 0.00$ ) (Milojević & Stanković, 2010) could influence LBEP performance. In terms of gender-specific maturity, and in support of Lennox *et al.* (2008), Malina *et al.* (2004a:352) states that static strength is positively related to female adolescents' maturity status.

Lennox *et al.* (2008) also found a relationship between strength variables in girls (flexed arm hang) and aerobic fitness, push ups and LBEP (standing long jump). Anaerobic sprinting speed (e.g. 40 m sprint) and LBEP (vertical jump) have also shown to correlate strongly in adolescent populations (Foran, 2001; Du Plessis, 2007; Nevill *et al.*, 2009). LBEP as measured from HJT performances, have demonstrated a higher correlation with sprinting speed than vertical jump test performances (Maulder & Cronin, 2005). With the emphasis on maturation, it seems that in more mature adolescent populations an increase in LBEP (vertical jump performance) is also accompanied by a decrease in agility shuttle run times and sprint values when compared with less mature adolescent populations (Figueiredo & E Silva, 2010). Maturity of male adolescents generally correlates positively with their strength and motor performance abilities (Malina *et al.*, 2004a:351), whereas motor performance generally is not significantly related to the maturity status of female adolescents, since most correlations are low and negative (Malina *et al.*, 2004a:352). This could be underlined by the fact that male adolescents experience an increase in maximal power delivery of 375% with muscle mass doubling, whereas female adolescents see an increase in maximal power delivery of 295% and a fat mass multiplication of 1.5 with the onset of maturation (Ronan *et al.*, 2003; Malina *et al.*, 2004a).

Currently, the available literature on LBEP prediction models for adolescents are limited and mostly applied in general on adult populations. In this regard, only Travill (2011) investigated the extent of various components' influence on the LBEP production of 7- to 12-year-olds as well as 13- to 18-year old male adolescents in South Africa. A LBEP prediction model will be of great value to various sporting codes such as soccer, tennis, basketball, handball and volleyball, which are all dependent on the ability to produce great LBEP (Karahan, 2011; Cherif *et al.*, 2012). Prediction models have been successfully used in the prediction of aerobic performance (Akalan *et al.*, 2008; Roberts *et al.*, 2009; Jacks *et al.*, 2012; Pienaar *et al.*, 2013), but to date, and to the authors' knowledge, no attempt has been made towards the development of a LBEP prediction model by making use of physical and motor performance variables for adolescents from South Africa. The only other study that has made an attempt at quantifying maximal short-term power production (a contribution model) in adolescents is that of Carvalho *et al.* (2011). In their study, they reported the percentage contribution of various indicators to maximal short-term power production, which in turn might indirectly influence the LBEP performances of adolescents. Their results indicated that anaerobic peak power production contributed 52% to maximal short-term power production. It is in light of the limited available literature and due to the fact that no physical and motor performance LBEP model currently exists for 15-year-old South African adolescents that the result of this study will equip rural South African coaches and sport scientists with a tool to accurately predict LBEP in adolescents.

## **PURPOSE OF THE STUDY**

The purpose of this study was therefore to develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province of South Africa.

## **RESEARCH METHOD**

### **Research design**

The research data for this study forms part of a larger observational multidisciplinary longitudinal study which started in 2010 and will continue until 2014 - The Physical Activity and Health Longitudinal Study (PAHLS) (Monyeki *et al.*, 2012). For purposes of the current study a cross-sectional experimental research design was employed in which the data of 2012 was used. The study was approved by the Ethics Committee of the North-West University (NWU-0058-01-A1) as well as the District Director of the Department of Basic Education in the Tlokwe Local Municipality.

### **Subjects**

Initially the study involved eight schools in the Tlokwe Local Municipality (Potchefstroom area) of the Dr Kenneth Kaunda District in the North-West Province of South Africa which were randomly selected to represent the distribution of the different racial groups in this area: Black Africans (~70%), White Africans (27.0%), Coloured (3%) and Asian (0.4%). The 126 female and 88 male adolescents from grade 10 ( $n=214$ ;  $15.8 \pm 0.68$  years) were purposefully selected from pre-required class lists from 6 high schools. Four of the selected schools were in the Ikageng Township area, which primarily consisted of learners living in rural areas and 2 of the schools were from the Potchefstroom City area, of which the learners lived in urban areas. At the time of measurement in 2012 only learners in grade 10 were eligible for participation. Prior to commencement, all participants were informed concerning the nature of the study, including all potential risks and benefits. Informed consent for the research was requested from the school authorities, the parents and learners of the participating schools in the weeks leading up to the research period.

### **Testing procedure**

To determine the reliability of the tests used in this adolescent population, a pilot study was performed before commencement of the main study during which one school's learners were subjected to the anthropometric protocol as well as all the physical and motor performance tests. The average test-retest reliability coefficient for the physical and motor performance component tests of the pilot study was between 0.89 and 0.99. For

### **Chapter 3: Physical and motor performance predictors of lower body explosive power (LBEP) among a cohort of male and female adolescents – the PAHL study**

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the main part of the study the subjects underwent one day of testing at the testing centre of the research institution. On arrival the subjects first completed the Demographic, General Information, Sport and Training Habits, Physical Activity and Maturity Determination Questionnaire after which the anthropometric measurements, physical, LBEP tests and motor performance tests followed. Before the start of the physical, LBEP and motor performance tests the subjects were firstly subjected to a thorough warm-up of approximately 15 minutes consisting of aerobic running exercises for an estimated 8 minutes. Thereafter a specific shorter warm-up period of high-intensity movements and dynamic stretches followed.

Firstly, measurements and data were obtained with regard to stature, sitting height and body mass according to methods of The International Society for the Advancement of Kinanthropometry (ISAK) (Stewart *et al.*, 2011), together with age, maturity age, and peak height velocity (PHV) age. The following tests were applied to measure the physical and motor performance variables. Physical performance component tests, each in accordance with their own method, included: sit and reach test (Maud & Kerr, 2006), shoulder external rotational (Harvey & Mansfield, 2000; Maud & Kerr, 2006), shoulder internal rotational (Harvey & Mansfield, 2000; Maud & Kerr, 2006), passive straight leg raise (Maud & Kerr, 2006), active straight leg raise (Harvey & Mansfield, 2000), modified Thomas Iliopsoas (MTIT) test (Harvey & Mansfield, 2000; Maud & Kerr, 2006) and the modified Thomas Quadriceps (MTQT) test (Harvey & Mansfield, 2000). The motor performance tests included: basketball throw (Ball, 1991), handgrip strength (Hofman, 2006), abdominal strength (Eurofit, 1988), bent arm hang (Eurofit, 1988), sit ups (Ellis *et al.*, 2000), 40 meter acceleration and speed test (Ellis *et al.*, 2000) and the 505 agility test (Ellis *et al.*, 2000).

PHV age can be calculated by using the birth date, measurement date and gender. For estimating maturity age, the anthropometric measurements of sitting height, body stature and body mass were used. For the final maturity age, chronological age was used from which PHV age at the date of measurement was subtracted (Thompson *et al.*, 2002). If the PHV age was identical to chronological age, maturity age was categorised as 0 (Thompson *et al.*, 2002). Noting at which age male adolescents' voice broke and at which age menarche onset occurred for female adolescents was a verification of maturation age for each gender. The determination of maturation age for individual adolescents could not be done utilizing the Tanner stages (Faulkner, 1996) as cultural beliefs and practices prohibited the researchers from doing so.

For purposes of LBEP measurements the following test or measurements were taken: the horizontal jump (HJT) or as referred to as the standing broad jump (SBJ), the vertical jump test (VJT) as well as peak velocity and peak power. The VJT is regarded as a ( $r=0.93$ ) and objective test ( $r=0.90$ ) for determining the peak anaerobic power output of subjects (Safrit, 1990; Maud & Kerr., 2006). The method of Harman *et al.* (2000)

was used to execute the VJT. The subjects performed a minimum of two trials with a 10-second rest period between each trial with the better of the two trials being used in the final analysis. Power output during the VJT was measured for each jump with a Tendo Power Output Unit (Tendo Sports Machines, Trensin, Slovak Republic). The Tendo unit consisted of a transducer that was attached to the waist of each subject which measured linear displacement and time. Subsequently, jump velocity was calculated and power would be determined. Both peak and mean power output was recorded for each jump and used for the subsequent analyses. According to Hoffman *et al.* (2009), the test-retest reliability of the Tendo unit is  $r \leq 0.90$ . The HJT measured the explosive power in the legs and the ability to jump in a horizontal direction. To measure horizontal power output the method of Maulder and Cronin (2005) was used. Each of the subjects was allowed two trials and the better of the two trials was used in the final analysis. The HJT is regarded as a reliable ( $r=0.89 - 0.9$ ) (Maulder & Cronin, 2005:79) and test for determining peak anaerobic power output of subjects.

### **Data analysis**

The statistical methods and procedures for the analysis of the research data were determined by the Statistical Consultation Services of the North-West University (Potchefstroom Campus). Analysis of the data was done with SPSS for Windows (version 20). Firstly, descriptive statistics (minimum, maximum, mean and standard deviations) for each test predictor was analysed. T-tests were used to indicate statistically significant differences between the mean value of the male and female adolescents. Secondly, an exploratory principal component factor analysis with varimax rotation was done for all the prediction variables. This was followed by a forward, stepwise multiple regression analysis in which the independent predictors identified from the factor analysis was included. The LBEP values, as measured by the vertical jump and the HJT were set as the dependant predictor. The level of significance was set at  $p \leq 0.05$ .

The four measurements which represented LBEP were the VJT, tendo peak power, tendo speed and the SBJ. Due to the high correlation between these four measurements a principal component factor analysis (PCFA) was performed. The results of the PCFA indicated that the measurement of the adolescents' VJT had the highest loading as predictor of LBEP with a value of 0.86 while tendo peak power (0.73), tendo speed (0.83) and the SBJ (0.70) each yielded a lower loading as predictors. The prediction model for LBEP was therefore based on the VJT performance by the adolescents.

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**RESULTS**

The descriptive statistics of the male and female adolescent are represented in Tables 1 to 3.

**TABLE 1: DESCRIPTIVE STATISTICS AND THE RESULTS OF THE INDEPENDENT T-TEST FOR CHRONOLOGICAL AND MATURITY AGE, STATURE, SITTING HEIGHT, BODY MASS AND PEAK HEIGHT VELOCITY OF THE ADOLESCENTS.**

Measurements	Total group (n=214)			Females (f) (n=126)			Males (m) (n=88)		
	Mean±std	Min	Max	Mean±std	Min	Max	Mean±std	Min	Max
Age (years)	15.82±0.68	13.6	17.1	15.81±0.71	13.6	17.0	15.84±0.63	14.4	17.1
Stature (cm)	163.70±8.69	146.7	196.2	159.85±6.12	147.4	173.7	169.08±8.87**	146.7	196.2
Maturity age (years)	1.78±0.42	1.0	2.0	1.80±0.41	1.0	2.0	1.77±0.43	1.0	2.0
Sitting height (cm)	119.83±14.51	13.8	141.2	118.50±13.46	13.8	141.2	121.60±15.81	18.8	137.9
Body mass (kg)	57.18±14.16	32.9	120.8	55.36±12.89	32.9	118.5	59.34±15.01	34.8	120.8
PHV age (years)	14.21±0.69	12.4	16.0	14.23±0.67	12.4	16.0	14.19±0.72	12.5	16.0

\* p<.005, \*\* p<.0001; cm = centimetre(s); kg = kilogram; PHV = Peak height velocity

The results of Table 1 indicate significant differences only in the stature of the male and female adolescents.

**TABLE 2: DESCRIPTIVE STATISTICS AND THE RESULTS OF THE INDEPENDENT T-TEST FOR THE FLEXIBILITY RELATED PREDICTORS OF THE ADOLESCENTS.**

Measurements	Total group (n=214)			Females (f) (n=126)			Males (m) (n=88)		
	Mean±std	Min	Max	Mean±std	Min	Max	Mean±std	Min	Max
Sit and reach end (cm)	30.63±9.19	0.0	53.5	32.29±7.39	10.7	49.0	28.29±10.96*	0.0	53.5
Shoulder external rotation best (°)	99.76±8.90	73.0	119.0	100.85±8.69	73.0	118.0	98.17±9.06*	77.0	119.0
Shoulder internal rotation best (°)	41.40±15.01	17.0	101.0	42.16±15.06	17.0	83.0	40.47±14.99	21.0	101.0
Passive straight leg raise best (°)	99.71±16.18	57.0	153.0	101.44±14.94	61.0	135.0	97.53±17.44*	57.0	153.0
Active straight leg raise best (°)	81.35±15.54	48.0	138.0	83.36±15.67	50.0	138.0	78.66±14.97*	48.0	121.0
MTIT best (°)	4.21±6.92	-16.0	22.0	3.89±7.51	-16.0	22.0	4.63±6.02*	-13.0	83.0
MTQT best (°)	66.11±11.49	40.0	97.0	67.84±11.42	40.0	97.0	63.68±11.24*	40.0	94.0

\* p<.005, \*\* p<.0001; cm = centimetre; ° = degrees; MTIT = Modified Thomas Iliopsoas test; MTQT = Modified Thomas Quadriceps test

The results from Table 2 indicate that the female adolescents showed statistically significantly better flexibility measurements (p<0.05) in the sit and reach test results, shoulder external rotational, passive straight leg raise, active straight leg raise, MTIT and the MTQT than their male adolescent counterparts.

