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Wingate Anaerobic Test Power of Boys and Girls Expressed in Relation to Lower Limb Muscle Mass as Determined Using Dual Energy X-ray Absorptiometry

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ABSTRACT

Chia YHM, Wingate Anaerobic Test Power of Boys and Girls Expressed in Relation to Lower Limb Muscle Mass as Determined Using Dual Energy X-ray Absorptiometry. Adv. Exerc. Sports Physiol., Vol.9, No.2 pp.55-59, 2003. The study investigated the Wingate Anaerobic Test (WAnT) power of in a group of 13 to 14 year old boys and girls. Participants were 48 adolescent boys (stature: 1.69 ± 0.05 m; body mass: 58.2 ± 9.7kg; lower limb muscle mass: 16.2 ± 2.1kg) and 38 adolescent girls (stature: 1.57 ± 0.08 m; body mass: 50.3 ± 7.4kg; lower limb muscle mass: 12.5 ± 1.2kg). Lower limb muscle mass (LLMM) was determined using a dual energy X-ray absorptiometric (DEXA) procedure. Participants completed a 30s Wingate Anaerobic Test (WAnT) with peak power (PP) and mean power (MP) expressed in relation to LLMM using simple ratio method and allometric procedures. LLMM was the strongest predictor for PP and MP in boys ($r = 0.76$ and $r = 0.66$, $p < 0.05$) and in girls ($r = 0.81$ and $r = 0.81$, $p < 0.05$). PP was significantly higher in boys than in girls when power was expressed in absolute terms (683 ± 62 vs. 473 ± 57W, $p < 0.05$), in ratio to $LLMM^{1.0}$ (11.9 ± 1.6 vs. 9.5 ± 1.3 W/kg, $p < 0.05$) and in allometric terms to $LLMM^{0.65}$ (112.0 ± 6.9 vs. 91.6 ± 6.0 W/kg, $p < 0.05$). MP was also significantly higher in boys than in girls when power was expressed in absolute terms (566 ± 62 vs. 318 ± 57W, $p < 0.05$), in ratio to $LLMM^{1.0}$ (9.9 ± 1.5 vs. 6.4 ± 1.0 W/kg, $p < 0.05$) and in allomtric terms to $LLMM^{0.79}$ (63.0 ± 5.7 vs. 43.1 ± 5.5W/kg, $p < 0.05$). Common b exponents for boys and girls expressed in relation to LLMM were $0.65 \pm$ 95% confidence interval$=0.47-0.82$) for PP and $0.79 \pm$95% confidence interval$=0.49-1.07$) for MP. These were markedly different from the *b* exponent of 1.0 for LLMM used in the simple ratio method but the identified *b* exponents were close to the 0.67 value predicted from geometric similarity theory. Despite a similar interpretation of data (i.e. boys were more powerful than girls) using either ratio-method or allometric modeling, allometric modeling of sample-specific exercise data is recommended to produce an appropriate size-independent variable, to allow valid and useful comparisons in performance between two distinct groups of participants.

Keywords: Wingate Anaerobic Test power, adolescent boys and girls

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INTRODUCTION

Performance in the Wingate Anaerobic Test (WAnT), an all-intensity cycle test, is often described in relation to a body size descriptor (e.g. stature, body mass, fat-free mass), so as to facilitate comparisons between boys and girls, or between distinctive groups (e.g. athletes vs. non-athletes). The capability to generate muscle power can be explained to a significant extent by the total mass of the muscle that is involved in producing the power (4). In exercise that involves moving and bearing the entire body mass such as during treadmill running, it is logical to express the performance in relation to body mass (BM) or to stature (HT), in the attempt to produce a size-independent variable (i.e. power that is free from the influence of body size) for ease of comparison between groups. However, in seated sprint cycling exercise (e.g. in the WAnT), where the body mass of the participant is supported, it may be more appropriate to describe the performance (e.g. power) to some indicator of size of the active muscle mass such as thigh muscle mass (TMM) or lower limb muscle mass (LLMM). Indeed, some researchers have described young people's exercise performance in relation to leg muscle volume using anthropometric methods (6, 15) or thigh muscle volume (TMV) using magnetic resonance imaging (14), in attempts to better describe the exercise performance in more defensible terms, where the involvement of the active muscles is better taken into account. Increasingly, the use of dual energy X-ray absorptiometry (DEXA) to determine bone mineral content and density, body composition and changes in body composition is gaining in popularity (7). Moreover, the use of DEXA has gained widespread acceptance as a valid and reliable procedure for scientific research in adults and in young people as it is easy to administer and most established research centers will be able to afford its intermediate cost of operation (8). The use of DEXA to quantify LLMM so that exercise performance can be more appropriately described in relation to the active muscle tissue during cycling can yield valuable data and perhaps provide additional insights that can better explain the performances of exercising young people.

