HERITABILITIES OF PEAK VO_2 IN ADOLESCENCE

***Thomis Martine AI*[1], *Vanden Eynde Bart*[2], *Maes Hermine H*[3], *Loos Ruth*[1], *Claessens Albrecht L*[1], *Vlietinck Robert*[4], *Beunen Gaston*[1]**

[1] Department Sports and Movement Sciences, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, Belgium
[2] Department Kinesiology, Faculty of Physical Education and Physiotherapy, Katholieke Universiteit Leuven, Belgium
[3] Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University, Richmond, VA, USA.
[4] Genetic Epidemiology, Centre for Human Genetics, Katholieke Universiteit Leuven, Belgium and Population Genetics and Genomics, University Maastricht, Netherlands

Keywords: interindividual variability, genetics, sex-specific modeling

Introduction
Studies on the importance of genetic and environmental factors explaining variability in peak or maximal oxygen uptake lack data on females and the period of rapid growth in adolescence. More extensive heritability estimations are available for males and young adults. Heritability estimates vary from about 40 to 90%, with estimates from family studies showing consistently lower estimates except when the age range of the children is rather small (Maes et al; 1996). The present study offers the possibility to quantify the contributions of genetic and environmental factors in VO_2 peak values, from 10 to 18 years of age in both male and female twins of the Leuven Longitudinal Twin Study.

Methods
VO2 peak value was measured in 91 twins at the last stage of the Bruce treadmill protocol (RQ > 1.00, HF > 180 beats/min). Longitudinal evaluations were taken at yearly intervals, however, sample sizes dropped from 91 to 73 at 15 years of age and to 60 and 42 at 16 and 18 years respectively. VO_2 peak values were analyzed as raw data (l/min), relative to body weight (l/min/kg) and as residual scores (l/min) after age and sex-specific regression of weight on VO_2 peak. Several sex-specific genetic and environmental path-analytic models were fitted to the data at each time point separately to select the most parsimonious model by Akaike's Information Criterion. Different sources of variation were tested: A= additive genetic factors, D= dominance genetic factors, C= common environmental factors – shared by members within a family, and E= unique environmental factors. Alternative models tested for evidence of different sets of genes acting in males and females, overall differences in total variation, or different contributions of each source to the total variation (specific scalars, SS). Alternative models were compared based on their Akaike's Information Criterion. For the best-fitting model, contributions of each source of variations in males and females were expressed compared to the total variation, giving variance components estimates. For the a^2 (narrow heritability), 95% confidence limits are presented.

Results
Cross-sectional analysis of peak VO_2 data indicate a clear increase in peak oxygen uptake in males (1.63±0.38 to 3.75±0.80 l/min) with a non-linear increase, indicative for a growth spurt (figure 1). For girls increases are smaller and performances level off from 14 years onward (1.39±0.28 to 2.30±0.57 l/min). Standard deviations increase with age in both males and females, indicating increased variability in peak oxygen uptake with age.

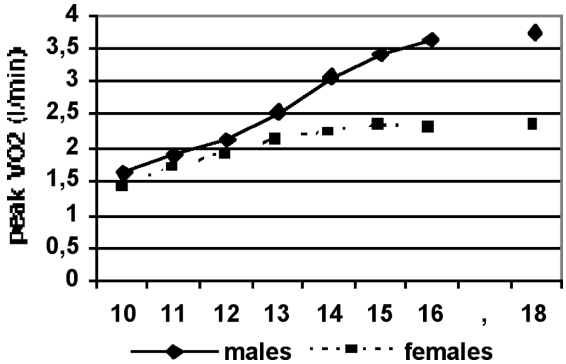
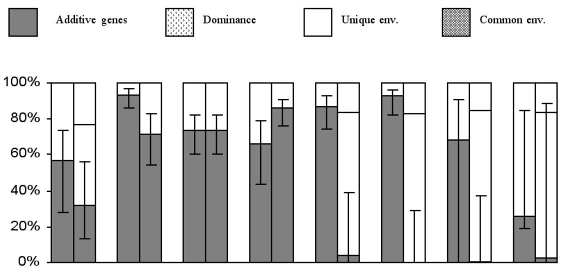


Figure 1. Evolution of peak VO_2 (l/min) in males and females from 10-18 years of age (cross-sectional analysis).

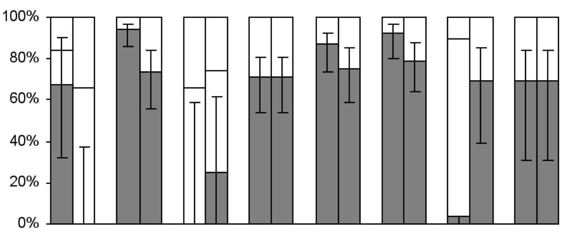
Figure and table 2 present the results of model-fitting of variation in peak (l/min) at each age. Goodness-of-fit indices show no significant Chi² values, indicating that the most parsimonious model represents the data sufficiently well. No evidence was found for differences in sets of genes that contribute to the observed sex-differences in VO_2 peak during growth (table 2). Most models indicated a sex-specific contribution of one source of variation (e.g. SS VO_2E AE at 11 years) meaning that e.g. unique environmental factors had a different contribution to the variation in peak VO_2 at 11-years of age in males and females, but genetic factors had equal non-standardized path estimates. When expressed to the total variation, sex-specific h^2 and e^2 are given. Large differences were observed in the heritability estimates. For the raw VO_2 peak values, h^2 varies from 28-94% in females, with larger contributions of the specific environment from 16 years onwards. In males, very high dizygotic intra-pair correlations induced high contributions of common environmental factors (45-83 %) at 10 years and from 14 years onward.
In general, heritability estimates increased from 10 to 13 years of age in both males (32%-83%) and females (58-64%). Contributions of individual environmental factors as well as shared environmental factors (in males) increased in importance from 14 to 18 years of age (h^2 about 0% in males, drops from 84% to 28% in females).
When peak VO_2 is expressed relative to body weight (l/min/kg) (figure and table 3), a slightly different result was found. Common environmental factors seem to become more important at 10 and 12 years of age in both males and females, but disappeared as significant contributing factors from 14 years onward. Heritability estimates for peak VO_2 per kg body weight are therefore small at age 10 and 12 especially in males, but vary between 69% and 79% in males and between 69% and 92% in females from 13 to 18 years of ages, without a clear age trend.



	F M	F M	F M	F M	F M	F M	F M	F M
Age	10	11	12	13	14	15	16	18

Model	SS ACE	SSE AE	SSA ACE	AE	SSE AE	SSE AE	mAE/ fADE	AE
Δ logL, Chi²	18.04	11.01	15.07	11.51	16.10	30.65	16.68	21.25
Δ df	9	12	11	13	12	12	10	13
Prob	0.03	0.53	0.18	0.57	0.19	0.00	0.08	0.07
AIC	0.04	-12.99	-6.93	-14.49	-7.90	6.65	-3.32	-4.76

Figure & table 2. Variance components (% explained variance) and 95% confidence intervals (a^2) for peak VO_2 values (l/min) in 10 to 18-year-old girls (F) and boys (M). Goodness-of-fit indices are presented for the most parsimonious model at each age.



	F M	F M	F M	F M	F M	F M	F M	F M
age	10	11	12	13	14	15	16	18

Model	SSC ACE	SSE AE	AE	SSA AE	mACE/fAE	mACE/fAE	mACE/fAE	mACE/fAE
Δ logL, Chi²	14.54	20.44	13.89	11.41	11.02	12.16	13.11	11.18
Δ df	11	12	13	12	10	10	10	10
Prob	0.20	0.06	0.38	0.49	0.36	0.27	0.22	0.34
AIC	-7.46	-3.57	-12.11	-12.59	-8.98	-7.84	-6.89	-8.82

Figure & table 3. Variance components (% explained variance) and 95% confidence intervals (a^2) for relative peak VO_2 values (l/min/kg) in 10 to 18-year-old girls (F) and boys (M). Goodness-of-fit indices are presented for the most parsimonious model at each age.