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**TABLE 3: DESCRIPTIVE STATISTICS RESULTS OF THE INDEPENDENT T-TEST FOR THE PHYSICAL AND MOTOR PERFORMANCE-RELATED PREDICTORS OF THE ADOLESCENTS.**

Measurements	Total group (n=214)			Females (f) (n=126)			Males (m) (n=88)		
	Mean±std	Min	Max	Mean±std	Min	Max	Mean±std	Min	Max
VJT (cm)	32.61±12.44	4.5	55.0	26.1±10.2	4.5	50.0	41.8±9.1**	15.5	55.0
Tendo peak power (W)	1347.21±373.90	696.0	2870.0	1207.5±258.7	696.0	2264.0	1535.5±408.8**	847.0	2870.0
Tendo speed (cm)	2.41±0.31	1.7	3.3	2.3±0.3	1.7	2.8	2.6±0.2**	2.2	3.3
SBJ (cm)	165.47±34.49	98.0	325.0	150.85±30.90	108.0	325.0	186.73±28.05**	98.0	280.0
Basketball throw (m)	4.51±0.81	1.2	7.4	4.10±0.56	1.2	5.4	5.09±0.75	3.6	7.4
Handgrip strength (kg)	30.83±8.40	9.3	58.2	26.18±4.75	9.3	40.6	37.44±8.03**	18.4	58.2
Abdominal strength (Level)	2.29±1.87	0.0	7.0	1.90±1.75	0.0	6.0	2.91±1.89**	0.0	7.0
Bent arm hang (sec)	10.11±12.47	0.0	55.4	3.20±4.22	0.0	21.4	20.21±13.61**	0.0	55.4
Sit ups (repetitions)	26.98±10.37	2.0	52.0	22.52±9.78	2.0	46.0	33.20±7.60**	13.0	52.0
5 m speed (sec)	1.27±0.16	0.9	1.8	1.35±0.14	0.9	1.8	1.16±0.10**	0.9	1.5
10 m speed (sec)	2.16±0.24	1.6	2.9	2.29±0.20	1.7	2.9	1.96±0.13**	1.6	2.3
40 m speed (sec)	7.16±3.37	5.3	54.3	7.49±0.82	5.9	10.4	6.67±5.18	5.3	54.3
505 left (sec)	3.00±0.25	2.3	3.8	3.11±0.23	2.3	3.8	2.83±0.18**	2.4	3.3
505 right (sec)	3.01±0.26	2.4	4.0	3.14±0.23	2.7	4.0	2.82±0.18**	2.4	3.4

\* p<.005, \*\* p<.0001; VJT = Vertical jump test; cm = centimetre(s); sec = second(s) SBJ = Standing broad jump

From Table 3 it is clear that significant differences ( $p<0.001$ ) were found in the following tests: VJT, tendo peak power, tendo speed, SBJ, basketball throw, handgrip strength, abdominal strength, bent arm hang, sit ups, 5 m speed, 10 m speed, 40 m speed, 505 left and 505 right, with the results of the male adolescents being better than those of female adolescents.

In addition, an exploratory principal component factor analysis with varimax rotation was done on all the physical and motor performance predictors and reduced the predictors from 27 to 7. The remaining predictors used in further analyses were: gender, 10 m speed (sec), sit-and-reach's end measurement (cm), the MTIT right (degrees), shoulder internal rotation test right (degrees), shoulder external rotation test right (degrees) and 40 m speed (sec). These 7 predictors, together with the dichotomised value of gender (male=1, female=0) were entered into the forward stepwise regression analysis. The results are presented in Table 4.

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TABLE 4: RESULTS OF THE FORWARD STEPWISE REGRESSION ANALYSIS.

Predictors	$\beta$ eta	Regression coefficient	R-square change	p-value
Gender	0.39	9.81	0.39	0.000*
10 m speed (sec)	-0.34	-18.33	0.07	0.000*

\*p $\leq$ 0.001

The results in Table 4 indicated that only gender ( $R^2=0.39$ ) and 10 m speed ( $R^2=0.07$ ) acted as statistically significant ( $p\leq 0.001$ ) predictors of LBEP in the adolescents with gender contributing 39% and 10 m speed contributing a further 7% to the total LBEP of the adolescents. The results further show that males will achieve greater LBEP than female adolescents. The stepwise forward regression analysis coefficient of  $R^2=0.458$  suggests that gender and 10 m speed contributes 46% to the variance of the LBEP values of the adolescents. Variables other than those used in this study contribute a further 54% to the LBEP of the adolescents.

The prediction formula derived for LBEP from the predictors of gender and 10 m speed, equated to:

$$\text{LBEP} = 68.21 + 9.82 (\text{gender}) - 18.33(10 \text{ m speed})$$

**DISCUSSION**

To the best of the authors’ knowledge this is the first study which has made an attempt to develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province of South Africa. The results revealed that a model can be compiled by making use of the gender and the 10 m speed results of the adolescents.

Accordingly, gender delivered a LBEP production contribution of ( $R^2=0.39$ ) 39% to the prediction model ( $p<0.001$ ). Gender-specific differences during maturation resulting in increased body weight can be seen from our results (Table 1) and are in accordance with previous reports by Rogol *et al.* (2000). Tomkinson (2007) demonstrated that an increase in fat mass impaired LBEP jumping values whereas an increase in muscle mass led to increased LBEP jumping values in children and adolescents from 6 to 19 years of age. For further clarification of the afore-mentioned, Nevill *et al.* (2009) found male adolescents to have a LBEP 9% higher than female adolescents of 12 years of age due to males’ marked increase in muscle mass. The increase in muscle mass and corresponding increase in LBEP is not experienced in female adolescents, as is

the case for male adolescents, mainly due to a lesser increase in testosterone production (Bratić *et al.*, 2010). This resulting muscle mass increase will therefore positively influence the absolute anaerobic power output needed for LBEP (Malina *et al.*, 2004a; Tomkinson, 2007; Lazzer *et al.*, 2009). The higher LBEP production seen in males is also emphasized by the fact that female adolescents experience a 1.5 times increase in their fat mass during maturation (Malina *et al.*, 2004a).

The results of the study further indicated that 10 m speed contributes 7% ( $R^2=0.07$ ,  $p<0.001$ ) to the LBEP of the cohort of adolescents. In similar findings, it was found that the counter movement jump test (CMJ), a variation of the VJT which is also used to evaluate LBEP, significantly correlated ( $r=-0.89$ ,  $p<0.001$ ) with the 10 m speed values of 12- to 15-year-old male and female tennis players (Girard & Millet; 2009). The ability to cover the longest possible distance in the shortest time span is vital for performance in some sporting events and this ability is directly related to maximum speed during the sprinting phases to propel the body horizontally (Mandy & Boyle, 2011). Therefore the application of vertical jumping force and the ability to transfer the power generated into horizontal force, is key to the propulsion of the body during each stride in sprinting (Mandy & Boyle, 2011; Paja, 2011). More specifically Mandy and Boyle (2011) found that LBEP, as measured by the SBJ, have a correlation of  $r=-0.54$  to an adolescent's 10 m sprinting time. This take-off speed of a LBEP jump may influence the performance of adolescents in the VJ as the forward propulsion of the jump is also applied as vertical power (Mandy & Boyle, 2011), and thus it will be assumed that a high take-off speed improves jumping performance (Papadopoulos *et al.*, 2011). Sprinting distances specifically of 10 m correlates positively and significantly with the VJ ( $r=-0.36$ ;  $p\leq 0.05$ ) (Mandy & Boyle, 2011).

For LBEP jumps, a stronger positive relationship is found between horizontal jumps than between vertical jumps (Maulder & Cronin, 2005). In this regard, Mandy and Boyle (2011) reported that LBEP, as measured in the SBJ, explained 29% of the variance in 10 m sprinting time and 10 – 20% in 5 m sprinting time. No explanatory variable depicting VJ forces such as the afore-mentioned proposed by Mandy and Boyle (2011) could be found for adolescent populations. Mandy and Boyle (2011) further indicated that elite under 15 to under 17 male soccer players' 5 m sprinting time equation would be 20% less accurate if the LBEP (horizontal and vertical) production was not accounted for. The initiation of the sprinting action requires LBEP (Mandy & Boyle, 2011) and thus emphasises the use of LBEP during the initial phases, and also the first 10 m of a sprint in order to accelerate. The results of our study fully concur with these afore-mentioned results.

It is acknowledged that very little is currently known with regard to the maturity effects on anaerobic power necessary for LBEP (Malina *et al.*, 2004a). To further emphasize the complicating effects between gender,

motor performance variables (i.e. LBEP and speed) and maturity (as with increased muscle mass), Figueiredo and E Silva (2010) found that more mature adolescents showed a higher vertical jump performance in conjunction with an increase in sprint and agility shuttle run values than less mature adolescents.

The significant contribution of 46% ( $R^2=0.458$ ) made by only gender (39%) and 10 m speed (7%) to the LBEP prediction model of the cohort of adolescents, leads to the conclusion that LBEP is also influenced by various other factors. Anthropometrical (Malina *et al.*, 2004b; Girard & Millet, 2009), psychological (Escarti & Guzman, 1999) and external factors (Chillón *et al.*, 2011) as well as technique and training experience (Vanezis & Lees, 2005; Moresi *et al.*, 2011; Paja, 2011) might explain the remaining variables in the LBEP prediction model.

## CONCLUSIONS

The results from the present study led to the development of a LBEP prediction from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province of South Africa. According to the authors' knowledge, this is the first study to investigate the possibility of predicting LBEP in adolescents. It is conclusive that an adolescent's gender ( $r=0.390$ ) as well as the power generated by an adolescent for propulsion of their own body weight in a 10 m sprint ( $r=-0.349$ ) is significantly correlated to their VJ height achieved during LBEP production. Limitations of this study are extended to non-demographic representation of the South African adolescent population. With regard to the data collected in this study, female adolescents were represented 48% more than male adolescents. Furthermore, Caucasian adolescents were also measured, but not necessarily in relation to their South African representation in general.

Recommendations towards future research of this kind would be to compile LBEP prediction models for adolescents of all ages as well as to conduct the study on a broader population representative of South Africa as to give a better demographic representation of all races as well as a more balanced gender representation. Thus, sport scientists, coaches or teachers can use the developed LBEP prediction model where no other measurement options are available or if expensive and time-consuming test batteries cannot be applied to obtain VJT measurements. The LBEP prediction model developed from the study can be used by making use of a gender notation entry and a 10 m sprint time result and will allow for accurate prediction of adolescents' LBEP. This study will significantly contribute to the overall knowledge regarding adolescents' LBEP in the South African context.

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# CHAPTER 4

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# **4 AN ANTHOROPOMETRICAL RELATED LOWER BODY EXPLOSIVE POWER (LBEP) PREDICTION MODEL AMONG A COHORT OF ADOLESCENTS: THE PAHL STUDY.**

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**TITLE:** AN ATHROPOMETRICAL RELATED LOWER BODY EXPLOSIVE POWER (LBEP) PREDICTION MODEL AMONG A COHORT OF ADOLESCENTS: THE PAHL STUDY.

**RUNNING HEAD:** ANTHROPOMETRICAL PREDICTORS OF LBEP OF ADOLESCENTS.

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## **Chapter 4: An anthropometrical related lower body explosive power (LBEP) prediction model among a cohort of adolescents: The PAHL study**

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**An anthropometrical related lower body explosive power (LBEP) prediction model among a cohort of adolescents: The PAHL study.**

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### **ABSTRACT**

In the prediction of LBEP, very few researchers have investigated the possibility of making use of anthropometric variables to compile prediction models. Therefore the purpose of this study was to develop a LBEP prediction model from several anthropometric measurements for a cohort of male and female adolescents living in the Tlokwe local municipality of the Dr Kenneth Kaunda district in the North-West Province, South Africa. A cohort of 214 adolescents ( $15.82 \pm 0.68$  years) consisting of 88 boys and 126 girls were purposefully selected from six secondary schools in the North-West Province. Data were obtained by means of skinfold (SF) measurements, LBEP measurements and maturity age calculation. A principal component factor analysis yielded the vertical jump test as the factor that best describes LBEP. For statistical purposes descriptive statistics, a *t*-test and forward stepwise regression analysis for variable identification was done. The results of the forward stepwise regression analysis revealed that stature (57%), muscle mass percentage (10%) and maturation age (3%) were the only anthropometric variables that served as significant ( $p < .001$ ) predictors of LBEP. In view of the fact that the majority of coaches and teachers in South Africa have very limited means to directly measure anthropometric variables and LBEP in adolescents, the use of adolescents' stature, muscle mass and maturity age may possibly serve as an accurate alternative to accurately predict adolescents' LBEP.

*Keywords:* Explosive power; Prediction model; Adolescent; Anthropometry.