Researchers commonly use the ratio method to address differences in body size but there is a growing conviction that the ratio method may not appropriately normalise exercise data or produce a size-independent variable that appropriately takes into account differences in body size (1, 10). The main aim of using the simple ratio method is that it is assumed that the simple division of the variable of interest (e.g. peak power) by a body size descriptor (e.g. LLMM) will provide a size-free variable (i.e. without the influence of body size) in watts per kg LLMM.

However, the simple ratio method often fails to achieve this; instead very light individuals are advantaged whereas very heavy individuals are penalized (1). For example, the authors demonstrated that in 212 12-year-old children, the use of the simple ratio method failed to remove the influence of body mass from peak $V0_2$ data, with significant negative correlations of $r=-0.48$ and $r=-0.64$ identified between body mass and ratio-adjusted peak $V0_2$.

Prior to using the scaling method of choice, researchers should be mindful that the use of the method must not violate the assumptions for its use based on the characteristics of the specific data set. The criteria for the use of the ratio method and allometric modeling have been described in detail elsewhere (1, 10). In essence the use of the ratio method is justified when the bivariate correlation between the ratio-scaled dependent variable (e.g. PP/BM or MP/LLMM) and the body size descriptor (e.g. BM or LLMM) is not significantly different from zero. Conversely, the assumptions for the use of allometric modeling of data are that the gradients or slopes of the regression equations that describe the relationship between the dependent variable (e.g. PP or MP) and the body size descriptor (e.g. LLMM) for boys and girls (or groups) must be common or parallel to each other (1).

It is critical that the appropriate normalization of exercise data for differences in body size is used as it allows the researcher to correctly interpret the results of the research. Conversely, an inappropriate use of scaling methods can lead to erroneous interpretations and consequently cloud our understanding of the performance of the exercising child.

Allometric (log-linear) methods are recommended as more appropriate in accounting for body size effects as they are able to accommodate data that are heteroscadastic (10) in nature, that is, as body size increases (e.g. LLMM), so does the variability of the performance variable of interest (e.g. PP or MP). In essence, the technique requires the derivation of a common b exponent for two different groups by applying the least-squares regression to logarithmically transformed data (e.g. Ln PP and Ln LLMM) (1).

Allometric methods have apparently not been used to describe young people's power performances in relation to LLMM. Therefore, the aim of the study was to examine the lower limb muscle power of boys and girls, as determined in the WAnT that are described in relation to LLMM using both ratio and allometric methods.

METHODS

Sequence of data collection

After obtaining institutional approval for the study, participants from two secondary schools were recruited for the study. Boys and girls reported to the laboratory on two separate days in the morning between 08 00 and 12 00 hours. Data collection followed this sequence: anthropometric measurements, sexual maturity status assessment, LLMM determination using DEXA and maximal sprint cycling (WAnT). The principal investigator was present throughout the data collection.

Participants and assessment of sexual maturity status

Forty-eight boys and thirty-eight girls with the appropriate written informed consent were involved in the study. Age and anthropometric variables-body mass and stature, were measured using standard procedures and that used calibrated machines. All participants had previously completed a familiarization session with sprinting on a cycle ergometer. The session involved three attempts on an abbreviated WAnT protocol.

An experienced female physician assessed the sexual maturity of the boys and the girls, one participant at a time, in a private setting, in accordance to the criteria that were popularized by Tanner (12). In essence, ratings of pubic hair development for both sexes were noted and recorded.

LLMM determination using DEXA

The DEXA equipment used was a QDR 4500 Elite X-Ray Bone Densitometer Hologic model manufactured in Waltham, MA, USA. The machine was equipped with a patented Hologic continuous calibration system and was operated by a trained and licenced technician. The use of DEXA, in particular machines that uses high speed fan-beam technology (9) to derive accurate measurements of body mass and lean mass in human subjects is gaining in popularity among researchers.