Discussion/Conclusion

The present study investigated the importance of genetic and environmental factors as contributing factors to variability in peak oxygen consumption in longitudinally evaluated male and female adolescents. Heritability estimates differ for males and females at most ages. In general, heritability estimates are lower when body weight is not taken into account. For males environmental factors shared within the family seem to contribute to variability in peak VO_2 (l/min) at 10 and from 14 years onward, however this factor is not significant when peak VO_2 is expressed relative to body weight (l/min/kg) and therefore heritability estimates are higher for peak VO_2 (l/min/kg) compared to peak VO_2 (l/min) in males.

In females only additive genes and unique environmental factors contribute to the observed variability in uncorrected peak VO_2 values with increasing heritabilities from 10 to 14 years of age, followed by a decreasing trend. A similar result was observed for relative peak VO_2 measures, except at 10 and 12 years of age where shared environmental factors also contributed to the total variation.

Further multivariate longitudinal model-fitting is needed to answers questions about time-specific contributions of new genetic and environmental factors in VO_2 peak determination during growth. Furthermore, allometric correction of VO_2 measures for weight, height or lean mass might more correctly represent changes in oxygen uptake during the period of rapid growth in adolescence.

References

Maes HHM, Beunen GP, Vlietinck RF, Neale MC, Thomis M, Vanden Eynde B, Lysens R, Simons J, Derom C, Derom R, (1996). Med Sci Sports Exerc 28: 1479-1491.

GENDER DIFFERENCES IN PEAK MUSCLE PERFORMANCE DURING GROWTH

Doré Eric, Martin Ronan, Bedu Mario, Duché Pascale, Van Praagh Emmanuel

Laboratoire Inter-Universitaire de Biologie des Activités Physiques et Sportives, France

Keywords: peak muscle power, gender, growth

Most research in the area of pediatric exercise science has traditionally been limited to male individuals. Because short-term muscle power (STMP) has been little investigated compared to prolonged maximal power, gender differences in STMP during growth has still to be clarified. The present study was undertaken to determine gender differences in changes in maximal leg power during growth. A non-selected population of 583 females and 530 males aged 8 to 20 years volunteered for the study. The population was divided in six age-groups (8-10, 10-12, 18-20 years of age). Anthropometric characteristics included height, body mass, leg length (LL) and lean leg volume (LLV). All subjects performed three all-out sprints on a cycle ergometer against three different braking forces (1.5, 2.5 and 5% of body weight for children up to 12 years and 2.5 and 5 and 7.5% of body weight for the other individuals) to determined cycling peak power (CPP, including the force required to accelerate the flywheel of the cycle ergometer) and optimal velocity (V_{opt}, cycling velocity at CPP). No significant gender-differences were observed up to 14 years old in anthropometric characteristics and CPP. From 14 years old however, males showed a higher CPP than females ($p<0.001$), but also a higher lean leg volume ($p<0.001$). Comparison of allometric relationship between CPP and LLV [ln CPP = ln(a) + b ln(LLV)] using ANCOVA showed a clear gender-differentiation ($p<0.001$) in adjusted CPP changes between 14 and 16 years ($b = 0.71$ in females vs. $b = 1.02$ in males). As a consequence, from 16 years of age, for similar body dimensions, males have a greater CPP than females. This gender-difference was also observed for optimal velocity adjusted for leg length. Therefore, from onwards age 14, for similar leg length, males have a higher optimal velocity (velocity at CPP) but also a higher maximal velocity than females. Qualitative muscle factors such as fiber type, neuromuscular activation or muscle enzyme activities might be responsible for this difference.

A LONGITUDINAL STUDY OF TETHERED SWIMMING FORCE IN COMPETITIVE AGE GROUP SWIMMERS

***Taylor Suzan R*[1,2], *Stratton Gareth*[1], *MacLaren Don PM*[2], *Lees Adrian*[2]**

[1] *REACH (Research into Exercise Activity and Children's Health) Group, Faculty of Education, Community and Leisure, Liverpool John Moores University, Liverpool, UK*
[2] *Research Institute for Sport and Exercise Sciences, School of Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK*

Keywords: longitudinal study, multilevel modelling, age group swimmers

Introduction
While much work has been carried out on the development of aerobic fitness in children considerably less attention has been applied to the development of anaerobic performance. The majority of the data in the literature are confined to untrained populations using young boys and fail to quantify level of maturation, preferring to use chronological age which has been shown to be a poor indicator of maturity (Matsudo and Matsudo, 1993). Studies involving girls are limited, with a particular lack of information available for the 13-16 year old age range. In addition the assessment of anaerobic performance in young athletes is an issue which has been addressed by few researchers, with the main basis of our current knowledge of the development of anaerobic performance based on non-athletic children. It is however, inappropriate to assume that trained children will perform in the same way as non-athletic children. Swimming offers an ideal opportunity to study the influence of these factors, as swimmers participate in regular training from a young age and training is generally prescribed in terms of chronological age.
The assessment of power output in swimming is complex due to the differences in body position, motor recruitment patterns and the fact that swimming takes place in the medium of water. At the present time tethered swimming is the most appropriate method to use with swimmers (Rohrs *et al*., 1990). However 'power output' cannot be determined as there is no forward velocity, as a result mean tethered force (MTF) is used as an indictor of anaerobic performance. Therefore the aim of this study was to assess the changes in anaerobic performance in circumpubertal competitive swimmers.

Methods
Subjects
A total of forty seven girls initially volunteered to take part in the study. The subjects were highly trained individuals who, for the 12 months prior to testing had completed at least 4 training sessions per week of 1.5-2 hours duration. Prior to the start of the study, parents and children were informed verbally and in writing of the experimental procedures. Parents and children also provided written consent in accordance with the University Ethics Committee. The study used a mixed longitudinal design with measurements taken at approximately 6 month intervals.

Tethered Swimming System Design
The fully-tethered swimming system consisted of a PC laptop computer (Toshiba Satellite 230CX, Tokyo, Japan) and software (PowerLab™ System, Chart for Windows®, ADI Instruments, Castle Hill, Australia), a starting block (used to anchor the force transducer), an amplifier (FE 359 TA 12v conversion, Fylde Electronic Labs, Preston, UK), a PowerLab™/400 system (ADI Instruments, Castle Hill, Australia), a 100 kgf force transducer (V4000, Maywood Instruments, Hampshire, UK), 3 karabiners (1000kN, EB Viper, Bangor), 6 m of pre-stretched rope (diameter 0.5 cm), and a climbing belt (Trat, Arizona, USA). A diagrammatic representation of the tethered swimming system is given in Fig 1.

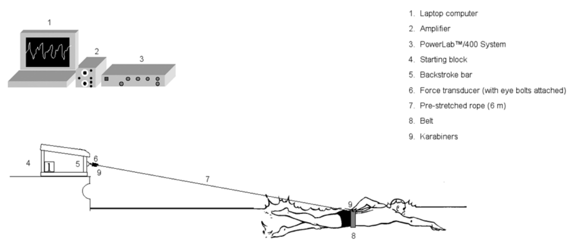


Fig. 1: A schematic diagram of the fully tethered swimming system.