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## **1. Introduction**

Lower body explosive power (LBEP) performance is dependent on various factors such as physiological, psychological, social and environmental factors although most of these factors are interrelated (Nikolaïdis, 2011:342). LBEP or explosive strength is the ability to rapidly increase force (Paja, 2011), or the maximal ability of a muscle to execute a dynamic contraction (Ruiz, Ortega, Gutierrez, Meusel, Sjöström, & Castillo, 2006). Performance in activities such as basketball, handball and volleyball will be directly influenced by the amount of LBEP players can produce (Karahana & Cecilia, 2011). The ability of players to produce more LBEP will enable them to produce higher velocities at ball release or impact during a single movement than players that do not possess this ability (Karahana & Cecilia, 2011).

One of the predictors of children's LBEP is their anthropometric makeup (Kinnunen, 2003). In this regard researchers have identified the following anthropometric measurements to be possible predictors of LBEP in children and adolescents: body weight ( $r = .34 - .71, p < .05$ ) (Baldari, Di Luigi, Emerenziani, Gallotta, Sgro, & Guidetti, 2009; Girard & Millet, 2009), stature ( $r = .37 - .67, p < .05$ ) (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004b; Baldari et al., 2009) and fat-free mass ( $r = .60 - .67, p < .05$ ) (Tomkinson, 2007; Baldari et al., 2009).

Muscle mass seems to have a great influence on the LBEP of adolescents. In this regard Kriemler, Zahner, Puder, Braun-Fahrlander, Schindler, Farpour-Lambert et al. (2008) reported that the statistically significant difference ( $p < .05$ ) between the vertical jumping height (which is a LBEP-related test) and the reach height was dependent on the adolescents' muscle mass value. Similarly, O'Brien, Reeves, Baltzopoulos, Jones, and Maganaris (2009) found a significantly positive ( $R^2 = .78 - .86, p < .01$ ) correlation between muscle volume and muscle power in children and young adults.

According to various researchers, another body composition-related component, namely fat mass impaired adolescents' maximal LBEP due to the additional load placed on the lower body musculature (Milanese, Bortolami, Bertucco, Verlato, & Zancanaro, 2010; Moliner-Urdiales, Ruiz, Vicente-Rodriguez, Ortega, Rey-Lopez, & España-Romero, 2011). Fat mass, as calculated by the summation of the SF, showed a significant negative correlation ( $r = -.49 - .575, p < .05$ ) with adolescents' LBEP (12-17 years) (Baldari et al., 2009; Kapetanakis, Papadopoulos, Fiska, Vasileiadis, Papadopoulos, Papatheodorou et al. 2010; Moliner-Urdiales et al., 2011). Similarly, Kinnunen (2003) found that the abdominal SF ( $r = -.36, p = .05$ ) and the sum of the triceps and subscapular SF correlated negatively ( $r = -.51, p = .05$ ) with the LBEP [standing long jump (SJ)] in 16-year-old females. The same was true for the correlation between the triceps and the subscapular SF ( $r = -.43, p = .05$ ) as well as LBEP in 12-year-old females. With regard to males, Kinnunen (2003) reported a significant negative correlation ( $r = -.43, p = .05$ ) between the triceps and subscapular SF and LBEP in 18-

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year-olds, while a significant negative correlation was found between the triceps ( $r = -.49, p = .05$ ) and abdominal SF ( $r = -.43, p = .05$ ) for LBEP among 14-year-olds.

Height- and weight-related measurements were also identified as possible anthropometric predictors of LBEP. In this regard, Kinnunen (2003) found a significant positive correlation ( $r = .46, p = .05$ ) between the sitting height and LBEP (SJ) of 18-year-old males, whereas a significant positive correlation ( $r = .44, p = .05$ ) between body stature and LBEP was found in 12-year-old females. Lengths of the lower extremities, which contribute to body stature, have also been shown to correlate significantly with LBEP [vertical jump (VJ)] ( $r = .588, p = .05$ ) in 13- to 16-year-old female adolescent volleyball players (Stamm & Stamm, 2004). Researchers also claim that greater height-to-weight ratios, as displayed by leaner and taller adolescents, would benefit these subjects during the execution of LBEP tests such as the VJT (Nevill, Tsiotra, Tsimeas, & Koutedakis, 2009). The afore-mentioned was made evident considering that the aim of the study of Nevill et al. (2009) was to identify the appropriate body size description characteristics for LBEP as for expression in a formula. Higher LBEP could be attributed to the fact that a larger lean body mass and muscle mass produces greater anaerobic power as found among male adolescents (Mikulic, 2011). Although research with regard to the possible influence of bone breadths on the LBEP values of adolescents are scarce, one study found that higher biacromial breadths have a significant negative effect on the LBEP [standing long jump (SL)] ( $r = -.18, p = .05$ ) of 14-year-old males (Kinnunen, 2003).

In relation to gender, male adolescents experience an increase of 375% in maximal power delivery from the age of 7.5 to 17.5 years (Ronan, Eric, Jos, Emmanuel, & Mario, 2003). Gender differences in total muscle mass are seen between male and female adolescents with increasing maturation, as males' muscle mass gain is magnified in the latter stages of adolescence (Malina, Bouchard, & Bar-Or, 2004a). A less pronounced significant increase of 295% in female adolescents for the same stage of maturation was also observed (Ronan et al., 2003). Gender differences of 9% between the LBEP of male and female adolescents was reported by Nevill et al. (2009). These researchers attributed these LBEP gender differences to the greater muscle mass values of the 12-year-old male than those of the female Greek adolescents. An increase in fat mass (to double the value of males) of the female adolescents during the growth and maturation period impairs jumping ability whereas the increase in fat-free mass (to 1.5 times the value of females) of male adolescents benefit jumping ability (Malina et al., 2004a; Tomkinson, 2007). Baxter-Jones, Eisenmann, Mirwald, Faulkner, and Bailey (2008) indicated that male adolescents between ages 9.9 and 17.1 years had a higher stature, body weight as well as a significantly higher BMD (bone mineral density) than female adolescents. Male adolescents also display greater bone breadths, skeletal weight and stature at the same levels of maturation than their female counterparts (Malina et al., 2004a).

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Very little is known about the effects of maturity-age on anaerobic power or LBEP (Malina et al., 2004a). Malina et al. (2004a) also suggested that age, independent of body size, may be a factor that affects anaerobic power.

Concerning LBEP prediction models, researchers have identified various LBEP prediction variables or factors that may contribute to LBEP. Despite the evidence that anthropometric measurements may serve as possible predictors of adolescents' LBEP, only one study could be found in which researchers made an attempt to compile an anthropometric-related LBEP prediction model for South African adolescents. In this study Travill (2011) indicated that a combination of medial calf SF, acromial height and chest girth explained 38.6% of the variance in LBEP as measured by the SL in 180 South African, prepubescent boys (under the age of 13 years). For the older adolescent boys (above the age of 13 years) a combination of contracted arm girth, upper limb length and abdominal SF accounted for 42% of the variation in LBEP. Female adolescents were not included in the study of Travill (2001).

It is against this background and the limited research concerning anthropometric-related LBEP prediction models for South African adolescents, that this study was conducted. Hence the purpose of this study was to develop a LBEP prediction model from several anthropometric measurements among a cohort of male and female adolescents living in the Tlokwe local municipality of the Dr Kenneth Kaunda district in the North-West Province, South Africa. The results of this study may be of value to researchers and practitioners that work with rural-living adolescents that need to be screened for LBEP. This model may also equip researchers and practitioners with an informal means of evaluating LBEP in male and female adolescents.

## **2. Methods**

### *2.1 Research design*

The research data for this study forms part of a larger study - The Physical Activity and Health Longitudinal Study (PAHLS), which is an observational multidisciplinary longitudinal study that started in 2010 and will be continued until 2014 (Monyeki, Neetens, Moss, & Twisk, 2012). For the purpose of the current study a cross-sectional experimental research design was implemented in which the data from the 2012 sample was used. The study was approved by the Ethics Committee of the North-West University (NWU-0058-01-A1) and by the District Director of the Department of Basic Education in the Tlokwe Local Municipality.

### *2.2 Subjects*

Eight schools were initially, in the Tlokwe Local Municipality (Potchefstroom area) of the Dr Kenneth Kaunda District of the North-West Province of South Africa, randomly selected to represent the racial

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distribution of the groups in the area: Black Africans (~70%), White Africans (27.0%), Coloured (3.0%) and Asian (0.4%). A total of 214 grade 10 adolescents ( $15.8 \pm 0.68$  years) from six secondary schools were purposefully selected from pre-required class lists of which 126 were female adolescents and 88 were male adolescents. According to Malina et al. (2004a), adolescents are defined as females between ages 8 and 19 years and males between ages 10 and 22 years.

Two of the selected schools were in the Potchefstroom City area, which comprised learners living in urban areas and four schools in the Ikageng Township area, which predominantly comprised learners living in rural areas. Only learners that were in grade 10 at the time of measurement were eligible to participate in this study. Prior to participating in the study, all subjects were informed about the nature of the study, and all potential risks and benefits were explained to them. Informed consent for the investigation was requested from the school authorities, the parents and learners of the participating schools during the weeks prior to the testing period.

### *2.3 Testing procedure*

To determine the reliability of the various testing procedures for the specific cohort of adolescents, a pilot study was performed in 2010 before commencement of the larger study. A pilot study, consisting of the various anthropometric measurements as well as physical and motor performance tests, was performed on one of the schools' children to determine the reliability of the tests in this population. The pilot study delivered an average test-retest reliability coefficient for the various anthropometrical, physical and motor performance tests of 0.93 with a range of 0.89 to 0.99. For the main study itself subjects underwent testing at the testing centre of the institution where the research was conducted. On arrival, all subjects first had to complete the Demographic, General Information, Sport and Training Habits, Physical Activity and Maturity Determination Questionnaire. Thereafter, anthropometric measurements, physical and motor performance tests which also included the LBEP tests were completed. A thorough warm-up prior to the start of the physical and motor performance tests were done by all the subjects. The duration of the warm up was 15 minutes and consisted of aerobic running exercises for 8 minutes and a shorter specific warm-up period of shorter, high intensity movements and dynamic stretches.

### *2.4 Test components*

#### *2.4.1 Anthropometric measurements*

Anthropometric measurements were taken according to the protocols of The International Society for the Advancement of Kinanthropometry (ISAK) (Stewart, Marfell-Jones, Olds, & De Ridder, 2011) and included the following: body mass to the nearest 0.1 kg with a portable electronic scale (Beurer Ps07 Electronic Scale, Ulm, Germany) and stature to the nearest 0.1 cm with a Harpenden portable stadiometer (Holtain Limited,

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U.K.); SF of the biceps-, triceps-, subscapular-, supraspinal-, abdominal-, frontal thigh- and the medial calf to the nearest 0.2 mm with a Harpenden SF calliper (Holtain Limited, U.K.) with a constant pressure of 10 g/mm<sup>2</sup>; breadths of the humerus, wrist, femur and ankle to the nearest 0.1 cm with a Holtain Bicondylar calliper (Holtain Limited U.K.); girths of the relaxed and flexed arm-, waist-, gluteal- and mid-thigh to the nearest 0.1 cm with a Lufkin metal tape (Cooper Industries, U.S.A.) and length measurements of the upper and lower arm as well as hand and foot to the nearest 0.1 cm with a Rosscraft segmometer (Rosscraft Innovations Incorporated, Canada). Certified level 2 ISAK Anthropometrists measured all of the above-mentioned anthropometric measurements twice on the right side of the subject's body. A calculation of the technical error of measurement (TEM) (Pederson & Gore, 1996) revealed the following TEM for the named measurements: SF measurements = 1.27% (1.24 mm), breadth measurements = 2.08% (0.56 cm); girth measurements = 0.11% (0.38 cm) and length measurements = 1.23% (0.79 cm).

Arm, calf and mid-thigh girth were corrected for the afore-mentioned SF at each of their respective landmark sites by using the following formula: Corrected girth = Girth – ( $\pi$  x skin fold thickness). Martin, Spenst, Drinkwater, and Clarys (1990) stated that at each of these sites the corrected girths are better indicators of musculoskeletal size.

The different anthropometric measurements were used to calculate percentage body fat according to the equations of Lohman, Caballero, Himes, Davis, Stewart, Houtkaper et al. (2000) as well as Slaughter, Lohman, Boileau, Harswill, Stillman, Van Loan et al. (1998). Muscle mass was calculated by the formula of Poortmans, Boisseau, Moraine, Moreno-Reyes, and Goldman (2005) and somatotype by using the formulas of Carter and Heath (1990). BMI was calculated as body mass/stature<sup>2</sup> (kg/m<sup>2</sup>).

### *2.4.2 LBEP measurements*

LBEP was determined by the horizontal jump test (HJT) of Maulder and Cronin (2005) and the vertical jump test (VJT) of Harman, Garhammer, and Pandorf (2000). Peak power output was measured for each jump (VJT) with a Tendo™ Power Output Unit (Tendo Sports Machines, Trencin, Slovak Republic). According to Hoffman, Ratamess, Kang, Rashti, Faigenbaum, and Tranchina (2009), the test-retest reliability of the Tendo unit is  $r \geq .90$ .