LLMM was determined using a DEXA procedure that involved the participant, dressed in shorts and a T-shirt, lying still in a supine position on the scanning table with both feet rotated inward toward each other, and with arms placed by the side with the palms pronated. The participant was instructed to remain still throughout the scan, which took about seven minutes. The lights were switched off and soothing music was played to help the participant remain relaxed and still throughout the scan. The time taken for each scan was three minutes. The radiation dose for each DEXA scan was less than 1 mrem. The precision error for fat and lean tissue using fan beam technology is reported as 300g and the reproducibility coefficient in replicate measurements is reported as $r=0.90$ or higher (9). After the scan, image adjustment (pixel size 2mm by 3 mm) and region selection was carried out to generate the required reports. LLMM was derived from the Hologic computer software (Version 9.80).

Conduct of the WAnT

Participants were taken through a standardized warm-up, which consisted of four minutes of pedaling at 60 $rev \cdot min^{-1}$ that was interjected with three maximal effort sprints of 2-3 seconds' duration, conducted at the start of each minute. Thereafter, the participants were taken through two minutes of stretching exercises for the quadriceps, hamstrings and groin muscles.

After the standardized warm-up, participants completed a 30s WAnT on a cycle ergometer (Monark 834E), from a rolling start of 60 $rev \cdot min^{-1}$, with the applied force set at 0.74 $N \cdot kg^{-1}$ body mass. Inertia-adjusted 1-s peak power (PP) and mean power over 30s (MP) were computed according to standard procedures that have been previously described (4, 5). In essence, PP was the highest 1-s power achieved during the test (usually within the first 10s). PP is often taken as a measure of explosive power (4). MP was the average power over 30s and is often regarded as a measure of muscle endurance (4).

Data management

The data were stored in computer and analysed using the Statistics Package for Social Sciences (SPSS for Windows Version 10.0). Descriptive statistics of the participantsnamely, means and standard deviations for stature, body mass, and LLMM were generated. Sex differences in descriptive characteristics and WAnT perfor-mances (peak power, PP and mean power, MP) were analysed using one-way analysis of variance (OW-ANOVA).

The best predictor for PP and MP among the body size descriptors-BM, HT and LLMM was identified using stepwise linear regression with PP and MP entered respectively as the dependent variable and BM, HT and LLMM entered as covariates.

Allometric scaling factors for PP and MP for the boys and girls were identified from log-linear analysis of covariance (ANCOVA), with LLMM entered as the covariate, to derive a common b exponent for boys and girls (1).

In essence the allometric procedure involved taking the natural logarithms of dependent variables (e.g. Ln PP and Ln MP) in turn, and entering the body size descriptor of choice (e.g. Ln LLMM) as the covariate in a general linear model (i.e. univariate analysis). In running the analysis, the exact b exponents that described the relationship between PP and LLMM, and between MP and LLMM in boys and girls were derived.

Power function ratios (i.e. $PP/LLMM^b$ and $MP/LLMM^b$) that are size-independent were subsequently computed (1, 10). The level of statistical significance was set at $p<0.05$.

RESULTS

The physical and anthropometric characteristics of the boys and girls are presented in Table 1.

Table 1 Anthropometric and descriptive characteristics of the participants.

Variable	Boys (N=48)	Girls (N=38)
Age (y)	14.5 ± 0.4	13.9 ± 0.6
Stature (m)	1.69 ± 0.05	1.57 ± 0.08*
Body mass (kg)	58.2 ± 9.7	50.3 ± 7.4*
Lower limb muscle mass (kg)	16.2 ± 2.1	12.5 ± 1.2*
Tanner stages 3 & 4	86%	89%
Pubic hair criterion only		

*Significantly different at $p<0.05$. Data are mean±SD.

Eighty-six percent of the boys and 89% of the girls were assessed as Tanner stages 3 and 4 for sexual maturity status, based on the pubic hair criteria. Boys were significantly, taller, had greater body mass and LLMM than the girls.

Stepwise regression analysis revealed that LLMM was the best predictor for PP ($r=0.78$ and $r=0.82$, $p<0.05$) and MP ($r=0.66$ and $r=0.82$, $p<0.05$) in boys and girls.

The relationships between PP and MP and LLMM in boys and girls are shown in Figures 1 and 2.

