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An anthropometrical related lower body explosive power (LBEP) prediction model among a cohort of adolescents in the North West Province, South Africa: The PAHL Study

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Abstract

In the prediction of lower body explosive power (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 adolescent boys and girls living in the Tlokwe local municipality of the Dr Kenneth Kaunda district in the North West Province, South Africa. This was a cross-sectional experimental design on a purposeively selected cohort of 214 adolescents (15.82±0.68 years) consisting of 88 boys and 126 girls who were part of the Physical Activity and Health Longitudinal Study (PAHLS). Data were obtained by means of skinfold (SF) and LBEP measurements as well as the calculation of maturity age. The results of the forward stepwise regression analysis shows that stature (57%), muscle mass percentage (10%) and maturation age (3%) were the anthropometric variables that served as significant ($p<0.001$) 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 predict adolescents' LBEP.

Keywords: Explosive power, prediction model, adolescent, anthropometry.

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Introduction

Lower body explosive power (LBEP) performance is dependent on various factors such as physiological, psychological, social and environmental factors which are all interrelated (Nikolaïdis, 2011). 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, Gutierez, 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 (Karahan & 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 (Karahan & Cecilia, 2011).

One of the predictors of children's LBEP is their anthropometric composition (Kinnunen, 2003). In this regard, researchers have identified body weight ($r= 0.34 - 0.71$, $p< 0.05$) (Baldari, Di Luigi, Emerenziani, Gallotta, Sgro & Guidetti, 2009; Girard & Millet, 2009), stature ($r=0.37 – 0.67$, $p<0.05$) (Malina, Eisenmann, Cumming, Ribeiro, & Aroso, 2004b; Baldari et al., 2009) and fat-free mass ($r=0.60 - 0.67$, $p<0.05$) (Tomkinson, 2007; Baldari et al., 2009) as possible anthropometric and body composition parameters predicting LBEP in children and adolescent.

Muscle mass seems to have a great influence on the LBEP of adolescents. In this regard, Kriemler et al. (2008) reported that the statistically significant difference ($p<0.05$) 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 ($R^2=0.78$ –0.86, $p<0.01$) 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 et al., 2011). Fat mass, as calculated by the summation of the SF, showed a significant negative correlation ($r=0.49$ – 0.575, $p<0.05$) with adolescents' LBEP (12-17 years) (Baldari et al., 2009; Kapetanakis et al., 2010; Moliner-Urdiales et al., 2011). Similarly, Kinnunen (2003) found that the abdominal SF ($r=0.36$, $p=0.05$) and the sum of the triceps and subscapular SF correlated negatively ($r=0.51$, $p=0.05$) with the LBEP [standing long jump (SJ) - LBEP-related test] in 16-year-old females. The same was true for the correlation between the triceps and the subscapular SF ($r=0.43$, $p=0.05$) as well as LBEP in 12-year-old females. With regard to males, Kinnunen (2003) reported a significant negative correlation ($r= 0.43$, $p=0.05$) between the triceps and subscapular SF and LBEP in 18-year-olds, while a significant negative correlation was found between the triceps ($r=-0.49$, $p=0.05$) and abdominal SF ($r=-0.43$, $p=0.05$) 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 ($r=0.46$, $p=0.05$) between the sitting height and LBEP (SJ) of 18-year-old males, whereas a significant positive correlation ($r=0.44$, $p=0.05$) between body stature and LBEP was found in 12-year-old females. Lengths of the lower extremities, which contribute to body stature, also correlated significantly with LBEP [vertical jump (VJ)] (r=0.588, p=0.05) 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 VJ (Nevill, Tsiotra, Tsimeas & Koutedakis, 2009). 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, the only known study (Kinnunen, 2003) revealed that higher biacromial breadths have a significant negative effect on the LBEP [standing long jump (SL)] (r=0.18, p=0.05) of 14-year-old males.

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 the gender differences in LBEP 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). 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 (Travill, 2011). Furthermore, Travill (2011) indicated that a combination of contracted arm girth, upper limb length and abdominal SF accounted for 42% of the variation in LBEP in boys. There is hardly any data investigating the gender differences in LBEP.

It is against this background that a study on LBEP prediction model from several anthropometric measurements among a cohort of boys and girls adolescents living in the Tlokwe local municipality of the Dr Kenneth Kaunda district in the North West Province, South Africa was undertaken. The findings of this study may be valuable to researchers and practitioners who work with adolescents that live in rural areas or are part of large epidemiological field studies that need to be screened for LBEP. This model may also equip researchers and practitioners with a less expensive means of evaluating LBEP in adolescents' boys and girls.

Methodology

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 to 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.