### *2.5 Maturity age*

The anthropometric measures of body mass, body stature and sitting height were used to estimate the maturity age. This calculation of PHV age was done with the variables of gender, date of birth and date of measurement. Subtracting PHV age from chronological age at the measurement time, delivered the final maturity age (Thompson, Baxter-Jones, Mirwald, & Bailey, 2002). Maturity age was categorised as 0 when the PHV age was identical to chronological age (Thompson et al., 2002). Verification of maturation age was

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done by considering female adolescents' age of menarche onset and male adolescents' age at which their voice broke. Determining the maturation age of each of the adolescents could not be done via the Tanner stages (Faulkner, 1996) as cultural beliefs and practices prohibited the researchers of this study from doing so. Maturity status was not a direct aim of the study but was done in order to clarify certain trends with regard to the participants' anthropometric and LBEP profiles.

### *2.6 Data analysis*

Processing of data was done by means of SPSS for Windows (version 20). Firstly, descriptive statistics (means; minimum and maximum values; standard deviations) of each test variable were determined. A *t*-test was done to indicate statistically significant differences between male and female adolescents' values. Secondly, an exploratory principal component factor analysis with varimax rotation was done in order to retain only the primary anthropometric and LBEP-related variables. Lastly, a forward, stepwise multiple regression analysis in which the identified anthropometric variables served as the independent variables and the identified LBEP-related measurement as the dependant variable was executed. The level of significance was set at  $p \leq .05$ . The principal component factor analysis (PCFA) identified VJT (loading of 0.86), SBJ (loading of 0.70), VJT Tendo peak speed (loading of 0.83) and peak power (loading of 0.73) in the named order of importance as the primary measures of LBEP.

### **3. Results**

The descriptive statistics of the different anthropometric variables as well as the LBEP-related measurements of the adolescents are presented in Tables 1 to 6. Gender was also included in the model analysis due to possible influence of this factor on the model prediction. However, the results indicated that gender did not exert any influence on the LBEP prediction model.

As mentioned before, VJT, SBJ, VJT Tendo peak speed and peak power were identified as primary measures of LBEP. Due to the result that VJT was identified as the primary indicator of adolescents' LBEP, only this measure was used as an indicator of LBEP.

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**Table 1.**

Descriptive statistics (mean ± std) and statistical significance of adolescents' age-related measurements, body stature and mass.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean ± std	Mean ± std	Mean ± std
Age (years)	15.82 ± 0.68	15.81 ± 0.71	15.84 ± 0.63
Maturity age (years)	1.78 ± 0.42	1.80 ± 0.41	1.77 ± 0.43
PHV age (years)	14.21 ± 0.69	14.23 ± 0.67	14.19 ± 0.72
Body stature (cm)	163.70 ± 8.69	159.85 ± 6.12	169.08 ± 8.87**
Sitting height (cm)	119.83 ± 14.51	118.50 ± 13.46	121.60 ± 15.81
Body mass (kg)	57.18 ± 14.16	55.36 ± 12.89	59.34 ± 15.01*

\*  $p < .05$ , \*\*  $p < .001$ ; cm = centimetre; kg = kilogram

The results in Table 1 show that the boys obtained significantly larger body stature and mass values than the girls.

**Table 2.**

Descriptive statistics (mean ± std) and statistical significance of adolescents' body composition and other related measurements.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean ± std	Mean ± std	Mean ± std
BMI (kg/m <sup>2</sup> )	21.228 ± 4.42	21.610 ± 4.55	20.564 ± 4.06
Fat percentage (%)	20.122 ± 9.49	25.176 ± 7.36	12.67 ± 7.03**
Fat mass (kg)	12.162 ± 8.38	14.648 ± 7.82	8.339 ± 7.53**
Sum of 2 SF (mm)	24.928 ± 12.77	29.998 ± 12.06	17.377 ± 9.64**
Sum of 7 SF (mm)	97.352 ± 49.77	119.308 ± 45.04	64.737 ± 36.67**
Muscle percentage (%)	35.217 ± 18.43	30.052 ± 2.91	39.759 ± 3.13**
Muscle mass (kg)	20.538 ± 19.13	16.511 ± 3.56	23.286 ± 4.51*
Endomorphy	3.667 ± 1.86	4.508 ± 1.64	2.423 ± 1.41**
Mesomorphy	3.815 ± 1.76	3.650 ± 1.93	4.007 ± 1.41
Ectomorphy	2.986 ± 1.58	2.621 ± 1.56	3.541 ± 1.43**
WHR	0.765 ± 0.13	0.739 ± 0.16	0.801 ± 0.04**
Waist-to-height ratio	0.418 ± 0.05	0.422 ± 10.35	0.412 ± 0.05

\*  $p < .05$ , \*\*  $p < .001$ ; % = percentage; BMI = Body Mass Index; kg/m<sup>2</sup> = kilogram/square meter; SF = skinfold; WHR = Waist-to-hip ratio

The results with regard to the adolescents' body composition and other related measurements (Table 2) showed that girls obtained statistically significantly ( $p < .05$ ) higher average values for fat percentage, fat mass (kg), sum of 2 and 7 SF and endomorphy than did the males. However, the males displayed

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significantly ( $p < .05$ ) higher values for muscle mass percentage, ectomorphy and waist-to-hip ratio than did the girls.

**Table 3.**

Descriptive statistics (mean  $\pm$  std) and statistical significance of adolescents' skinfold-related measurements.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean $\pm$ std	Mean $\pm$ std	Mean $\pm$ std
Biceps SF (mm)	7.351 $\pm$ 4.37	9.440 $\pm$ 4.30	4.290 $\pm$ 2.10**
Triceps SF (mm)	13.411 $\pm$ 6.60	16.580 $\pm$ 5.64	8.733 $\pm$ 4.93**
Subscapular SF (mm)	11.736 $\pm$ 7.47	13.790 $\pm$ 8.13	8.644 $\pm$ 5.01**
Supraspinal SF (mm)	10.921 $\pm$ 7.30	12.938 $\pm$ 7.13	7.867 $\pm$ 6.40**
Abdominal SF (mm)	17.013 $\pm$ 9.24	20.391 $\pm$ 8.63	11.933 $\pm$ 7.57**
Front thigh SF (mm)	22.040 $\pm$ 11.72	27.948 $\pm$ 10.35	13.374 $\pm$ 7.51**
Medial calf SF (mm)	15.099 $\pm$ 7.66	18.591 $\pm$ 7.04	9.897 $\pm$ 5.12**

SF = Skinfolds; \*\*  $p < .001$ ; mm = millimetre; SF = skinfold

The results in Table 3 show that the girls obtained significant higher ( $p < .001$ ) values for all the measured SF than the males.

**Table 4.**

Descriptive statistics (mean  $\pm$  std) and statistical significance of adolescents' breadth-related measurements.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean $\pm$ std	Mean $\pm$ std	Mean $\pm$ std
Humerus breadth (cm)	6.200 $\pm$ 0.60	5.848 $\pm$ 0.38	6.691 $\pm$ 0.47**
Wrist breadth (cm)	5.159 $\pm$ 2.01	4.865 $\pm$ 0.50	5.576 $\pm$ 3.05*
Femur breadth (cm)	8.956 $\pm$ 0.80	8.693 $\pm$ 0.73	9.306 $\pm$ 0.70**
Ankle breadth (cm)	6.808 $\pm$ 3.49	6.624 $\pm$ 4.53	7.058 $\pm$ 0.47

\*  $p < .05$ , \*\*  $p < .001$ ; cm = centimetre

Comparisons between the adolescents' breadth-related measurements (Table 4) revealed that only humerus and femur breadth delivered significantly higher ( $p < .05$ ) values for boys than for girls.

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**Table 5.**

Descriptive statistics (mean ± std) and statistical significance of adolescents' girth-related measurements.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean ± std	Mean ± std	Mean ± std
Head girth (cm)	55.108 ± 3.62	54.816 ± 3.93	55.497 ± 3.12
Relaxed arm girth (cm)	25.376 ± 4.00	25.218 ± 3.77	25.48 ± 4.19
Flexed arm girth (cm)	27.787 ± 6.62	27.544 ± 7.84	28.035 ± 4.25
Waist girth (cm)	68.459 ± 9.38	67.431 ± 9.34	69.621 ± 8.86
Hip girth (cm)	90.270 ± 11.37	92.422 ± 11.82	86.916 ± 9.64**
Mid thigh girth (cm)	48.586 ± 6.60	48.999 ± 7.07	47.852 ± 5.71
Maximum calf girth (cm)	33.089 ± 6.85	32.802 ± 3.84	33.392 ± 3.75
Forearm girth (cm)	23.795 ± 2.58	22.997 ± 2.14	24.872 ± 2.69**

\*\*  $p < .001$ ; cm = centimetre

Table 5 indicates that only hip and forearm girth obtained significant differences ( $p < .001$ ) between the gender groups, with the girls that revealed the highest average hip girth measurement whilst the males revealed the highest average forearm girth measurement.

**Table 6.**

Descriptive statistics (mean ± std) and statistical significance of adolescents' length-related measurements.

Measurements	Total group (N = 214)	Girls (f) (n = 126)	Boys (m) (n = 88)
	Mean ± std	Mean ± std	Mean ± std
Arm span (cm)	166.717 ± 14.48	161.788 ± 15.13	173.636 ± 10.03**
Acromiale-radial (cm)	31.104 ± 2.30	30.189 ± 2.05	32.381 ± 1.94**
Radiale-styilion (cm)	24.612 ± 1.60	24.053 ± 1.52	25.397 ± 1.35**
Midstyilion-dactyilion (cm)	19.618 ± 1.50	18.704 ± 0.94	20.914 ± 1.10**
Foot length (cm)	25.160 ± 1.81	24.118 ± 1.22	26.623 ± 1.38**

\*\*  $p < .001$ ; cm = centimetre

All of the length-related measurements showed significantly higher values ( $p < .001$ ) for the boys than for the girls (Table 6).

In the next step an exploratory principal component factor analysis with varimax rotation was used to reduce the anthropometric and age-related variables from 40 to 6. The 6 variables that remained were: body stature (cm), maturity age (years), sitting height (cm), fat percentage (%), WHR and muscle mass percentage. These variables were entered into a forward, stepwise regression analysis of which the results are presented in Table 7. Gender was also entered into stepwise regression analysis as a co-variable to test for the possible influence

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this variable may have on the prediction of LBEP. Non-significant  $p$ -values of 0.32 – 0.99 were, however, delivered for gender which meant that this variable needed not to be considered for the rest of the analyses.

**Table 7.**

Results of the forward stepwise regression analysis based on the anthropometrical data of the adolescents.

Variables (N = 214)	Beta	Regression coefficient	R-square change	$p$ -value
Stature (cm)	0.64	0.84	0.57	0.000**
Muscle mass percentage (%)	0.34	0.70	0.10	0.000**
Maturity age (years)	0.17	4.60	0.03	0.001**

\*\* $p \leq .001$

The results of the forward stepwise regression analysis indicate that the following variables made a significant contribution ( $p < .001$ ) to the prediction of the adolescents' LBEP (as indicated by VJ test results): stature (57% contribution), muscle mass percentage (10% contribution) and maturity age (3% contribution). The last-mentioned variables were therefore included in the following prediction function for calculating LBEP (maximum VJ height:

$$\text{LBEP (VJ)} = -136.30 + 0.84(\text{stature}) + 0.7(\text{muscle mass percentage}) + 4.6(\text{maturity age}).$$

The overall stepwise regression analysis correlation coefficient ( $R^2 = 0.69$ ) further revealed that 69% of the variance in the adolescents' LBEP values can be explained by making use of the above-mentioned variables as predictors. Variables other than the variables considered in this study are therefore responsible for a further 31% of the variance in adolescents' LBEP values.

**4. Discussion**

The purpose of this study was to develop a LBEP prediction model from several anthropometric measurements among a cohort of adolescents living in the Tlokwe local municipality of the Dr Kenneth Kaunda district in the North-West Province, South Africa. To the knowledge of the authors this is the first study of its kind to develop an anthropometric-related LBEP prediction function for South African adolescents. The forward stepwise regression analysis identified stature (57%), muscle mass percentage (10%) and maturity age (3%) as the only significant anthropometric-related predictors ( $p < .001$ ) of boys' and girls' LBEP. Together these variables accounted for 69% of the variance in LBEP.