Log-transformed data analysed by ANCOVA that described the allometric relationships between WAnT performances (i.e. PP and MP) and LLMM, revealed common b exponents for PP for boys and girls as ($b=0.65$[95% confidence interval$=0.47-0.82$]) and for MP as ($b=0.79$ [95% confidence interval $0.49-1.10$] for boys and girls. Despite the boys being taller than the girls, the inclusion of stature into the log-linear equation(s) did not make a significant additional contribution to the b exponent.

WAnT performances in absolute terms and described in relation to LLMM are shown in Table 2.

DISCUSSION

The DEXA data demonstrated that boys had greater LLMM than girls, in contrast to previously reported data, that showed no gender difference in TMV of seven to 15 year old children, measured using anthropometric methods

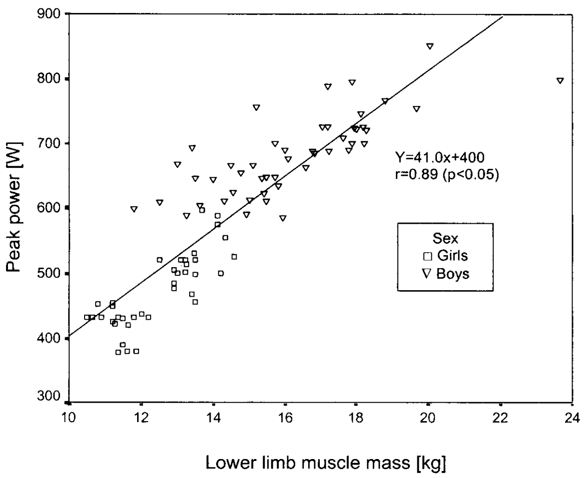

Fig. 1 Relationship between peak power and lower limb muscle mass in boys and girls

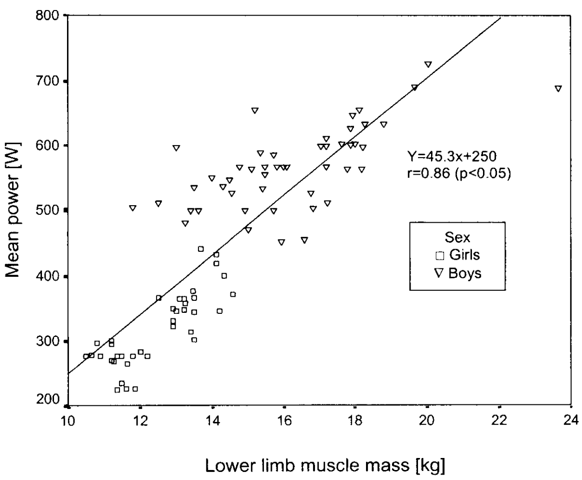

Fig. 2 Relationship between mean power and lower limb muscle mass in boys and girls

Table 2 Peak and mean power of the participants in absolute terms and described in relation to LLMM.

Variable	Boys (N=48)	Girls (N=38)
Peak power (W)	683 ± 62	473 ± 57*
Peak power (W/kg LLMM$^{1.0}$)	11.7 ± 1.6	9.5 ± 1.3*
Peak power (W/kg LLMM$^{0.65}$)	112.0 ± 6.9	91.6 ± 6.0*
Mean power (W)	566 ± 62	318 ± 57*
Mean power (W/kg LLMM$^{1.0}$)	9.9 ± 1.5	6.4 ± 1.0*
Mean power (W/kg LLMM$^{0.79}$)	63.0 ± 5.7	43.1 ± 5.5*

*Significantly different at $p<0.05$. Data are mean ±SD.

(13). Inter-study participant differences and the limitations of anthropometric techniques to estimate TMV of the cited study could account for the dissimilar results between the cited study and the present study.

A result of the present study showed that boys were significantly taller than the girls and this could explain the greater LLMM of the boys. Moreover, many studies have shown that after male puberty, lean muscle mass of boys increases sharply in contrast to girls of equivalent maturity status (1, 6). However in terms of sexual maturity, the girls in the present study were slightly more mature, based on the pubic hair criterion. However, 86% of boys were assessed as Tanner stages 3 and 4 for sexual maturity.