Subjects

Eight schools in the Tlokwe Local Municipality (Potchefstroom area) of the Dr Kenneth Kaunda District of the North West Province of South Africa, were initially randomly selected to represent the racial distribution of the groups in the area: Black Africans (~70%), White Africans (27.0%), Coloured (3.0%) and Asian (0.4%) participated in the project. A total of 214 grade 10 adolescents (15.8±0.68 years) were purposefully selected from pre-required class lists of which 126 were girl adolescents and 88 were boy adolescents. According to Malina et al. (2004a), adolescents are defined as girls between ages 8 and 19 years and boys 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 area, which predominantly comprised learners living in a Township. 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.

The participants were free to withdraw from the study at any time. 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.

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, 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 standardized 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.

Test components:

Anthropometric measurements

Anthropometric measurements were collected according to the protocols of the International Society for the Advancement of Kinanthropometry (ISAK) (Stewart, Marfell-Jones, Olds & De Ridder, 2011). Body mass was measured 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, 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^2; 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 the hand and foot to the nearest 0.1 cm with a Rosscraft segmometer (Rosscraft Innovations Incorporated, Canada). All measurements were taken twice on the right side of the body by certified level 2 ISAK Anthropometrists. 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 – (π x skinfold 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 et al. (2000) as well as Slaughter 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^2 (kg/m^2).

LBEP measurements

LBEP was determined by the horizontal jump test (HJT) of Maulder and Cronin (2005) and the vertical jump test (VJ) of Harman, Garhammer and Pandorf (2000). Peak power output was measured for each jump (VJ) 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 $r \geq 0.90$.

Maturity age

The anthropometric measures of body mass, body stature and sitting height were used to estimate the maturity age of the participants. This calculation of Peak Heigh Velocity (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 done by considering girls' adolescents' age of menarche onset and boys' 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.

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. An independent *t*-test was done to indicate statistically significant differences between boys and girls 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 $p \leq 0.05$.

Results

The descriptive statistics of the anthropometric variables as well as the LBEP-related measurements of the adolescents are presented in Tables 1 to 3.

Table 1: Descriptive statistics (mean ± SD) and statistical significance of adolescents' age-related anthropometric and maturity measurements

Measurements	Total group (N = 214)	Girls (n = 126)	Boys (n = 88)
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*
Skinfolds (mm)			
Biceps	7.351 ± 4.37	9.440 ± 4.30	4.290 ± 2.10**
Triceps	13.411 ± 6.60	16.580 ± 5.64	8.733 ± 4.93**
Subscapular	11.736 ± 7.47	13.790 ± 8.13	8.644 ± 5.01**
Supraspinal	10.921 ± 7.30	12.938 ± 7.13	7.867 ± 6.40**
Abdominal	17.013 ± 9.24	20.391 ± 8.63	11.933 ± 7.57**
Front thigh	22.040 ± 11.72	27.948 ± 10.35	13.374 ± 7.51**
Medial calf	15.099 ± 7.66	18.591 ± 7.04	9.897 ± 5.12**
Breadths (cm)			
Humerus	6.200 ± 0.60	5.848 ± 0.38	6.691 ± 0.47**
Wrist	5.159 ± 2.01	4.865 ± 0.50	5.576 ± 3.05*
Femur	8.956 ± 0.80	8.693 ± 0.73	9.306 ± 0.70**
Ankle	6.808 ± 3.49	6.624 ± 4.53	7.058 ± 0.47

Measurements	Total group (N = 214)	Girls (n = 126)	Boys (n = 88)
Girths (cm)			
Head girth	55.108 ± 3.62	54.816 ± 3.93	55.497 ± 3.12
Relaxed arm	25.376 ± 4.00	25.218 ± 3.77	25.48 ± 4.19
Flexed arm	27.787 ± 6.62	27.544 ± 7.84	28.035 ± 4.25
Waist	68.459 ± 9.38	67.431 ± 9.34	69.621 ± 8.86
Hip	90.270 ± 11.37	92.422 ± 11.82	86.916 ± 9.64**
Mid -thigh	48.586 ± 6.60	48.999 ± 7.07	47.852 ± 5.71
Maximum calf	33.089 ± 6.85	32.802 ± 3.84	33.392 ± 3.75
Forearm	23.795 ± 2.58	22.997 ± 2.14	24.872 ± 2.69**
Lengths (cm)			
Arm span	166.717 ± 14.48	161.788 ± 15.13	173.636 ± 10.03**
Acromiale-radial	31.104 ± 2.30	30.189 ± 2.05	32.381 ± 1.94**
Radiale-stylion	24.612 ± 1.60	24.053 ± 1.52	25.397 ± 1.35**
Midstylion-dactylion	19.618 ± 1.50	18.704 ± 0.94	20.914 ± 1.10**
Foot length	25.160 ± 1.81	24.118 ± 1.22	26.623 ± 1.38**

* $p < 0.05$, ** $p < 0.001$; cm = centimetre, kg = kilogram, mm = millimetres

Gender was also included in the model analysis due to the 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.