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According to Malina et al. (2004a), maturity age, stature and muscle mass are highly correlated with each other, which means that the separate contribution of each of these variables to the prediction of LBEP cannot be discussed without considering the influence of the other two components. Growth and maturation can be influenced by independently acting factors, while these independent factors may also work simultaneously to influence an adolescent's growth (Rogol, Clark, & Roemmich, 2000). Our results indicated that maturation accounted for 3% (Table 7) of the variance in adolescents' LBEP. The significant contribution of maturation has also been established by previous studies. In this regard Stang and Story (2005) stated that the growth tempo varies greatly even among adolescents of the same age, with for example a 13-year-old boy near the end of his linear growth spurt has a greater muscular development than a 13-year-old boy counterpart that has not yet experienced puberty (Stang & Story, 2005). A study by Quatman, Ford, Myer, and Hewett (2005) also showed that boy athletes' increase in LBEP (as indicated by VJ results) was significantly related ( $p < .001$ ) to the increase in maturation status. The same researchers also observed that the boys in their study showed a bigger maturation-related increase in LBEP than their girl counterparts (Quatman et al., 2005). Although this study did not identify gender to be a significant contributing factor to the prediction of LBEP, other studies suggested that gender plays a significant role and needs to be considered as an explanatory variable rather than maturation (Ronan et al., 2003; Malina et al., 2004a). This was emphasized in Rogol et al. (2000) who reported that gender-specific differences during maturation resulted in increased body mass as can be seen from our results (Table 1).

In terms of muscle mass percentage, our model indicated that this variable contributed significantly with 10% (Table 7) of the variance in LBEP that could be explained by this measurement. In this regard, other studies revealed that boys experienced a higher corresponding increase in muscle mass and LBEP than did girls (Bratić, Nurkić, Ignjatović, Stanković, & Radovanović, 2010), which led researchers to conclude that boys achieve higher LBEP values due to a greater muscle mass (Malina et al., 2004a; Tomkinson, 2007; Lazzar, Pozo, Rejc, Antonutto & Francesato, 2009). This was confirmed in our study (Table 2) that muscle mass percentage ( $p < .001$ ) and muscle mass (kg) ( $p < .05$ ) was significantly larger in boys than in girls. Furthermore, Ferrar, Tomkinson and Olds, (2010) found that boys with a smaller muscle mass performed worse in LBEP tests than their peers with a normal muscle mass. It is therefore correct to assume that adolescents with a higher muscle mass percentage, or muscle mass-to-body weight ratio, will be capable of producing more powerful leg propulsions due to decreased body resistance during LBEP jumps (Mandy & Boyle, 2011). In short, a higher muscle mass percentage contributes to a higher anaerobic power output, or LBEP (Klijn, Oudshoorn, Van der Ent, Van der Net, Kimpen, & Helders, 2004; Mikulic, 2011). In our study, body stature contributed 57% (Table 7) to the prediction of adolescents' LBEP whereas Stamm and Stamm (2004:17) reported that a combination of body mass and stature contributed 75% ( $R^2 = .75$ ) to the production of LBEP in 13- to 16-year-old volleyball girls. Kinnunen (2003:63) also found that body stature contributed

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significantly to the prediction of LBEP in 16-year-old girls with  $R^2 = .153$ . According to Figueiredo, Coeihoe Silva, Cumming, and Malina (2010), results from seventy-two 13- to 14-year-old boy soccer players indicated that the most mature adolescents were the tallest with a corresponding highest body weight and BMI values, thus suggesting an interrelation between maturity age and stature. These findings were also verified by research on 11- to 15-year-old girls (Malina, Ignasiak, Rozek, Slawinska, & Domaradzki, 2011).

Another study further showed that the body stature and maturity status of sixty-nine 13- to 16-year-old boy soccer players accounted for 41% of LBEP results (as measured by VJ) ( $p < .001$ ) (Malina et al., 2004b). From these and other results it is also clear that maturation together with age influences LBEP (Ayed, Latiri, Dore, & Tabka, 2011). This fact was also accentuated by Ronan et al. (2003) who showed that 57% of their maximal LBEP production in boys can be age related. It also seems that peak height velocity occurs 2 years before the growth in strength for 14- to 16-year-old boys (Carvalho, Coelho-e-Silva, Valente-dos-Santo, Gonçalves, Philippaerts, & Malina, 2012), which may explain why body stature contributed more to the prediction of LBEP in this study than muscle mass percentage. Despite the fact that the overall regression results indicated that nearly 70% ( $R^2 = .69$ ) of the adolescents' LBEP could be explained by making use of the anthropometric-related variables, variables other than the variables in this study contributed 30% to the prediction of adolescents' LBEP. It is therefore possible that physical and motor performance-related variables such as stiffness and flexibility, speed and agility may also contribute to LBEP performance due to the high correlations found with girls' and boys' LBEP (Girard & Millet, 2009; Korff et al., 2009; Nevill et al., 2009; Mandy & Boyle, 2011). Therefore the inclusion of these variables might strengthen the current anthropometric-related LBEP prediction model for boys and girls of this study.

### **5. Conclusions**

In conclusion, the results from this study demonstrated that the production of LBEP by the adolescents in this study was significantly influenced by their maturity age, muscle mass percentage and stature. Although previous research results suggested that the last-mentioned variables are all interrelated and are also influenced by gender differences, the contribution of each of the variables to the prediction of LBEP differed considerably. It is possible that the maturity age of the adolescents, especially for this late maturing phase, influenced the muscle mass percentage and body stature values. Overall, it can therefore be expected that a direct link will exist between the adolescents' maturity age, muscle mass percentage and body stature. Consequently, a higher stature is advantageous for reaching higher LBEP values and a higher muscle mass percentage for producing higher anaerobic power during LBEP-related tests.

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In view of the fact that the majority of coaches and teachers in South Africa have very limited means to estimate anthropometric variables and LBEP in adolescents, the use of adolescent's stature, muscle mass and maturity age may possibly serve as an accurate alternative to accurately predict adolescents' LBEP.

However, certain limitations of this study need to be considered when interpreting the results. Firstly, this subject group of adolescent learners cannot be considered to be representative of the population in the Potchefstroom area or of South Africa as a whole. As an indirect implication the proposed model can only be accurately used for the prediction of LBEP in a similar representative group of adolescents. Secondly, all subjects were obtained from a pre-requested class list and therefore not randomly selected. Thirdly, this study has to be undertaken as a longitudinal study for development of a LBEP prediction model for other age groups. This will allow the models to test the developed models' reliability over time. Lastly, any other possible factors also need to be investigated, namely socio-economic status, and nutritional and psychological factors.

### **6. Acknowledgements**

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### **7. Disclaimer**

Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors; therefore the NRF and MRC do not accept any liability in this regard.

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# CHAPTER 5

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# **5 SUMMARY, CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS.**

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- 1. SUMMARY**
  - 2. CONCLUSIONS**
  - 3. LIMITATIONS AND RECOMMENDATIONS**
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## **1. SUMMARY**

The purpose of this study was firstly to develop a LBEP prediction model from various physical and motor performance components among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa. Secondly, to develop a LBEP prediction model from several anthropometric measurements among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.

Chapter 1 provided a brief summary of the problem underlying the research questions, objectives and hypotheses of the study and included the structure of the dissertation.

Chapter 2 consisted of a literature review titled: “Literature review: Anthropometric, physical and motor performance predictors of lower body explosive power (LBEP)”. The purpose of the literature review was firstly to describe underlying physiological models of LBEP where after the different measurement tests for LBEP were described. Simultaneously the literature review was done to gather all information available with regard to age, gender, anthropometrical, physical and motor performance factors which correlate and influence LBEP. Lastly, available LBEP prediction models were reviewed and discussed.

LBEP is defined as the largest amount of force production delivered in the shortest time period for propulsion of the subject’s body in any direction. This production of LBEP is best described by the mechanical and the neurophysiological models. To measure LBEP, various tests have been developed with small variations in execution. These tests include: the counter movement jump/ vertical jump test, the Sergeant jump, the standing triple jump, the standing long jump/ horizontal jump test/ broad jump test, modified Ablakow jump with/without arm swing, squat jump, drop jump and the static jump.

In all the available literature, correlations between the variables and LBEP were identified. The variables were grouped into physical and motor performance predictive variables in one group and descriptive and anthropometrical predictive variables in the other group. Each grouping had 24 predictive variables or combinations thereof. These variables for the physical and motor performance group included: arm hang time, 5 m sprint, 9.1 m sprint, 10 m sprint, 18.3 m sprint, 20 m sprint, 27.4 m sprint, 36.6 m sprint, 40 m sprint, grip strength in the dominant and non-dominant hand, leg stiffness and flexibility, average power output,  $VO_2$  at stage 2,  $VO_2$  at stage 3,  $VO_2$  at stage 4, running 20 m, running 40 m, T-test, velocity, 20 m run with a high start and arrow head agility to the right and left. The descriptive and anthropometrical predictive variable groups included: weight; stature; sitting height; biacromial width; bicristal width; acromion-radial length; radio-stylion length; arm girth; thigh girth; calf girth; tricep SF; tricep and subscapular SF; triceps, subscapular and umbilical SF; age; lower body length; upper limb length; lower limb length; horizontal arm span; pelvis breadth; fat-free mass; body fat percentage; triceps, biceps, subscapular and suprailiac SF; triceps, subscapular, chest, abdominal and frontal thigh SF, and biceps, triceps, subscapular, suprailiac, thigh and medial calf SF. Of all the afore-mentioned variables only a certain handful correlated negatively with LBEP, whereas the rest all correlated positively with LBEP. These negatively correlated variables were: SF measurements, sum of the SF measurements,  $VO_{2max}$ , speed measurements (in some of the available studies), agility tests (arrowhead and T-test) as well as power production, force and jumping take-off velocity measurements.

With regard to LBEP models, four authors quantified the prediction percentage of certain variables in the development of contribution models whereas only one author developed a LBEP prediction model by making

use of certain anthropometric variables as well as the standing long jump. In relation to the prediction power of various motor performance variables, only one author developed a contribution model by investigating the contribution of LBEP to or the influence thereof on the performance in various sprinting distances (5 – 40 m).

The literature review was completed in light of the limited literature available on LBEP prediction models, with specific reference to adolescents as well as to a South African population.

The first article (as contained in Chapter 3) was titled “Physical and motor performance predictors of lower body explosive power (LBEP) among a cohort of male and female adolescents – the PAHL Study”. The article in Chapter 3 was compiled as per the guidelines of The South African Journal for Research in Sport, Physical Education and Recreation. The purpose of this study was to develop a LBEP prediction model from various physical and motor performance components among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa. The following physical and motor performance predictors showed statistically significant differences between the male and female adolescents: sit and reach (cm), active knee extension best (°), passive knee extension best (°), shoulder external rotation best (°), modified Thomas Quadriceps best (°) and modified Thomas Iliopsoas best (°) with  $p < 0.05$  while tendo peak (cm) and speed (m/s), standing broad jump (cm), handgrip strength (kg), abdominal strength (Level), bent arm hang (sec), sit ups (repetitions), 5 and 10 m speed (sec), 505 left and right (sec) with  $p < 0.001$ . An exploratory principal component factor analysis with varimax rotation was done to reduce the predictors from 27 to 6. Thereafter, to determine which LBEP measurement test best represent LBEP values, a principal component factor analysis (PCFA) was done. From the PCFA it was determined that the vertical jump test (VJT) yielded the highest loading of 0.86 and was used in all further analyses as LBEP indication. The other factors with lower yieldings were the tendo speed (0.83), tendo peak power (0.73) and the standing broad jump (SBJ) (0.70). The forward stepwise regression analysis revealed that gender and 10 m speed (sec) were the only two variables that provided a significant prediction model for LBEP for the cohort of adolescents. For the prediction of LBEP, gender delivered a significant contribution of 39% ( $R^2 = 0.39$ ,  $p < 0.001$ ) and 10 m speed a significant contribution of 7% ( $R^2 = 0.07$ ,  $p < 0.001$ ). The predictive model equated to  $LBEP = 68.21 + 9.82 (\text{gender}) - 18.33(10 \text{ m speed})$ . From the statistical differences in the descriptive values as well as the gender and speed intercept values of the LBEP prediction formula it can be seen that male adolescents produce greater LBEP than do female adolescents.

Chapter 4 comprised the second article, titled “An anthropometrical related lower body explosive power (LBEP) prediction model among a cohort of adolescents: The PAHL Study”. The article was written according to the guidelines of Human Movement Science Journal. The purpose of this study was to develop a LBEP prediction model from several anthropometric measurements among a cohort of male and female

adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa. The following descriptive and anthropometrical variables showed statistically significant differences between male and female adolescents: wrist breadth (cm) with  $p < 0.05$  and maturity age (years), fat mass (kg), fat percentage (%), sum of 7 SF avg., sum of 2 SF avg., muscle mass percentage (%), ectomorphy, endomorphy, WHR, triceps SF (SF) (mm), biceps SF (mm), supraspinal SF (mm), subscapular SF (mm), front thigh SF (mm), abdominal SF (mm), medial calf SF (mm), femur breadth (cm), humerus breadth (cm), forearm girth (cm), hip girth (cm), acromiale-radial (cm), midstylium-dactylium (cm), radiale-stylium (cm) and foot length (cm) with  $p < 0.001$ . The method of an exploratory principal component factor analysis with varimax rotation was completed to reduce the 40 predictors to 6. For the best representation of LBEP values a PCFA was completed. The PCFA determined that the VJT showed the highest loading of 0.86 whilst the tendo speed (0.83), tendo peak power (0.73) and the SBJ (0.70) yielded lower loadings. Therefore the VJT was used as indication of LBEP for the adolescents. These results from the article showed that a LBEP can be developed by making use of the stature (cm), muscle mass percentage (%) and maturity age (years) of the cohort of adolescents. Stature delivered a significant contribution to LBEP of 57% ( $R^2 = 0.57$ ,  $p < 0.001$ ), muscle mass percentage a significant contribution of 10% ( $R^2 = 0.10$ ,  $p < 0.001$ ) and maturity age a significant contribution of 3% ( $R^2 = 0.03$ ,  $p < 0.001$ ). The predictive model equation developed from the results is as follows:  $LBEP = -136.30 + 0.84 (\text{stature}) + 0.7 (\text{muscle mass percentage}) + 4.6 (\text{maturity age})$ . From the results of the study and based on the variables entered into the developed prediction model it can be seen that a taller, muscular and more mature adolescent will be able to produce greater LBEP than peers of a similar age group.