The force transducer was attached to the starting block via a 15 cm length of pre-stretched rope that was looped around the backstroke bar and had a karabiner to attach the force transducer, via the eyebolts. The signal from the force transducer was amplified by a transducer amplifier which was linked to a data acquisition module that consisted of an analogue-to-digital (A/D) converter and software. A sample rate of 100 Hz was used for all data collection.
The force transducer was calibrated prior to testing by hanging a series of known masses (0,10, 20, 30, 40, and 50 kg) from the force transducer. As the force vector in the tether was at a small angle to the horizontal (Fig. 1), the data were corrected by computing the horizontal component of force. The raw data were averaged every second over the 30 s period; from this mean force was calculated.

Experimental methods
Decimal age was computed from the date of birth and date of testing. The maturity status of the subjects was assessed using a self-assessment questionnaire devised by Morris and Udry (1980). Fourteen anthropometric measures were also

taken, these included stature, body mass, circumferences (bicep (relaxed), calf, and chest), breadths (biacromial and biiliac), lengths (acromiale-radiale, radiale-stylion, hand, foot, arm span), and body composition (subscapular and triceps skinfolds) using the standardised procedures outlined by Lohman *et al*. (1991).

In order to standardise the testing procedure subjects were tested at the same time of day across the 18 month period, as diurnal variation is known to affect swimming performance (Martin and Thompson, 2000). In addition subjects were asked to refrain from training on the day of testing and to standardise their nutritional intake.

Prior to testing the subjects completed a standardized warm-up (700 m). The subjects then completed a tethered familiarisation which included a 30s practice test, this was followed by a 30min low intensity (heart rate 120-140 beats • min^{-1}) standardized training session which preceded the actual 30s tethered swimming test. The reliability of tethered swimming force in age group swimmers has been reported elsewhere (Taylor *et al*., 2001). In the tethered swim test, the swimmers commenced from a rolling start, which involved taking up the slack in the rope and swimming sub-maximally until a whistle was blown. The subjects were verbally encouraged throughout the test, instructed to avoid pacing and to maintain maximal effort for the duration of the test. The raw data were averaged every second of the 30s period and from this MTF was calculated. Immediately after the test the subjects completed a standardised swim down (400 m).

Data Analysis

Descriptive statistics for the anthropometric variables were calculated for each phase of the testing using SPSS (ver 11.0.1, SPSS Inc, 2001).

Factors associated with the longitudinal development of anaerobic performance, such as age, maturity status and anthropometric measures were investigated using the multi-level modelling program MLwiN (version 1.12, Rasbash *et al*., 2001). Multilevel modelling is fundamentally an extension of multiple regression and allows the assessment of nested or hierarchical data. In longitudinal data sets, the hierarchy can be described as the repeated measurement occasions (level 1 units) and individual subjects (level 2 units).

In the present study a multiplicative allometric model was used in which all parameters were fixed with the exception of the constant (intercept term) and age parameters which were allowed to vary randomly at level 2 (between individuals) and the multiplicative error ratio ε, which described the variance at level 1 (between occasions). The subscripts i and j denote random variation at levels 1 and 2 respectively. 'Age' was centred (subtracting the mean age from each subjects decimal age) on the group mean of 12.9 years to make the interpretation of the intercept term easier and to reduce the risk of numerical errors when using the Iterative Generalised Least Squares (IGLS) estimation method. The model was linearised by using log-transformation.

$$\log_e \text{MTF} = (k_1 \times \log_e \text{arm span}) + \alpha_j + (b_j \times \text{age}) + \log_e \varepsilon_{ij}$$

Where: $k_1 = \log_e$ arm span, α = constant, b = centred age and $\log_e \varepsilon$ = multiplicative error. The subscripts i and j denote random variation at levels 1 and 2 respectively. From this baseline model, additional explanatory variables were investigated. Where maturity was found to be significant it was entered into the model as a categorical variable.

The multiplicative allometric model has been shown to be statistically superior to the additive polynomial model which was first proposed by Goldstein (1986), as it accommodates the skewness and heteroscedasticity which is often present in size-related exercise data (Nevill *et al*., 1998).

Results

The swimmers physical characteristics and time trial performance are described in Table 1.

Table 1: Physical characteristics and time trial performance of the swimmers.

	Test 1 (n = 47)	Test 2 (n = 41)	Test 3 (n = 40)	Test 4 (n = 38)
Age (y)	12.4 ± 1.1	12.7 ± 1.1	13.2 ± 1.1	13.6 ± 1.1
Stature (cm)	155.6 ± 8.6	158.7 ± 8.6	160.2 ± 8.0	161.9 ± 7.7
Body Mass (kg)	47.4 ± 9.5	49.4 ± 10.2	51.1 ± 9.2	52.6 ± 8.9
Skinfolds (mm)*	24.4 ± 7.8	20.6 ± 10.4	20.3 ± 10.8	18.6 ± 10.7
50 m Time Trial (s)**	35.29 ± 2.0	35.01 ± 2.21	35.12 ± 2.7	34.23 ± 2.5

** Sum of triceps and subscapular skinfolds. **50 m Freestyle Time Trial performed from a push start. Values are means (SD).*

In a multilevel model the fixed parameters describe the subject population mean response and the random parameters reflect the individual departures from the mean response or the variation at both level 1 (within individuals or between occasions) and level 2 (between individuals). The intercept (constant) and age were allowed to vary randomly at level 2, which ensured that each child had their own growth trajectory over the test period.

The first model is the baseline, and from this baseline model other anthropometric measures were investigated as additional explanatory variables. Due to multicollinearity between the anthropometric variables, only measures that were significantly correlated but not collinear (i.e. $r < 0.8$) with arm span were included in the model. The statistical significance of a parameter is determined by dividing the value of the parameter estimate by its standard error term. If this value exceeds ± 2.0, the estimate may be considered significantly different from zero $P<0.05$ (Duncan *et al*., 1996). The deviance statistic (the log likelihood value) describes the models goodness of fit. In hierarchical data, such as the present data, the log likelihood value is negative and therefore the smaller the number the better the fit. However, the log likelihood value must be considered in relation to the number of fitted parameters, and as a result, a reduction in the log likelihood value does not necessarily indicate a 'better' fitting model.

Table 2: Multilevel regression analysis for mean tethered force (n=*166*)

Parameter	Model 1 Estimate (SE)	Model 2 Estimate (SE)	Model 3 Estimate (SE)	Model 4 Estimate (SE)
Fixed				
Constant	3.994 (0.018)	3.995 (0.018)	3.994 (0.017)	3.998 (0.017)
$\log_e$ arm span	1.657 (0.306)	1.843 (0.308)	1.339 (0.338)	1.245 (0.331)
$\log_e$ subscapular skinfold	Not entered	-0.131 (0.041)	-0.173 (0.042)	-0.173 (0.041)
$\log_e$ calf girth	Not entered	Not entered	0.556 (0.174)	0.600 (0.171)
Age	N.S.	N.S.	N.S.	N.S.
Tanner Stage V	Not entered	Not entered	Not entered	-0.183 (0.040)
Random				
Between subjects (Level 2)				
Constant	0.012 (0.003)	0.013 (0.003)	0.012 (0.003)	0.012 (0.003)
Age	N.S.	N.S.	N.S.	N.S.
Covariate	N.S.	N.S.	N.S.	N.S.
Between occasion (Level 1)				
Constant	0.005 (0.001)	0.005 (0.001)	0.004 (0.001)	0.004 (0.001)
-2 x log (likelihood)	-290.299	-300.007	-309.868	-318.375

N.S. Non –significant $P > 0.05$.