Peak power (PP) in absolute terms of the boys was 144% that of the girls. When PP was expressed in ratio to LLMM$^{1.0}$, PP in watts per kg LLMM$^{1.0}$ in boys was still 125% that of girls (see Table 2). Mean power (MP), in absolute terms and expressed in ratio to LLMM$^{1.0}$ were significantly higher in boys than in girls (see Table 2). This result is not supported by the findings of others (e.g. 1, 2). In essence, results of the cited studies show that during a period between late childhood and early puberty, girls could be more powerful, or just as powerful as boys in the WAnT. This was not apparent in the present study, even though girls were sexually more mature than the boys. It should be noted however that in the cited studies of Armstrong and Welsman (1) and Carlson and Naughton (2), PP and MP were expressed in watts and watts per kg BM$^{1.0}$, and not LLMM$^{1.0}$.

Stepwise regression analysis revealed that among the body size descriptors, BM, HT and LLMM, LLMM was the strongest predictor for PP and MP (see Figures 1 and 2) in boys and girls. This was expected since LLMM was more specifically engaged than BM or HT in the generation of PP and MP in the WAnT. This result suggested that BM or HT should not always be the body size descriptor of choice when expressing performance in relation to body size. Rather, the body size descriptor of choice should be based on the informed decision of the researcher, and where possible the decision should be buttressed by the results of statistical analysis, as was the case in the present study.

Although the use of allometric modeling of data is common in biological science (11) its use in sports science is less widespread (1, 3). The use of the common ratio method among sports scientists to compare performances (e.g. PP in W/kg BM$^{1.0}$ or peak $V0_2$ in ml/min/kg BM$^{1.0}$) between distinct groups (e.g. male vs. female, athletes vs. non-athletes), without first verifying if the common b exponent is equal or not significantly different from 1.0 has been criticized as inappropriate (1, 16). Such indiscriminate use of the ratio method without proper verification of its suitability of application to data sets could potentially lead to erroneous interpretations.

Power function ratios derived for PP (W/kg $LLMM^{0.65}$) and MP (W/kg $LLMM^{0.79}$) for boys and girls revealed that boys were significantly more powerful than girls (see Table 2). This result contrasted with the result of no sex difference in allometrically adjusted peak oxygen uptake expressed in relation to TMV in 13 to14-year-old boys and girls (1).

However, the finding that boys were more powerful than girls in maximal exercise tests is supported by other studies (6). Even though testosterone was not measured in the present study, many researchers are of the view that boys are more powerful than girls after puberty because of increased musculature and the effects of circulating testosterone in boys (6, 13). However, it should be noted that in the cited studies, the performance comparisons have been made using PP and MP expressed in ratio to $BM^{1.0}$ or to $HT^{1.0}$.

In the present study, *b* exponents identified for PP (i.e. $b=0.65$, $p<0.05$) and MP (i.e. $b=0.79$, $p<0.05$) in boys and girls, in relation to LLMM were markedly different from 1.0, which is the *b* exponent used in the simple ratio method. These results of the present study echoed the arguments of others (e.g. 1, 10, 16) that the simple ratio method inappropriately adjusts for body size differences in groups.

It is noted that the *b* exponents identified for PP and MP that were expressed in allometric terms in relation to LLMM, were close to $b=0.67$ as predicted by geometric similarity theory (11). However, it should be cautioned that the exponent $b=0.67$ should not, like the b exponent used in the simple ratio method (i.e. $b=1.0$) be applied indiscriminately to all data sets. It is prudent to derive the exact *b* exponent to appropriately describe the relationship between a performance variable and the body size descriptor so as to accurately generate a size-free variable in the form of a power function ratio (i.e. performace/body size descriptor$^{\text{b exponent}}$)

CONCLUSION

Data in the study support that there are sex differences in PP and MP generated by 13-14 year old boys and girls when the performances were allometrically adjusted for in relation to LLMM. Despite a similar interpretation of boys generating significantly greater WAnT power than girls when the same data-set was ratio-scaled to $LLMM^{1.0}$, in order to appropriately adjust for the influence of body size, the identified b exponent should be used rather than a *b* exponent of 1.0.

Common *b* exponents, for boys and girls that defined the allometric relationship between PP and MP in the WAnT were not exactly 1.0 (i.e. *b* exponent used in the ratio standard), but were close to 0.67 as suggested by geometric similarity theory. It is therefore strongly recommended that sample-specific allometric modeling of the data be used to appropriately describe relationships between power elicited in the WAnT and the relevant body size descriptor, in this case LLMM.

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