## **2. CONCLUSIONS**

The conclusions drawn from the research as well as the set hypotheses are presented in accordance with Chapter 1:

**Hypothesis 1:** *A LBEP prediction model can be developed by making use of speed, agility, explosive power, strength and flexibility measurements among a cohort of male and female adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.*

Hypothesis 1 is partly accepted in that a LBEP prediction model was developed for the cohort of adolescents by making use of the 10 m speed values and gender of the adolescents. These two variables contributed significantly to the LBEP of the adolescents. None of the other speed, agility, explosive power, strength and flexibility measurements contributed significantly to the LBEP model that was developed.

**Hypothesis 2:** *A LBEP prediction model can be developed by making use of fat percentage, body mass, stature, muscle mass, length, breadth and girth measurements as well as maturity status among a cohort of adolescents living in the Tlokwe local municipality of Dr Kenneth Kaunda district in the North-West Province, South Africa.*

Hypothesis 2 is partly accepted, based on the fact that stature, muscle mass percentage and maturity status significantly contributed to the development of the LBEP prediction model for the cohort of male and female adolescents. None of the other anthropometric-related variables such as fat percentage, body mass, length, breadth and girth measurements contributed significantly to the LBEP of the male and female adolescents.

### **3. LIMITATIONS AND RECOMMENDATIONS**

To our knowledge, this is the first study of its kind. This study provides the means to predict the LBEP of a cohort of male and female adolescents in South Africa by making use of two models developed from the anthropometric, physical and motor performance components. This study provides significant insight into the field of study for especially South African adolescents with regard to LBEP testing and prediction. However, the study had certain shortcomings that will need to be addressed and taken into consideration when interpreting the results:

- Firstly, the adolescent participants that took part in the study are from 6 schools in a single province of South Africa. This implies that the results cannot be generalized for all adolescents of a similar age as those of the participating adolescents (15 years). In order to generalize the results it would be necessary to include participants from a larger geographical area, with equal race, gender and socio-economic status distribution.
- Secondly, subjects were not randomly selected, but acquired from a pre-requested class list and might therefore not best represent the current population of the region.
- Thirdly, the study rather needs to be addressed as a longitudinal study in order to provide LBEP prediction models for other age groups as well as to test the reliability of the developed models over time.
- Lastly, the anthropometrical variables accounted for 69% of the developed LBEP prediction model, and the physical and motor performance variables were responsible for 46% of the variation in the LBEP prediction model of the cohort of adolescents. It is therefore recommended that future studies investigate other possible factors such as psychological, nutritional, socio-economic status etc that might also contribute to the LBEP prediction of adolescents.

# APPENDIX

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# APPENDIX A, B AND C.

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**TITLE PAGE**

**APPENDIX A           ETHICS FORM; INFORMED CONSENT FORMS; GENERAL INFORMATIONAL QUESTIONNAIRE AND ANTHROPOMETRICAL, PHYSICAL AND MOTOR PERFORMANCE DATA COLLECTION FORMS OF ADOLESCENTS.**

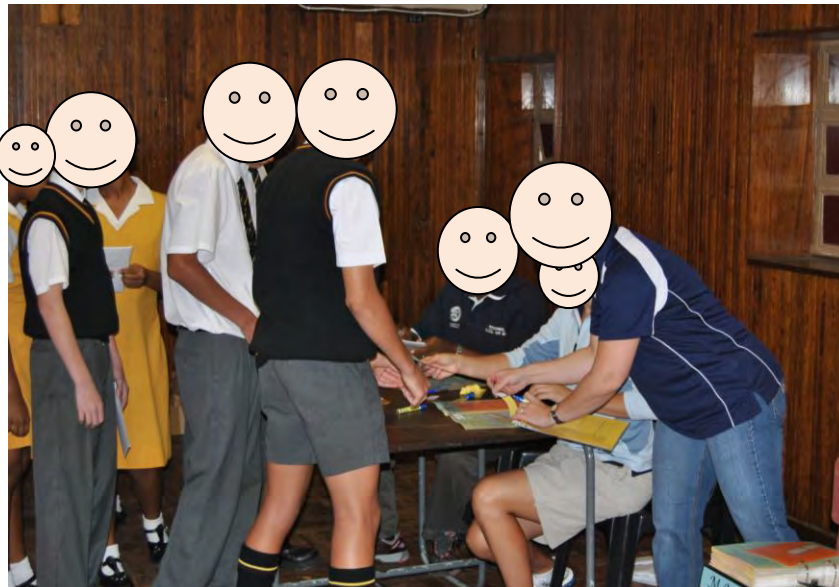
**APPENDIX B           SUBMISSION GUIDELINES FOR AUTHORS.**

**APPENDIX C           LETTER FROM LANGUAGE EDITOR.**

# APPENDIX A

## ETHICS FORM; INFORMED CONSENT FORMS; GENERAL INFORMATIONAL QUESTIONNAIRE AND ANTHROPOMETRICAL, PHYSICAL AND MOTOR PERFORMANCE DATA COLLECTION FORMS OF ADOLESCENTS.

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**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**



NORTH-WEST UNIVERSITY  
YUNIBESITHI YA BOKONE-BOPHIRIMA  
NOORDWES-UNIVERSITEIT

Private Bag X6001, Potchefstroom  
South Africa 2520

Tel: (018) 299-4900  
Faks: (018) 299-4910  
Web: <http://www.nwu.ac.za>

Prof A Monyeki

**Ethics Committee**

Tel +27 18 299 4850  
Fax +27 18 293 5329  
Email [Ethics@nwu.ac.za](mailto:Ethics@nwu.ac.za)

**ETHICS APPROVAL OF PROJECT**

The North-West University Ethics Committee (NWU-EC) hereby approves your project as indicated below. This implies that the NWU-EC 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.

<b>Project title:</b> Five year Longitudinal Study of Physical Activity status and the Determinants of Health in Adolescents attending high school in Potchefstroom areas of South Africa (PAHLS-Study)
<b>Ethics number:</b> N W U - 0 0 5 8 - 1 0 - A 1
<b>Approval date:</b> 2010/07/19
<b>Expiry date:</b> 2015/07/18

Special conditions of the approval (if any): None

<p>General conditions:</p> <p>While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, please note the following:</p> <ul style="list-style-type: none"><li>• The project leader (principle investigator) must report in the prescribed format to the NWU-EC:<ul style="list-style-type: none"><li>- annually (or as otherwise requested) on the progress of the project,</li><li>- without any delay in case of any adverse event (or any matter that interrupts sound ethical principles) during the course of the project.</li></ul></li><li>• The approval applies strictly to the protocol as stipulated in the application form. Would any changes to the protocol be deemed necessary during the course of the project, the project leader must apply for approval of these changes at the NWU-EC. Would there be deviated from the project protocol without the necessary approval of such changes, the ethics approval is immediately and automatically forfeited.</li><li>• 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-EC and new approval received before or on the expiry date.</li><li>• In the interest of ethical responsibility the NWU-EC retains the right to:<ul style="list-style-type: none"><li>- request access to any information or data at any time during the course or after completion of the project;</li><li>- withdraw or postpone approval if:<ul style="list-style-type: none"><li>• any unethical principles or practices of the project are revealed or suspected,</li><li>• it becomes apparent that any relevant information was withheld from the NWU-EC or that information has been false or misrepresented,</li><li>• the required annual report and reporting of adverse events was not done timely and accurately,</li><li>• new institutional rules, national legislation or international conventions deem it necessary.</li></ul></li></ul></li></ul>
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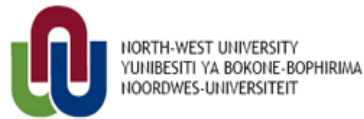
The Ethics Committee would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the Ethics Committee for any further enquiries or requests for assistance.

Yours sincerely

Prof MMJ Lowes  
(chair NWU Ethics Committee)

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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School of Biokinetics, Recreation and Sport  
Science

Private Bag x6001,

Potchefstroom

2520

South Africa

The District Operational Director

Department of Education

North-West Province

Potchefstroom

**REQUEST TO CONDUCT RESEARCH WITHIN YOUR DISTRICT**

Dear Sir,

We the researcher from the School of Biokinetics, Recreation and Sport Science are hereby making a request to conduct research in the district under your authority.

To give the background of the study, research revealed that physical activity in adolescents is drastically declining. The decline in the level of physical activity of human populations has been observed, and such decline is been associated with increased mechanization, reliance on technology and urbanization, and the high rate of crime in South Africa and elsewhere in the world. Physical inactivity is thought to be one of the

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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main risk factors for the development of obesity, diabetes, cardiovascular disease, osteoporosis and psychological constraints or risks of behavioral health.

Cross-sectional studies in South Africa which investigate the relationship between physical activity and determinants of cardiovascular disease for children and adults are available. Findings from these study revealed inactivity was significantly related to the determinants of cardiovascular disease. Little from the abovementioned studies could investigate physical activity and determinants of cardiovascular disease on a longitudinal basis. It is therefore important to note that South Africa is a country of paradox where obesity in children co-exists with malnutrition and many other ailments of health. It is therefore, against this background that a longitudinal study investigating the development and tracking of physical activity and the determinants of cardiovascular diseases in South African adolescents is needed. Adolescence is a time when independence is established, and dietary and activity patterns may be adopted that are followed for many years. Most of the physiological, psychological and social changes within people take place during this period of life. The period of adolescence can be looked upon as a time of more struggle and turmoil than childhood. Adolescents have long been regarded as a group of people who are searching for themselves to find some form of identity and meaning in their lives. Thus, it has great influence on adult fatness and chronic disease of lifestyle as well as long-term outcome on quality of life. If youth health behaviors are tracked during adolescence, it would add support to the primary assumptions given for early interventions to prevent cardiovascular disease as well as delay in cognitive development. For this longitudinal study, tracking is defined as the stability of health behaviors over time, or the predictability of future values by early measurements. From the above given background, therefore, the aims of the study is to investigate over a five year period (2010-2014) a follow-up longitudinal development of physical activity and determinants of health risk factors of health behavior in 14 years-old adolescents attending schools in Potchefstroom area of the North West Province of South Africa.

**The above matter background information refers:**

1. Permission is requested to conduct research in selected schools in your district as follows:

- 1.1. BA Seobi Sec. School
- 1.2. Tlokwe High School
- 1.3. Resolofetse High School
- 1.4. Botokwa High School
- 1.5. Potchefstroom High School for Boys
- 1.6. Potchefstroom High School for Girls
- 1.7. Hoër Volksskool Potchefstroom

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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1.8. Potchefstroom Gimnasium School

2. The targeted groups are boys and girls aged 14 years, in essence the grade 8 learners (**NB:** the proportion will be as follow: in mixed schools, 35 girls and 35 boys; in blacks schools 30 boys and 30 girls will be required).

3. The targeted term is the first term of 2010 (to be continued during the same term in the subsequent years up until 2014)

4. Items to be assessed or measured are:

4.1. Demographic information of the selected participants

4.2. Anthropometric measurements (i.e. body height; weight; SF thickness (triceps, subscapular and calf SF), and waist and hip circumferences)

4.3. Maturation (Tanner questionnaire)

4.4. Blood pressure measurement (mercury sphygmomanometer)

4.5. Physical activity questionnaire

4.6. ActiHeart (heart rate recorder with an integrated omnidirectional accelerometer. It is clipped onto two ECG electrodes worn on the chest.)

4.7. Health-related physical fitness (i.e. 20m shuttle run, standing broad jump, sit-and-reach, bent arm hang, sit-ups)

4.8. Social and self-efficacy questionnaire

4.9. Resting metabolic rate (determined by means of a mobile gas analyser)

4.10. Blood sampling (i.e. The participants will be requested to fast overnight (10 hours). A fasting sample of 10 ml blood will be taken from each participant in order to obtain ample blood for the various analyses of the study.)

4.11. Nutritional intake questionnaire.

4.12. Leisure and recreation constraint questionnaires

5. The schedule of the project will be as follow (Specific dates for selected schools will be finalised per arrangement with the principals concerned):

<b>Month and week</b>	<b>Duration</b>
April 2010, week 12 – 16	3 hours per child in a selected school
April 2010, week 19 – 23	3 hours per child in a selected school

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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Due to the fact that participants will be asked to fast 10 hours without eating breakfast in the morning, therefore sandwiches provision will be made available upon completion of the measurements. The outcomes of this project will benefit the children and the schools with the information regarding the physical activity status and the determinants of health for future.