Table 2 shows the results of the multilevel regression analysis for MTF. The inclusion of arm span proved to be a significant explanatory variable in the baseline model with an exponent of 1.657 (± 0.306), which made the age parameter non-significant. The random components of the model at level 2 showed that age and the covariance of the slope were non-significant, whereas the intercepts at level 1 and 2 were significant. The baseline log likelihood value was –290.299.
The addition of the subscapular skinfold measurement improved the fit of the model, with a significant change ($P < 0.01$) in the log likelihood value compared to the baseline model for one more parameter. Furthermore calf girth also imparted a significant ($P < 0.01$) effect on mean force production (model 3). The inclusion of the third anthropometric exponent in the model decreased the arm span and the subscapular skinfold exponent increased from -0.131 to -0.173. The log likelihood value decreased by 9.861, which signifies that the third model accounted for more of the variance than the preceding models and is consequently a better statistical fit. The final significant explanatory variable added was maturity (Tanner Stage V), which was found to have a negative effect on MTF.

Discussion

Longitudinal studies represent the most rigorous approach to studying the interaction of growth and maturity on anaerobic performance, however the analysis of longitudinal data sets has until recently been challenging, especially when the data are sampled in relation to body size and composition. With the advent of multilevel modelling more flexible and sophisticated analyses can now be conducted on data (Welsman and Armstrong, 2000).
Armstrong *et al*. (2000) used multilevel modelling to examine the effects of age, body size, skinfold thickness, gender and maturation on the short-term power output. These analyses revealed a significant sex-related difference in short-term power output, and a significant effect of later maturity on mean power output. In a later study using the same subjects, Armstrong *et al*. (2001) examined the development of mean and peak power output over 5 years. Despite a reduction in the sample size mean and peak power output were shown to increase with age but there was no effect of maturity. In addition, De Ste Croix *et al*. (2001) reported no effect of maturity on mean or peak power output in children aged 10 to 12 years. Previous studies have demonstrated the influence of stature and body mass on mean and peak power (Armstrong *et al*., 2000; Armstrong *et al*., 2001; De Ste Croix *et al*., 2001) and have subsequently included both variables in the baseline allometric equation. However, as the mean force production measurements are performed in water, body mass cannot be used to differentiate between swimmers, as the weight of the body is reduced to a few kilograms when submersed in water. As a result the stature term was replaced by arm span which was found to be a better predictor of anaerobic performance and has been involved in the prediction of sprint ability among swimmers (Carter and Ackland, 1994). The precise meaning of the arm span effect is thought to be related to stroke length and stroke frequency in 50 and 100 m freestyle events (Pelayo *et al*., 1996) and may consequently affect the application of force over the 30 s maximal test. In addition, the force produced by the arm is the product of the characteristics of the all of the muscles that span the shoulder joint and the musculoskeletal architecture, both of which are altered during puberty.
Although the arms provide most of the propulsive force in swimming, the legs also make significant contributions to the overall force, with the kick accounting for up to 25% of the overall propulsion in sprinters (Vorontsov and Rumyantsev, 2000). Young swimmers are more reliant on propulsion from the legs until sufficient strength is developed in the arms, back and trunk. Athletes who perform on land have the daily stimulation of walking and standing from approximately 9-16 months old, whereas swimmers receive virtually no training of the muscles used in swimming (arm, back and trunk) unless in the pool.
The significant negative effect of skinfold thickness on anaerobic performance has previously been reported in untrained children (Armstrong *et al*., 2000; Armstrong *et al*., 2001; De Ste Croix *et al*., 2001). The results of the present study generally show that those swimmers with lower subscapular skinfold values have a higher anaerobic performance and therefore support the findings reported in untrained children (Armstrong *et al*., 2000); Armstrong *et al*., 2001; De Ste Croix *et al*., 2001).
The final significant explanatory variable added to the model was maturity (Tanner Stage V), which had a negative affect on MTF. The impact of maturity on anaerobic performance is relatively unknown; the present study is the first to address the impact of maturity on anaerobic performance in children aged 10 to 15 years. Previous studies have looked at children of the same age who span the five maturation stages but the results appear to be contradictory (Armstrong *et al*., 2000; Armstrong *et al*., 2001; De Ste Croix *et al*., 2001). The results of this study indicate that the mature girls generate less MTF relative to changes in body size.
In summary all variables except age made significant contributions to the prediction of MTF. This finding indicates that MTF increases at the same rate as increases in body size. Although age was not a significant explanatory variable in the model it must be retained as it is allowed to vary for each swimmer in the random part of the model. In conclusion these results indicate that the development of MTF is proportional to the general increases in arm span, calf girth and subscapular skinfold thickness up to Tanner stage V when the development of MTF is altered.

References

Armstrong N, et al (2000). Med Sci Sports Exerc 32:1140-1145.
Armstrong N, et al (2001). Brit J of Sports Med 35:118-124.
Carter JEL and Ackland, TR (1994). Kinanthropometry in Aquatic Sports: A study of world class athletes. Champaign, Ill: Human Kinetics.
De Ste Croix MBA, et al (2001). J Sports Sci 19:141-148.
Duncan C et al (1996). Social Science and Medicine, 42, 817-830.
Goldstein H (1986). Ann Hum Biol 13, 129-141.
Lohman TG et al (Eds.) (1991). Anthropometric Standardization Reference Manual. Champaign, Ill: Human Kinetics.
Martin L and Thompson K (2000). Int J Sports Med 21, 387-392.
Matsudo SM and Matsudo VR (1993). In World-Wide Variation in Physical Fitness (AL Claessens, J Lefevre, B Vanden Eynde, Eds), pp 106-110. Leuven: Institute of Physical Education.
Morris NM and Udry R (1980) J Youth Adolescence 9: 271-280.
Nevill AM et al (1998). J Appl Physiol, 84, 963-970.
Pelayo P et al (1996). J Appl Biom 12:197-206.
Rasbash J et al (2001). A user's guide to MLwiN version 2.1c. London: Centre for Multilevel Modelling, Institute of Education, University of London.

Rohrs DM, et al (1990). J Swim Res 6:15-19.
Taylor SR, et al (2001). Sports Sci 19:12-13, (Abstract).
Vorontsov A and Rumyantsev VA (2000) In Biomechanics in Sport (VM. Zatsiorsky, Ed), pp 224. London: Blackwell Science.
Welsman JR, and Armstrong N (2000). Pediatr Exer Sci 12: 112-127.