The principal component factor analysis (PCFA) identified VJ (loading of 0.86), SBJ (loading of 0.70), VJ 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. Due to the result that VJ was identified as the primary indicator of adolescents' LBEP, only this measure was used as an indicator of LBEP.

The results in Table 1 show that the boys obtained significantly larger body stature and mass values than the girls, while the girls obtained significant higher ($p<0.001$) values for all the measured SF than the males. Comparisons between the adolescents' breadth-related measurements revealed that only humerus and femur breadth delivered significantly higher ($p<0.05$) values for boys than for girls. Furthermore, the results indicate that only hip and forearm girth obtained significant differences ($p<0.001$) between the gender groups, with the girls having the highest average hip girth measurement whilst the males revealed the highest average forearm girth measurement. All of the length-related measurements showed significantly higher values ($p<0.001$) for the boys compared to the girls.

The results with regard to the adolescents' derived body composition and other related measurements (Table 2) showed that girls obtained statistically significantly ($p<0.05$) higher average values for fat percentage, fat mass (kg), sum of two and seven SF and endomorphy than the males. However, the males displayed significantly ($p<0.05$) higher values for muscle mass percentage, ectomorphy and waist-to-hip ratio than the girls.

Table 2: Derived descriptive statistics (mean ± SD) of adolescents' body composition and other related measurements

Measurements	Total group (N = 214)	Girls (*n* = 126)	Boys (*n* = 88)
Body mass index (kg/m^2)	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 skinfolds (mm)	24.928 ± 12.77	29.998 ± 12.06	17.377 ± 9.64**
Sum of 7 skinfolds (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**
Waist-to-hip ratio	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

* $p<0.05$, ** $p<0.001$

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 six (6). The six (6) variables that remained were: body stature (cm), maturity age (years), sitting height (cm), fat percentage (%), WHR (waist-to-hip ratio) and muscle mass percentage. These variables were entered into a forward, stepwise regression analysis (Table 3). Gender was also entered into the stepwise regression analysis as a co-variable to test for the possible influence this variable may have on the prediction of LBEP. As gender showed no significant influence on the LBEP values, it was not considered for the rest of the analyses.

Table 3: Results of the forward stepwise regression analysis based on the anthropometrical data of the adolescents

Variables	ßeta	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**

** $p \leq 0.001$

The results of the forward stepwise regression analysis indicate that the following variables made a significant contribution ($p<0.001$) 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:

LBEP (VJ) = -136.30 + 0.84(stature) + 0.7(muscle mass percentage) + 4.6(maturity age).

The overall stepwise regression analysis 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.

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 which aimed 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 ($p<0.001$) of boys' and girls' LBEP. Together these variables accounted for 69% of the variance in LBEP.

According to Malina et al. (2004a), maturity age, stature and muscle mass are highly correlated with each other, which mean 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 3) 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 compared to a 13-year-old boy which has not yet reached puberty (Stang & Story, 2005). A study by Quatman, Ford, Myer and Hewett (2005) also showed that boys' increase in LBEP (as indicated by VJ results) was significantly related ($p<0.001$) to the increase in maturation status. The same researchers also observed that the boys in their study showed a larger 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 reported in the current findings (Table 1).

In terms of muscle mass percentage, our model indicated that this variable contributed significantly with 10% (Table 3) 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 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; Lazzer, Pozo, Rejc, Antonutto & Francesato, 2009). This was confirmed in our study (Table 2) where muscle mass percentage ($p<0.001$) and muscle mass (kg) ($p<0.05$) were 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 (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 3) to the prediction of adolescents' LBEP whereas Stamm and Stamm (2004) reported that a combination of body mass and stature contributed 75% (R^2=0.75) to the production of LBEP in 13- to 16-year-old volleyball girls. Kinnunen (2003) also found that body stature contributed significantly to the prediction of LBEP in 16-year-old girls with R^2=0.153. According to Figueiredo, Coeiho e 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) ($p<0.001$) (Malina et al., 2004b). It is clear that maturation and 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 two 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=0.69) of the adolescents' LBEP could be explained by making use of the anthropometric-related variables, of which the remaining 30% may be accounted by other variables not included in the present study. 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; Nevill et al., 2009; Boyle, 2011). The inclusion of these variables therefore, might strengthen the current anthropometric-related LBEP prediction model for boys and girls of this study.

Certain limitations of this study, however, need to be considered when interpreting the results. Firstly, this 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.

Conclusion

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 influence 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.

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.

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