Hoping for a positive response.

Yours sincerely,

Thank you,

Prof. M. Andries. Monyeki

Dr. Hanlie Moss

(Principal Investigator, NWU-Potchefstroom) Leader of Niche Area for Physical Activity, Sports and Recreation, NWU-Potchefstroom



## **INFORMATION LETTER TO THE PARENTS AND CONSENT FORMS: *PAHLS STUDY***

Dear Parent or Guardian,

Your child is been invited to participate in a study entitled – Five year Longitudinal Study of Physical Activity status and the Determinants of Health in Adolescents attending high school in Potchefstroom areas of South Africa (*PAHLS-Study, 2010–2014*).

My name is Professor Makama Andries Monyeki (from Potchefstroom Campus of the North-West University) principal investigator in the project together with the research team would like to ask your permission to allow your child (or a child under your care) to participate in our study. To give the background of the study, research revealed that physical activity in adolescents is drastically declining. The decline in the level of physical activity of human populations has been observed, and such decline is been associated with increased mechanization, reliance on technology and urbanization, and the high rate of crime in South Africa. Physical inactivity is thought to be one of the main risk factors for the development of obesity, diabetes, cardiovascular disease, osteoporosis and psychological constraints or risks of behavioral health. Therefore, the purpose of this study is to gather information about physical activity (i.e. by questionnaire & ActiHeart rate monitor) and health determinants (i.e. through measurements of anthropometry, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption (by the use of a portable gas analyser apparatus), blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life) over a period of five years (2010–2014).

Participation in this study is not part of the child's regular classroom work; it is an optional activity in which the learner can choose to participate. The study will assess and test the following variables: anthropometric

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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measurements, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption, blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life. Blood samples will be collected by a registered professional nurse who will be obliged to health profession practices at all times.

The data of the study will be used for research purpose only. The measurements will not be shared with your child classmates or teacher. All information collected in this study will be kept confidential. Your child's participation is important because the information that shall be gathered on him/her will help him/her with knowledge for personal development and life skills.

Your child participation in the project is very important, but it is entirely your choice. If your child chooses to refuse to participate in any part of the study or withdraw from the study at any time, for any reason, this will not cause anyone to be upset or angry, and this will not result in any type of penalty.

There are no costs required from your child (or a child under your care) to participate in the study. Further, no payment will be granted to your child (or a child under your care) for participating in the study.

If you have any question regarding this study, please feel free to call me at (018) 2991790 / e-mail: [andries.monyeki@nwu.ac.za](mailto:andries.monyeki@nwu.ac.za) or the PHASrec Niche Area Leader Dr. Hanlie Moss at (018) 2991821 / e-mail: [hanlie.moss@nwu.ac.za](mailto:hanlie.moss@nwu.ac.za). If you have any questions regarding your rights or your child's rights as participants in this study you can call Ms Hannekie Botha at (018) 299 4850 from Potchefstroom Campus of the North-West University Research Ethics Office.

Thank you, in advance, for considering your child participation in this study. Should you choose that your child participate, please read and sign the attached consent form. Keep one consent form for your records and return the other copy. All received consent forms will be kept locked during the entire period of the study. In addition, your child is requested to bring along his/her birth clinic card. The card will be given back to the child immediately after collecting information on birth date and birth weight. A child who shall have returned a completed and signed consent form will participate in the study.

Sincerely,  
Prof. Makama Andries Monyeki  
Principal Investigator – PAHLS Study

**CONSENT FORM**

**(Parent/Guardian Copy)**

**FIVE YEAR LONGITUDINAL STUDY OF PHYSICAL ACTIVITY STATUS AND THE DETERMINANTS OF HEALTH IN ADOLESCENTS ATTENDING HIGH SCHOOL IN POTCHEFSTROOM AREAS OF SOUTH AFRICA (PAHLS-STUDY, 2010–2014).**

I, ....., father/mother/guardian of .....

agree to permit my child to provide the information on physical activity (i.e. by questionnaire & ActiHeart rate monitor) and health determinants (i.e. through measurements of anthropometry, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption (by the use of a portable gas analyser apparatus), blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life), by the researchers at my child school. I understand that the results of this study of Five year longitudinal study of physical activity status and the determinants of health in adolescents attending high school in Potchefstroom areas of South Africa (*PAHLS-STUDY NWP*) will be used for research purpose and nothing else. I am aware that if I have any question or concerns about the study I can contact the researcher at (018) 299 1790 or the PHASRec Niche Area Leader at (018) 299 1821. Any questions or concerns regarding my child rights as a participant in this study can be addressed to Ms Hannekie Botha at (018) 299 4850 from Potchefstroom Campus of the North-West University Research Ethics Office. I understand that there will be no discomfort or foreseeable risks for my child to participate in the study. I understand that all information my child provide will remain strictly confidential. I have read and understand the information provided above and in the information letter. I have been provided with the opportunity to ask questions and my questions have been answered satisfactorily. I consent to have my child participate in the study described above, understanding that he/she may refuse to participate in any part of the study and can withdraw from the study at any time. I have kept one copy of this consent for my records and will return the second copy with the **clinic birth card**. I am aware that by giving consent my child can participate in the study. The return consent form will be kept locked during the entire period of the study.

Child's Age:.....

Grade:.....

Teacher:.....

School Name:.....

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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Name of Child:.....

Name of Parent/Guardian:.....

.....

(Signature of Child)

.....

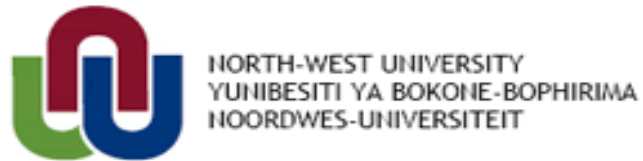
(Signature of Parent/Guardian)

.....

(Date)

.....

(Date)



**CONSENT FORM (PAHLS)**

**(Return this copy with the demographic questionnaire)**

**FIVE YEAR LONGITUDINAL STUDY OF PHYSICAL ACTIVITY STATUS AND THE DETERMINANTS OF HEALTH IN ADOLESCENTS ATTENDING HIGH SCHOOL IN POTCHEFSTROOM AREAS OF SOUTH AFRICA (PAHLS-STUDY, 2010–2014).**

I, ....., father/mother/guardian of .....

agree to permit my child to provide the information on physical activity (i.e. by questionnaire & ActiHeart rate monitor) and health determinants (i.e. through measurements of anthropometry, maturation, blood pressure measurement, health-related physical fitness, social and self-efficacy questionnaire, resting metabolic rate, oxygen consumption (by the use of a portable gas analyser apparatus), blood sampling, leisure and recreation constraint questionnaires, nutritional intake questionnaire as questionnaire on risk factors of life), by the researchers at my child school. I understand that the results of this study of Five year longitudinal study of physical activity status and the determinants of health in adolescents attending high school in Potchefstroom areas of South Africa (*PAHLS-STUDY NWP*) will be used for research purpose and nothing else. I am aware that if I have any question or concerns about the study I can contact the researcher at (018) 299 1790 /e-mail:andries.monyeki@nwu.ac.za or the PHASRec Niche Area Leader at (018) 299 1821 /e-mail:hanlie.moss@nwu.ac.za. Any questions or concerns regarding my child rights as a participant in this study can be addressed to Ms Hannekie Botha at (018) 299 4850 from Potchefstroom Campus of the North-West University Research Ethics Office. I understand that there will be no discomfort or foreseeable risks for my child to participate in the study. I understand that all information my child provide will remain strictly confidential. I have read and understand the information provided above and in the information letter. I have been provided with the opportunity to ask questions and my questions have been answered satisfactorily. I consent to have my child participate in the study described above, understanding that he/she may refuse to participate in any part of the study and can withdraw from the study at any time. I have kept one copy of this consent for my records and will return the second copy with the clinic birth card. I am aware that by giving consent my child can participate in the study. The return consent form will be kept locked during the entire period of the study.

Child's Age:.....

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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Grade:.....

Teacher:.....

School Name:.....

Name of Child:.....

Name of Parent/Guardian:.....

.....

(Signature of Child)

.....

(Signature of Parent/Guardian)

.....

**(Date)**

.....

**(Date)**

## PHYSICAL ACTIVITY QUESTIONNAIRE (PAHLS-IPAQ)

### A: GENERAL INFORMATION ABOUT YOU

<b>School:</b>									
<b>Grade:</b>									
<b>School number:</b>									
<b>Name of the participant:</b>									
<b>Subject number:</b>									
<b>Address:</b>									
Date of Survey			Grade	Sex (mark with a X)		Date of birth			Age
dd	mm	Yy		F	M	dd	mm	yy	

*In the next few questions cross out the answers that are applicable to you!!*

**Ethnic group**

White	Coloured	Black	Indian
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Do you participate in sport or have you been participating in sport during the last two years?

**YES**

**NO**

If your answer is **YES**, answer the next questions, and **IF** your answer is **NO** go to the next page.

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

**INFORMATION REGARDING SPORT AND TRAINING HABITS**

**1. Type of sport that you are participating in or did participate in during the last two years – main sport.**

Soccer	Rugby	Netball	Hockey	Volleyball	Athletics Javelin/ Shot pot/ Discus	Athletics Long jump/High jump
Athletics 100m/ 200m	Athletics 400m	Athletics 800m	Athletics 1500m	Athletics Cross country	Tennis	Squash
Badminton	Cricket	Golf	Wrestling	Boxing	Karate	Swimming
Cycling	Triathlon	Biathlon	Duathlon	Ballet	Artistic gymnastics	Rhythmic gymnastics

Other: \_\_\_\_\_

**2. Type of sport that you are participating in or did participate in during the last two years – secondary sport.**

Soccer	Rugby	Netball	Hockey	Volleyball	Athletics Javelin/ Shot pot/ Discus	Athletics Long jump/High jump
Athletics 100m/ 200m	Athletics 400m	Athletics 800m	Athletics 1500m	Athletics Cross country	Tennis	Squash
Badminton	Cricket	Golf	Wrestling	Boxing	Karate	Swimming
Cycling	Triathlon	Biathlon	Duathlon	Ballet	Artistic gymnastics	Rhythmic gymnastics

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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Other: \_\_\_\_\_

**3. Years you've been participating in your main sport.**

<1 year	1-2 years	3-4 years	5-6 years	7-8 years	8-9 years	>9 years
---------	-----------	-----------	-----------	-----------	-----------	----------

**4. Years you've been participating in your secondary sport.**

<1 year	1-2 years	3-4 years	5-6 years	7-8 years	8-9 years	>9 years
---------	-----------	-----------	-----------	-----------	-----------	----------

**5. Frequency of training - how many days per week do/did you normally train for your main sport?**

1 day	2 days	3 days	4 days	5 days	6 days	7 days
-------	--------	--------	--------	--------	--------	--------

**6. Frequency of training - how many days per week do/did you normally train for your secondary sport?**

1 day	2 days	3 days	4 days	5 days	6 days	7 days
-------	--------	--------	--------	--------	--------	--------

**7. Frequency of training - how many days per week do/did you normally do weight training?**

1 day	2 days	3 days	4 days	5 days	6 days	7 days
-------	--------	--------	--------	--------	--------	--------

**8. Frequency of training - how many days per week do/did you normally do training on the field/track/court or in the pool/ring?**

1 day	2 days	3 days	4 days	5 days	6 days	7 days
-------	--------	--------	--------	--------	--------	--------

**9. How many hours per day do/did you normally train?**

1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	7 or more
--------	---------	---------	---------	---------	---------	-----------

**10. On what level do/did you compete in your main sport?**

Recreational	School	Provincial	National
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**11. On what level do/did you compete in your secondary sport?**

Recreational	School	Provincial	National
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**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

**12. What is the best performance/s that you achieved in your main sport:**

Year	Sport	Distance/Height/Time/ Team/Achievement

**INFORMATION REGARDING MATURITY**

**1. FOR GIRLS ONLY: At what age did you experience menarche?**

9 years	10 years	11 years	12 years	13 years	14 years	Not yet
---------	----------	----------	----------	----------	----------	---------

**2. FOR BOYS ONLY: At what age did your voice break?**

11 years	12 years	13 years	14 years	Not yet
----------	----------	----------	----------	---------

**SECTION B: PHYSICAL ACTIVITY QUESTIONNAIRE**

IT IS IMPORTANT TO ANSWER ALL QUESTIONS, AND BE HONEST WITH YOUR ANSWERS

1. During the **last 7 days**, on how many days did you do **very hard** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

\_\_\_\_\_ days per week

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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No very hard physical activities → *Skip to question 3*

2. How much time did you usually spend doing **very hard** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

\_\_\_\_\_ **days per week**

No moderate physical activities → *Skip to question 5*

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

5. During the **last 7 days**, on how many days did you **walk** for at least **10 minutes** at a time?

\_\_\_\_\_ **days per week**

No walking → *Skip to question 7*

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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6. How much time did you usually spend **walking** on one of those days?