THE ATTAINMENT OF PEAK VO_2 DURING SUPRAMAXIMAL INTENSITY SPRINT CYCLING

Williams Craig, Ratel Sebastien

Children's Health and Exercise Research Centre, Exeter, UK

Keywords: peak oxygen uptake, supramaximal sprinting, isokinetics

Previous evidence in adults suggests that a plateau in power decrement occurs during all out exercise of >80 s. When such a plateau in power is reached it has been hypothesised that the power is maintained as the same rate as for aerobic metabolism during a peak oxygen uptake (peak VO_2) test. The aim of the study was to compare the PVO_2 obtained from a conventional ramp test to exhaustion in adolescents to the PVO_2 attained in a 90s supramaximal intensity cycle sprint. Seventeen adolescents (14 boys and 3 girls, 14.6±0.3 y) volunteered to participate, which was approved by the ethics committee of the University. On day 1 participants completed a PVO_2 test on an isokinetic cycle ergometer (SRM, Julich, Germany) to volitional exhaustion using a 25 $W.min^{-1}$ ramp protocol commencing at 50W. Peak VO_2 was defined as the highest VO_2 value as determined by a stationary 10s average and aerobic maximal power (Wmax) was calculated from the final 30s of the test. After a 24 hr recovery period, participants returned to the laboratory and completed two 90s supramaximal sprints (S1 & S2) at a fixed cadence of 110rev.min^{-1}. The sprints were separated by a 45 minute recovery period. In all tests (ramp, S1 & S2) pulmonary gas exchange was measured breath-by-breath using a mass spectrometer (CaSE QP9000, Morgan Medical, Kent). Peak power (PP) was determined as the highest power output over 1s and minimum power (MinP) as the power attained in the last 30s of the supramaximal 90s sprints. The oxygen uptake attained during the final 30s was determined as the PVO_2 value for S1 & S2. All oxygen uptake data were interpolated and time aligned to 1 s intervals. Differences between the ramp and sprint protocol for PVO_2 and power were analysed using Student's paired t-test. The PP for S1 & S2 were 538±129 and 533±139 W respectively. Peak was VO_2 not significantly different between the ramp, S1 or S2 (2.6±0.6, 2.5±0.5 and 2.5±0.5 $L.min^{-1}$ respectively, p> 0.05). The MinP for S1 (137±53 W) and S2 (154±60 W) were significantly different to the max (211±42 W) of the ramp test (p< 0.05). The PVO_2 , but not the MinP, produced in a supramaximal 90s sprint is comparable to that achieved in a conventional aerobic ramp test. Hence for researchers solely interested in PVO_2 values, a shorter but more intensive protocol may suffice.

THE ECCENTRIC/CONCENTRIC RATIO OF THE KNEE AND ELBOW EXTENSORS AND FLEXORS OF CHILDREN AND ADULTS

Deighan Martine*, De Ste Croix Mark, Wood Louise, Armstrong Neil

Children's Health and Exercise Research Centre, University of Exeter, UK

Keywords: concentric , eccentric, children

Previous literature has indicated a greater Eccentric/Concentric ratio (Ecc/Con) of muscle groups in women than men (Griggin et al. 1993; Seger and Thorstensson 1994) but the Ecc-Con relationships of the knee and elbow musculature in children has been less well studied. Therefore the aim of this study was to determine if there are sex or age-associated differences in the Ecc/Con of the elbow and knee extensors and flexors (EE, EF, KE and KF). 21 boys and 24 girls with a mean age of 9.5±0.4 y and 21 males and 21 females with a mean age of 24.3±3.6 y volunteered for the study. After a separate day familiarisation, Con and Ecc isokinetic peak torque was assessed at 0.52 rad/s using a Biodex System 3. After a warm-up of 3min cycling, 20s stretches and 3 submaximal and 1 maximal Con extension/flexion cycles on the Biodex, 3 maximal continuous extension/flexion cycles were performed with a 2min rest between the Con and Ecc test. The data were gravity corrected, windowed and the greatest torque value was selected for analysis. The significance level for all statistical tests was p<0.05. One sample t-tests revealed that Ecc/Con was greater than 1.0 except for EE Ecc/Con in both female groups and the male children. Sex by group (2 by 2) ANOVA revealed no significant effects for KE Ecc/Con which had a mean of 1.28, but a significant group effect was found (p=0.012) for KF Ecc/Con with the ratio of the children (1.70±0.42) being higher than that of the adults (1.52±0.31). There was a main effect of sex (p=0.029) for EE with the males Ecc/Con being higher than that of the females (1.19±0.23 vs. 1.09±0.20). The analysis of EF Ecc/Con indicated significant main effects of sex (p=0.010) and group (p=0.010) which reflected higher ratios in the adults (male 1.29±0.26, female 1.33±0.23) than the children (male 1.22±0.29, female 1.29±0.25) and in females than males. No interaction effects were found for any of the Ecc/Con variables. In conclusion, the results of this study do not indicate a particular trend with respect to sex or age differences in the Ecc/Con of the knee and elbow extensors and flexors and with the exception of EF Ecc/Con there was no indication that Ecc/Con is greater in females than males.

Griffin, J.W. et al. (1993). Medicine and Science in Sport and Exercise, 25, 936-944
Seger, J.Y. and Thorstensson, A. (1994). European Journal of Applied Physiology, 69, 81-87

*(Dr. Deighan is now with the University of Wolverhampton)

PLANTAR FLEXION TORQUE PER UNIT MUSCLE CROSS-SECTIONAL AREA IS SIMILAR IN BOYS AND YOUNG MEN

Tolfrey Keith, Morse Chris, Thom Jeanette, Vassilopoulos Will, Narici Marco V

Manchester Metropolitan University, England

Keywords: specific torque, ACSA, boys

The effect of biological maturation on specific torque is not clear. To this end, the purpose of this study was to compare maximum plantar flexion torque per triceps surae (TS) anatomical cross-sectional area (ACSA) in boys and young men. Twelve early pubertal boys (mean (SD) 11.3 ± 0.3 y; 1.46 ± 0.03 m; 39.0 ± 8 kg; pubic hair stage 2) and ten young men (24.3 ± 4.8 y; 1.80 ± 0.08 m; 77.3 ± 13 kg) volunteered for the study. Torque was measured at six different ankle joint angles, from 20 deg dorsiflexion (-20 deg) to 30 deg plantar flexion (+30 deg), with the participants lying prone (knee at 180 deg) using a Cybex dynamometer. The TS ACSA (cm^2) was determined in vivo using magnetic resonance imaging (MRI). Specific torque was then calculated as the ratio between maximum torque at the optimal angle of -20 deg and TS ACSA ($Nm.cm^{-2}$). Between group differences were assessed using independent Student's t-tests. Zero order correlations were used to examine the relationships between TS ACSA and the torque values at each joint angle in the separate groups.
In both boys and young adults, maximum torque was attained at -20 deg of dorsiflexion. At this angle, maximum torque was 75 ± 23 Nm in the boys and 163 ± 43 Nm in the young men. Similarly, TS ACSA was 29 ± 9 cm^2 in the boys and 60 ± 10 cm^2 in the young men. The ACSA of the gastrocnemius medialis (GM) and lateralis (GL), and the soleus as a percentage of the TS ACSA was the same for both groups (29%, 20%, and 51% respectively, $P>0.05$). For the boys, the correlations between TS ACSA and torque ranged from r = 0.81 to 0.91 across the different joint angles ($P<0.001$). In contrast, the relationship was weaker in the men, r = 0.53 to 0.66. When normalised for TS ACSA, the maximum torque of the boys was 2.64 ± 0.4 $Nm.cm^{-2}$ and 2.71 ± 0.6 $Nm.cm^{-2}$ in the young men ($P>0.05$).
It is concluded that, despite the significantly smaller TS cross-sectional area of these early pubertal boys, their maximum torque scaled to muscle size in the same fashion as that of the young men. Hence, the specific torque of these 11 year old boys was not different from the men's.

EFFECTS OF HIGH-INTENSITY TRAINING ON EXERCISE PERFORMANCE OF PRE-ADOLESCENT FEMALE SOCCER PLAYERS

Grossner Colleen M, Johnson Emily M, Cabrera Marco E

Pediatrics, Case Western Reserve University, Cleveland, Ohio, USA

Keywords: high-intensity, soccer, training

Introduction
Children ordinarily engage in short bursts of high-intensity physical activity interspersed with periods of moderate or low activity (Bailey). Consequently, exercise programs that mimic this pattern of physical activity may foster improved adherence to the training regime by children, therefore promoting physiological adaptation to conditioning. However, the actual metabolic responses to high-intensity exercise are unknown in a pediatric population.
Traditionally, an improvement in maximal O_2 uptake (VO_{2max}) has been the most common criteria used to determine the effectiveness of training programs in adults. However, when children have been trained, increases in VO_{2max} are not always evident (Williams). Therefore, changes (post- minus pre-training values) in submaximal parameters of exercise performance (e.g., lactate threshold (LT), submaximal oxygen uptake ($VO_{2submax}$), heart rate (HR), minute ventilation (VE) may be more appropriate indicators of the physiological adaptation to exercise training.
Therefore, the purpose of this study was to examine the effects of an 8-week high-intensity intermittent running program on exercise performance and cardiorespiratory function on a group of healthy, pre-pubertal, pre-adolescent, female soccer players. We compared the cardiovascular, respiratory, and metabolic responses to maximal and submaximal exercise on a treadmill before and after training to test our hypothesis that a high-intensity conditioning program would improve peak aerobic power and submaximal indices of performance in healthy children.

Methods
Subjects, Baseline Tests, and Experimental Design
Seven healthy, non-sedentary girls (age: 10.4 ± 0.05 yr, height: 139.4 ± 5.9 cm, weight: 32.0 ± 7.2 kg) were recruited from a local elementary school (Shaker Heights, Ohio). All of the subjects were pre-menarcheal and six of the seven subjects participated on a travel soccer team in addition to participation in the program. Prior to participation, written informed consent was obtained from a parent or guardian for all subjects. The research protocol was approved by the Institutional Review Board for Human Investigation of University Hospitals of Cleveland (UHC). This study also obtained approval from the Shaker Heights City School District.
Subjects visited the exercise lab in Rainbow Babies and Children's Hospital of UHC for exercise testing on 4 separate days, for approximately 90 min/day (2 days: pre-training; 2 days: post-training). Subjects answered a modified version of the Physical Activity Readiness Questionnaire (Canadian Society for Exercise Physiology) to assess history of disease and habitual physical activity. Persons with a history of chronic disease of any organ system and persons who were not allowed to participate in normal physical education programs at school were excluded. Baseline testing consisted of anthropometric measurements and two exercise tests on a treadmill (1 maximal, 1 submaximal). The training protocol included three 1-hour supervised training sessions per week, on non-consecutive days for 8 consecutive weeks, after regular school hours. During each training session, subjects ran two non-consecutive bouts of 10 minutes each at an individually pre-determined target heart rate (85-95% HRmax) and performed soccer drills and scrimmages for 20 minutes in between these running bouts. The remaining portion of the exercise session was devoted to warm-up, stretching, and cool-down exercises. In addition to the training program, on average, girls participated in two 1-hour soccer practice sessions and a soccer game each week. After completion of training, subjects repeated pre-testing measurements in the exercise laboratory.

Measurements
On the first visit to the lab, weight and height were measured. Body composition was determined using triceps and subscapular skinfolds measured in triplicate with a skinfold caliper (Human Kinetics).
Prior to each exercise test, before data collection, each subject's

facemask (8940 Series, Hans Rudolph, Inc., Kansas, MO) was properly fitted and sealed with a gel (Hans Rudolph, Inc.) to minimize any gas leaks. Subjects breathed through a flow meter from which two sample lines transported expired air to a metabolic measurement system (VMax 29, SensorMedics, Yorba Linda, CA), which was calibrated for flow volume, VO_2, and VCO_2 before each test. Subjects were given enough time to familiarize themselves with the breathing apparatus to minimize non-physiological results.

During exercise testing and recovery periods, an electrocardiogram, as well as respiratory and metabolic variables (VE (BTPS), V_T (BTPS), RR, VO_2 (STPD), and VCO_2 (STPD)) were continuously monitored. Ventilatory equivalent for O_2 (VE/VO_2), respiratory exchange ratio ($RER = VCO_2/VO_2$), ventilatory equivalent for CO_2 (VE/VCO_2), and oxygen pulse ($O_2P = VO_2/HR$) were derived from the above variables. Blood pressure was measured during the maximal treadmill protocol with an automated cuff (STBP-780, Colin).

Exercise Testing Protocols

On the first day, subjects performed a maximal exercise test on a motor-driven treadmill. After a 3-min warm-up at 1 mph and 0% grade, the treadmill speed and slope were increased to 1.7 mph and 10% grade. Following the initial work rate change, treadmill speed and grade increased every 6-sec until exhaustion (DiBella). Exercise was followed by a 3-min active recovery stage. Subjects were told not to grip the handrails during the test, except to hold on during the increase in speed from walking to running if necessary. On the second day, subjects performed a submaximal exercise test at the speed and grade which corresponded to 75% VO_2max from the maximal treadmill test. After the 8-week conditioning program, subjects repeated these exercise tests.

During the maximal exercise tests, the following criteria were used as indicators of a maximal effort: (a) HR >85 % of predicted peak heart rate, (b) RER > 1.0, and (c) the achievement of a VO_2 plateau. Attainment of at least two of these criteria was required in order for an exercise test to be considered maximal.

During the submaximal tests, a steady-state was assumed to be achieved when VE, VO_2, and HR did not change more than 5 % for a 90-second period.

High-Intensity Training Program

Subjects were engaged in training 3 days/week (1 hr/day) for 8 weeks. All subjects wore a HR monitor (Polar Beat, Polar USA), so that they could individually monitor their HR and maintain the prescribed intensity. Subjects then warmed up and stretched for 10 minutes. After the warm up, subjects began a 10-minute bout of running around a quarter-mile cinder track. During the 10-minute running bouts there were 2-minute intervals of high intensity running interspersed with 2-minute intervals of moderate intensity running totaling 3 "fast" intervals and 2 "moderate" intervals. After the first running bout subjects participated in soccer drills and scrimmages for 20 minutes. In the last 10 minutes, subjects repeated the running phase previously described. Each training session ended with a recovery period of jogging and stretching.

Subjects were instructed to maintain their HR in a range of 85-95 % of their maximal HR as determined from pre-training exercise testing. During running bouts subjects were frequently asked about their heart rates by a supervising exercise physiologist as a means of monitoring intensity. Verbal encouragement was also provided throughout training.

Data Processing and Analysis

From smooth breath-by-breath data, averages were calculated for exercise variables measured during the last 20 seconds of warm-up and exercise. Paired Student's t-tests were used to compare pre-training and post-training measurements. Statistical significance was taken at the $p < 0.05$ level for all tests. Values that are displayed in results are presented as mean ± standard deviation (SD).

Results

Anthropometrics

Except for height and body surface area (BSA), no significant differences were found when comparing anthropometrics before and after training (Table 1).

Characteristics	Pre-training (n = 7)	Post-training (n = 7)
Height (cm)	139.4 ± 5.9	140.2 ± 6.5**
BM (kg)	32.0 ± 7.2	32.6 ± 7.9
BSA (m^2)	1.12 ± 0.13	1.13 ± 0.15*
BMI (kg/m^2)	16.4 ± 3.1	16.5 ± 3.3
Percent Body Fat	18.6 ± 5.5	17.6 ± 8.1
LBM (kg)	6.2 ± 3.6	6.2 ± 4.9

*Table 1: Anthropometric characteristics of girls before and after training Values are means ± SD; n, no. of subjects; BM, body mass; BSA, body surface area; BMI, body mass index; LBM, lean body mass. *, p >0.05; **, p > 0.01.*

Peak Responses to Maximal Treadmill Test

Relative VO_{2peak} values for pre-training (44.8 ± 6.1) and post-training (46.2 ± 4.5 $mL·kg^{-1}·min^{-1}$) were not different. However, there were significant differences in absolute peak VO_2, RER, and VE/VO_2 (Table 2). There were also significant improvements in exercised time (Figure 1), speed, and slope when pre- and post-training tests were compared. The maximum speed increased from 5.1 ± 1.3 to 5.8 ± 0.3 mph (p >0.005) and the maximum slope increased from 18.7 ± 1.2 to 21.4 ± 1.2 % grade (p > 0.001).