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**? (watching TV, Video games/Internet, Listening to music, reading)

\_\_\_\_\_ **hours per day**

\_\_\_\_\_ **minutes per day**

Don't know/Not sure

**PAHLS STATION CONTROL CARD**

Subject Number:		D.O.B.(dd/mm/yy):    /    /199	
Subject Name:		Gender: M / F	
Date of Test:(dd/mm/yy)    /    /20			
School Name:			
<b>NB:</b> Tick in the box when measurement are completed			
<b>Stature:</b>	(cm)	<b>Tick (√) &amp; sign</b>	
<b>Body mass:</b>	(kg)	<b>Tick(√)</b>	<b>Head of station</b>
Station 1 – RMR & BP			
Station 2 - Landmarking			

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

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Station 3 – Skinfolds (mm)		
Station 4 – Breadths (cm)		
Station 5 – Girths (cm) Armspan (cm)		
Station 6 – Lengths (cm)		
<b>Snack</b>		
Station 7 – Flexibility (°)		
Station 8 – Bruinicks		
Station 8 – Vertical reaching height (cm)		
Station 9 – Vertical jump height (cm)		
Station 7 – Horizontal jump (cm)		
Station 8 – Basketball throw (cm)		
Station 9 – Handgrip (kg)		
Station 10 – Abdominal strength (level) Sit ups (repetitions)		
Station 11 – Bent arm hang (sec.)		
Station 12 – Speed (m/s)		
Station 13 – Agility (sec)		
Station 14 – Bleep (level)		
<b>Subject receive a snack/meal</b>		

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

**RAW DATA FOR PAHLS (Anthropometry)**

**NAME OF LEARNER:** \_\_\_\_\_

**SUBJECT NO.** \_\_\_\_\_

TEST COMPONENT	1 <sup>ST</sup> READING		
BOX HEIGHT (CM)			
TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
BODY MASS (KG)			
BODY STATURE (CM)			
SITTING HEIGHT (CM)			
ARMSPAN (CM)			
TEST COMPONENT	1 <sup>ST</sup> READING	2 <sup>ND</sup> READING	MEAN
L: BICEPS SKINFOLD (MM)			
R: BICEPS SKINFOLD (MM)			
L: TRICEPS SKINFOLD (MM)			
R: TRICEPS SKINFOLD (MM)			
L: SUBSCAPULAR SKINFOLD (MM)			
R: SUBSCAPULAR SKINFOLD (MM)			
L: SUPRASPINALE SKINFOLD (MM)			
R: SUPRASPINALE SKINFOLD (MM)			
ABDOMINAL SKINFOLD (MM)			
L: FRONT THIGH SKINFOLD (MM)			
R: FRONT THIGH SKINFOLD (MM)			
L: MEDIAL CALF SKINFOLD (MM)			

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

R: MEDIAL CALF SKINFOLD (MM)			
<b>TEST COMPONENT</b>	<b>1<sup>ST</sup> READING</b>	<b>2<sup>ND</sup> READING</b>	<b>MEAN</b>
L: HUMERUS BREADTH (CM)			
R: HUMERUS BREADTH (CM)			
L: WRIST BREADTH (CM)			
R: WRIST BREADTH (CM)			
L: FEMUR BREADTH (CM)			
R: FEMUR BREADTH (CM)			
L: ANKLE BREADTH (CM)			
R: ANKLE BREADTH (CM)			
<b>TEST COMPONENT</b>	<b>1<sup>ST</sup> READING</b>	<b>2<sup>ND</sup> READING</b>	<b>MEAN</b>
HEAD GIRTH (CM)			
L: RELAXED ARM GIRTH (CM)			
R: RELAXED ARM GIRTH (CM)			
L: FLEXED ARM GIRTH (CM)			
R: FLEXED ARM GIRTH (CM)			

<b>TEST COMPONENT</b>	<b>1<sup>ST</sup> READING</b>	<b>2<sup>ND</sup> READING</b>	<b>MEAN</b>
WAIST (MINIMUM) GIRTH (CM)			
GLUTEAL (HIP) GIRTH (CM)			
L: MID THIGH GIRTH (CM)			
R: MID THIGH GIRTH (CM)			

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

L: MAXIMUM CALF GIRTH (CM)			
R: MAXIMUM CALF GIRTH (CM)			
L: FOREARM GIRTH (CM)			
R: FOREARM GIRTH (CM)			
<b>TEST COMPONENT</b>	<b>1<sup>ST</sup> READING</b>	<b>2<sup>ND</sup> READING</b>	<b>MEAN</b>
L: ACROMIALE-RADIALE LENGTH (CM)			
R: ACROMIALE-RADIALE LENGTH (CM)			
L: RADIALE-STYLION RADIALE LENGTH (CM)			
R: RADIALE-STYLION RADIALE LENGTH (CM)			
L: MIDSTYLION-DACTYLION (CM)			
R: MIDSTYLION-DACTYLION (CM)			
L: FOOT LENGTH (CM)			
R: FOOT LENGTH (CM)			

**RAW DATA FOR PAHLS (Flexibility tests)**

**NAME:** \_\_\_\_\_ **SUBJECT NO.** \_\_\_\_\_

SIT-AND-REACH TEST – STARTING POINT (CM)			
<b>TEST COMPONENT</b>	<b>1<sup>ST</sup></b>	<b>2<sup>ND</sup></b>	<b>BEST</b>
SIT-AND-REACH TEST (CM) – END POINT (CM)			
L: SHOULDER EXTERNAL ROTATION TEST (°)			
R: SHOULDER EXTERNAL ROTATION TEST (°)			
L: SHOULDER INTERNAL ROTATION TEST (°)			

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

R: SHOULDER INTERNAL ROTATION TEST (°)			
L: LEG LENGTH (CM)			
R: LEG LENGTH (CM)			
L: FUNCTIONAL LEG LENGTH (CM)			
R: FUNCTIONAL LEG LENGTH (CM)			
L: PASSIVE KNEE EXTENSION TEST (°)			
R: PASSIVE KNEE EXTENSION TEST (°)			
L: ACTIVE KNEE EXTENSION TEST (°)			
R: ACTIVE KNEE EXTENSION TEST (°)			
L: ANKLE DORSIFLEXION (°)			
R: ANKLE DORSIFLEXION (°)			
L: ANKLE PLANTAR FLEXION (°)			
R: ANKLE PLANTAR FLEXION (°)			
L: MODIFIED THOMAS ILIOPSOAS TEST (°)			
R: MODIFIED THOMAS ILIOPSOAS TEST (°)			
L: MODIFIED THOMAS QUADS TEST (°)			
R: MODIFIED THOMAS QUADS TEST (°)			

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

**RAW DATA FOR PAHLS (Fitness tests)**

**NAME OF LEARNER:** \_\_\_\_\_

**SUBJECT NO.** \_\_\_\_\_

TEST COMPONENT	1 <sup>ST</sup> TIME								
POLE HEIGHT (CM)									
VERTICAL JUMP REACHING HEIGHT (CM)	A								
FINAL VERTICAL JUMP HEIGHT A-B (CM)									
TEST COMPONENT	1 <sup>ST</sup> READING			2 <sup>ND</sup> READING			HIGHEST		
VERTICAL JUMP HEIGHT (CM)							B		
TENDO PEAK POWER (W)									
TENDO SPEED (M/SEC)									
TEST COMPONENT	1 <sup>ST</sup> READING			2 <sup>ND</sup> READING			HIGHEST		
HORIZONTAL JUMP DISTANCE (CM)									
TEST COMPONENT	1 <sup>ST</sup> READING			2 <sup>ND</sup> READING			HIGHEST		
BASKETBAL THROW DISTANCE (M)									
TEST COMPONENT	1 <sup>ST</sup> READING			2 <sup>ND</sup> READING			HIGHEST		
L: HAND GRIP STRENGTH (KG)									
R: HAND GRIP STRENGTH (KG)									
TEST COMPONENT	1 <sup>ST</sup> READING								
ABDOMINAL STRENGTH TEST (LEVEL)	0	1	2	3	4	5	6	7	
TEST COMPONENT	1 <sup>ST</sup> TIME								
BENT ARM HANG (SEC)									
TEST COMPONENT	1 <sup>ST</sup> TIME								

**Appendix A: Ethics form; informed consent forms; general informational questionnaire and anthropometrical, physical and motor performance data collection forms of adolescents.**

SIT UPS (REPS)																							
<b>TEST COMPONENT</b>		<b>1<sup>ST</sup> READING</b>		<b>2<sup>ND</sup> READING</b>		<b>LOWEST</b>																	
5M SPEED (SEC)																							
10M SPEED (SEC)																							
40M SPEED (SEC)																							
<b>TEST COMPONENT</b>		<b>1<sup>ST</sup> READING</b>		<b>2<sup>ND</sup> READING</b>		<b>LOWEST</b>																	
L: AGILITY 505-TEST (SEC)																							
R: AGILITY 505-TEST (SEC)																							
<b>TEST COMPONENT</b>		<b>1<sup>ST</sup> READING</b>																					
GENDER		M / F																					
BIRTH DATE		year / month / day																					
<b>20M SHUTTLE RUN</b>																							
<b>LEVEL</b>		<b>SHUTTLE NUMBER AND HEART RATES</b>																					
<b>1</b>		1		2		3		4		5		6		7									
<b>2</b>		1		2		3		4		5		6		7		8							
<b>3</b>		1		2		3		4		5		6		7		8							
<b>4</b>		1		2		3		4		5		6		7		8		9					
<b>5</b>		1		2		3		4		5		6		7		8		9					
<b>6</b>		1		2		3		4		5		6		7		8		9		10			
<b>7</b>		1		2		3		4		5		6		7		8		9		10			
<b>8</b>		1		2		3		4		5		6		7		8		9		10		11	
<b>9</b>		1		2		3		4		5		6		7		8		9		10		11	



# APPENDIX B

## SUBMISSION GUIDELINES FOR AUTHORS.

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It is important that the file be saved in the native format of the wordprocessor used. The text should be in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the wordprocessor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier: <http://www.elsevier.com/guidepublication>). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork.

To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your wordprocessor.

#### *Article structure*

##### *Subdivision - numbered sections*

Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

##### *Introduction*

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

##### *Results*

Results should be clear and concise.

##### *Discussion*

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

##### *Conclusions*

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

##### *Appendices*

If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

#### *Essential title page information*

- **Title.** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
- **Author names and affiliations.** Where the family name may be ambiguous (e.g., a double name), please indicate this clearly. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
- **Corresponding author.** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. **Ensure that phone numbers (with country and area code) are provided in addition to the e-mail address and the complete postal address. Contact details must be kept up to date by the corresponding author.**

• **Present/permanent address.** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

### Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

### Graphical abstract

A Graphical abstract is optional and should summarize the contents of the article in a concise, pictorial form designed to capture the attention of a wide readership online. Authors must provide images that clearly represent the work described in the article. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. See <http://www.elsevier.com/graphicalabstracts> for examples.

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### Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

### Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

### Math formulae

Present simple formulae in the line of normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text).

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#### Table footnotes

Indicate each footnote in a table with a superscript lowercase letter.

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#### Electronic artwork

#### General points

- Make sure you use uniform lettering and sizing of your original artwork.
- Embed the used fonts if the application provides that option.
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- Number the illustrations according to their sequence in the text.

- Use a logical naming convention for your artwork files.
- Provide captions to illustrations separately.
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- Submit each illustration as a separate file.

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Number tables consecutively in accordance with their appearance in the text. Place footnotes to tables below the table body and indicate them with superscript lowercase letters. Avoid vertical rules. Be sparing in the use of tables and ensure that the data presented in tables do not duplicate results described elsewhere in the article.

### *References*

#### *Citation in text*

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

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### Examples:

Reference to a journal publication:

Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2010). The art of writing a scientific article. *Journal of Scientific Communications*, 163, 51–59.

Reference to a book:

Strunk, W., Jr., & White, E. B. (2000). *The elements of style*. (4th ed.). New York: Longman, (Chapter 4).

Reference to a chapter in an edited book:

Mettam, G. R., & Adams, L. B. (2009). How to prepare an electronic version of your article. In B. S. Jones, & R. Z. Smith (Eds.), *Introduction to the electronic age* (pp. 281–304). New York: E-Publishing Inc.

### Journal abbreviations source

Journal names should be abbreviated according to

Index Medicus journal abbreviations: <http://www.nlm.nih.gov/tsd/serials/lji.html>;

List of title word abbreviations: <http://www.issn.org/2-22661-LTWA-online.php>;

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One author has been designated as the corresponding author with contact details:

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Further considerations

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- Color figures are clearly marked as being intended for color reproduction on the Web (free of charge) and in print, or to be reproduced in color on the Web (free of charge) and in black-and-white in print
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# APPENDIX C

## LETTER FROM LANGUAGE EDITOR

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28 November 2013

I, Ms Cecilia van der Walt, hereby confirm that I took care of the editing of the Dissertation of Mr Koert van der Walt titled *Selected anthropometric, physical and motor performance predictors of lower body explosive power in adolescents: The PAHL study*.

MS CECILIA VAN DER WALT

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