Exercise Variables	Pre-training (n=7)	Post-training (n=7)
VO_2, $L·min^{-1}$	1.39 ± 0.20	1.48 ± 0.28*
VCO_2, $L·min^{-1}$	1.52 ± 0.21	1.55 ± 0.29
HR, bpm	210 ± 10	209 ± 11
O_2-pulse, $mL·beat^{-1}$	6.7 ± 1.2	7.2 ± 1.8
VE, $L·min^{-1}$	60 ± 9	60 ± 14
V_T, L	1.02 ± 0.16	1.05 ± 0.13
RR, $breaths·min^{-1}$	58 ± 10	56 ± 13
RER	1.10 ± 0.05	1.05 ± 0.01*
VE/VO_2	43.0 ± 31.3	40.6 ± 2.7*
VE/VCO_2	39.9 ± 2.0	39.5 ± 2.9

*Table 2: Peak responses to maximal treadmill tests Values are means ± SD; n, no. of subjects; *, p >0.05; oxygen uptake, VO_2; carbon dioxide output, VCO_2; heart rate, HR; oxygen pulse, O_2-pulse; minute ventilation, VE; tidal volume, V_T; respiratory rate, RR; respiratory exchange ratio, RER; ventilatory equivalent for oxygen; VE/VO_2; ventilatory equivalent for carbon dioxide, VE/VCO_2.*

Time to exhaustion and relative efficiency were significantly different before and after training (Fig. 1). When time to exhaustion was utilized in order to estimate peak power (Foster), significant improvements were detected (Fig. 2).

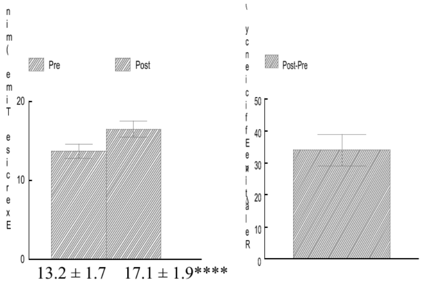


*Fig. 1: Exercise time to exhaustion and change in relative efficiency Values are means ± SD; n, no. of subjects; ****, p >0.0001.*

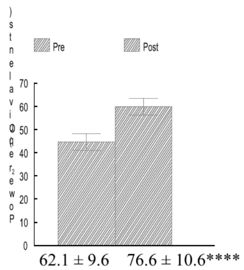


Fig. 2: Pre- and post-training estimated peak power

Lactate Threshold

There were significant changes in LT as a result of training when expressed in terms of percent of VO_{2max}, percent of predicted VO_{2max}, absolute and body mass-relative VO_2, and VE (Table 3).

	Before (n=7)	After (n=7)
% Actual VO_{2max}	51 ± 9	60 ± 11*
% Predicted VO_{2max}	29 ± 7	83 ± 22***
VO_2 (mL·kg·min^{-1})	22.4 ± 2.2	27.7 ± 6.0*
VO_2 (L·min^{-1}) @ LT	0.72 ± 0.17	0.91 ± 0.28*
VE (L·min^{-1}) @ LT	28.5 ± 6.0	35.1 ± 10.6*
HR (bpm) @ LT	165 ± 18	167 ± 15

*Table 3: Lactate threshold changes with training Values are means ± SD; n, no. of subjects; *, p<0.05; ***, p<0.001.*

Submaximal Exercise Parameters

With the exception of HR there were no significant differences in any exercise variables when comparing girls' pre- and post-training values at an intensity of 75 % VO_{2max}, (Table 4). Submaximal HR was significantly lower following the training program.

Exercise Variables	Before (n=7)		After (n=7)	
VO_2 (mL·kg·min^{-1})	37.3	± 5.9	36.2	± 7.4
VO_2 (L·min^{-1})	1.17	± 0.18	1.18	± 0.35
VCO_2 (L·min^{-1})	1.17	± 0.20	1.18	± 0.34
RER	1.00	± 0.06	1.00	± 0.06
HR (bpm)	206	± 8	196	± 11**
VE (L·min^{-1})	49.8	± 7.6	47.4	± 11.7
RR (breaths·min^{-1})	29	± 8	54	± 15
V_T (L)	0.87	± 0.16	0.9	± 0.11

*Table 4: Exercise variables during 75% VO_2max before and after training Values are means ± SD; n, no. of subjects; **, p < 0.01.*

Discussion/Conclusion

Cardiovascular training studies in adults are numerous. However, there is little research on high-intensity training in youth, especially with girls. Determining specific exercise programs that may be beneficial to children rather than relying on unexamined assumptions and adult-based training research, is imperative (Pate and Ward). Therefore, the intent of this study was to determine the physiological adaptations of a high-intensity conditioning program on healthy, pre-pubertal, female soccer players.

Several clearly positive training effects were observed as a result of the current exercise program. Time to exhaustion during a maximal exercise test increased significantly (29.5 %) after training while VO_{2max} did not. This indicates an improvement in relative efficiency in that subjects exercised longer (therefore reaching faster speeds and higher grades) before reaching their maximal aerobic capacity (same VO_{2max}). While absolute VO_{2max} did significantly increase by 6.5 %, there was no change when changes in body mass were considered to VO_{2max} (44.8 to 46.2 mL·kg·min^{-1}). Lactate threshold, which is believed to be a sensitive indicator of training (Wasserman, Mahon) increased by 17.6 % (from 51% to 60 % of VO_{2max}), indicating an improvement in cardiorespiratory fitness. With regard to submaximal indices, steady-state HR decreased significantly by 10 bpm during a treadmill test at a work rate of 75% Vo_{2max} after training. While it may at first be discouraging that subjects did not significantly improve their VO_{2max}, Pate and Ward note that submaximal HR is a more sensitive indicator of training adaptation than VO_{2max} (Pate and Ward). A substantial physiological training effect (such as improved VO_{2max}) is normally seen in adults after 5-10 weeks of training (Casaburi). However, there is no consensus on the training time needed to see improvements in VO_{2max} in children (Pate and Ward). The 8-week duration of this training program was well above that of other studies reporting significant improvements in VO_{2max} in children after a 6-week (Massicotte and MacNab) and even a 4-week program (Docherty). On the other hand, it is possible that even if the duration of the current program greatly exceeded 8-weeks, there still may not have been increases in VO_{2max} since some quite long studies (14 months of training) have been unable to improve subjects' VO_{2max} values (Yoshida).

While performance measures were not completed in this study, it may be anecdotally to note that the team of which most of these girls were members had lost all of its games in the previ-

ous year; however, in the season during which the conditioning program was conducted they only loss one game! This is not a specific performance parameter measurement, however, it clearly points toward an improvement in performance in a sport that demands excellent aerobic and anaerobic fitness levels.
The conditioning program was well attended, as each girl missed at most two days of training, resulting in 92 % adherence. However, one of the eight subjects who participated in the training needed to be eliminated from data analysis due to low effort level during exercise sessions. She was not even able to complete post-training exercise testing.
Having many of the subjects coming from the same soccer team was advantageous in that the girls all knew each other and already knew how to work together. Additionally, there were girls who prefer both offensive and defensive positions resulting in successful drills and scrimmaging. There was a positive competitive spirit evident since the subjects knew each other.
In conclusion, there were clearly some physiological adaptations to the training observed during both submaximal and maximal exercise tests. These included increased maximal exercise time and LT, as well as decreased submaximal HR for a given intensity. However, this mode of training did not provide the usual observation of increased VO_{2max} with training when there is an appropriate stimulus (Rowland).
While spot-checking method for monitoring HR worked quite well, as subjects were almost always within the appropriate target HR range during exercise when periodically asked to read their HR monitor, it may be beneficial in future studies to use HR monitors that are capable of recording HR throughout training, so that actual intensities achieved according to HR may be verified quantitatively. Also, relating performance testing to physiological improvements will be a useful piece of information to add to the body of knowledge of exercise training and performance development in children and adolescents.

References
Bailey RC, Olson J, Pepper Sl, Barstow TJ, Porszsasz J, Cooper DM (1995). Med Sci Sports Exerc 27:1033-1041
Williams CA, Armstrong N, Powell J (2000). Aerobic responses of prepubertal boys to two modes of training. 34:168-173
Canadian Society for Exercise Physiology (1994). PAR-Q and you. Gloucester, Ontario 1-2.
DiBella II JA, Johnson EM, and Cabrera ME (2002). Pediatric Exercise Science 14(4): 391-400
Foster C, Jackson AS, Pollock ML, et al. (1984). Am Heart J 107:1229-1234
Pate RR, Ward DS (1989). Advances in Sports Med Fit 3::37-55
Wasserman K, Whipp BJ, Koyal SN, Beaver WL (1973). J Appl Physiol 35:236-243
Mahon AD, Vaccaro P (1989). Med Sci Sports Exerc 21:425-431
Massicotte DR, MacNab RBJ (1974). Med Sci Sports Exerc 6:242-246
Yoshida T, Ishiko I, Muraoka I (1980). Int J Sports Med 1:91-94
Docherty D, Wenger HA, Collis ML (1987). J Appl Physiol 19:389-392
Rowland TW (1992).Can J Sport Sci 17: 259-263

PHYSIOLOGICAL DEMANDS OF PLAYING FOUR GAMES IN ONE DAY ON JUNIOR RUGBY UNION TOURNAMENT PLAYERS

Carlson John, Naughton Geraldine, Searl John

Victoria University, CRESS Melbourne, Australia

Keywords: rugby, physiology, elite junior

Australian Rugby Union strives to provide safe and optimal playing environments for young participants. Due to the highly competitive nature of National Championships they may create unprecedented stress on Under 18 players, but the physiological stresses of a tournament are poorly understood. This study compiled a physiological profile of players and described several fatigue-related factors across four, 20 minute games of rugby in 45 adolescent males in a one-day tournament. Measures included body mass changes at the start and end of the day, and pre and post game changes in ratings of leg muscle soreness, perceived exertion and repeated sprint times and blood lactate concentrations. Coaches/managers were asked to record the amount of playing time of participants and injuries. Descriptive characteristics revealed a mean age (17.2 ± 95% CI 0.2 yr), body mass change over the day (0.2 ± 0.14 kg) and mean change in blood lactate concentration following pre and post game repeated sprints (2.89 ± 1.34 mM). Ratings of leg muscle soreness and perceived exertion increased with games played and playing time correlated with rating of perceived exertion and change in lactate following games. Total mean playing time was 36 ± 6 minutes, and seven of the ten injuries reported in players occurred in Games 3 and 4. Further development of a model for monitoring markers of psychological and physiological fatigue under highly competitive situations will provide empirical data on which to base decisions regarding f demands of junior rugby players in terms of games times and the number of competitive games to be played in one day or over a period of days.

CARDIOVASCULAR RESPONSE TO ENDURANCE TRAINING IN CHILDREN IS NOT GENDER DEPENDENT

***Obert Philippe*[1]*, Mandigout Stephane*[2]*, Vinet Agnes*[1]*, N'Guyen Long Dang*[2]*, Stecken François*[2]*, Lecoq Anne-Marie*[2]

1 Laboratory of Cardiovascular Physiology, University of Avignon, France
2 Faculty of Sport Sciences and Physical Education, University of Orléans, France

Keywords: Training, cardiac, echocardiography

Introduction
In healthy children, aerobic training increases maximal O_2 uptake (VO_{2max}) but magnitude of improvement appears to be limited when compared to adults, even if training stimuli or initial physical fitness are taken into account [Rowland and Boyajian, 1995]. Mechanisms (i.e. central and/or peripheral adaptations) by which VO_{2max} increases in children after training are not yet fully elucidated. Cross-sectional studies have reported higher VO_{2max} in endurance trained children because of higher maximal stroke volume (SV_{max}) only [Nottin and al, 2002]. However, whether these superior cardiac functional capacities reflect the effect of training or are simply due to genetic factors can not be easily determined from such studies. Only one longitudinal study has evaluated the effect of an aero-

bic training program on the response of the cardiovascular system during maximal exercise in boys [Eriksson and Koch, 1973]. The latter confirmed an increase in VO_{2max} as a result of training induced by an increase in SV_{max} only. Mechanisms potentially responsible for SV_{max} improvement were however not investigated. Moreover this study involved boys only which does not therefore allow to determine whether gender influences cardiovascular response to training. This is however valuable since lower VO_{2max} in girls than in boys are frequently reported in the literature [Armstrong et al, 1991]. The aim of the present study was to determine in healthy children the effect of a well-controlled endurance training program on cardiac function at maximal exercise and to define whether gender affects the training-induced cardiovascular response. The contribution of factors potentially involved in those adaptations such as cardiac dimensions and diastolic and systolic functions was also investigated.

Methods
Thirty-five l0-11 year old children took part in this study : 19 children (10 girls and 9 boys) were assigned to participate in a 13 week endurance training program (3x1h/week, intensity: >80% HRmax) and 16 (7 girls and 9 boys) served as a control group. At first, an anthropometric evaluation (height, weight, and lean body mass by dual X ray absorptiometry), as well as M-mode, 2-dimensional and pulsed-wave Doppler analyses (Diasonics Vingmed CFM-750 ultrasound imaging system, incorporating a 3.5 MHz annular array transducer) were conducted at rest in the supine position. Cardiac dimensions (Left ventricular end-diastolic and end-systolic dimensions, LVEDd and LVEDs, respectively; posterior wall and interventricular septal thicknesses, PWT and ST, respectively, left ventricular mass, LVM) as well as systolic (LV shortening fraction SF) and diastolic (peak velocity of early diastolic rapid inflow , peak E; and of atrial contraction filling, peak A; ratio peak E / peak A) functions were evaluated. Then, cardiovascular (stroke volume and cardiac output by Doppler echocardiography, SV and Q, respectively; and systemic vascular resistance, SVR) and bioenergetic (VO2) data were monitored during an upright maximal exercise test conducted on a cycle ergometer.

Results
The training program led to a rise in VO_{2max}, brought about however only by an increase in SV_{max} in both genders. Moreover, boys increased their VO_{2max} to a greater extent than girls (boys: +15%; girls: +9%) only because of a higher SV_{max} improvement (boys: +15%; girls: +11%). No alterations were noticed in the SV pattern from rest to maximal exercise (values shifted upwards after training), indicating that the increase in SV_{rest} was a key factor in the improvement of SV_{max} and thus VO_{2max}. Regarding resting echocardiographic data, an increase in LVEDd, concomitant with an improvement in diastolic function (i.e. increase in peak E), were observed after training and constituted an essential element in the rise in VO_{2max} after training in these children. Moreover, during maximal exercise, a decrease in SVRmax, was noticed which could also have play an important role in the increase in VO_{2max}. Highly significant correlations were found between percent variation after training in VO_{2max} and Q_{max} ($p<0.001$), SV_{max} ($p<0.001$), SV_{rest} ($p<0.01$), LVEDd ($p<0.001$) and SVR_{max} ($p<0.01$). For both groups and regardless of time intervention, boys had significantly higher VO_{2max}, Q_{max}, SV_{max}, LVEDd, PWT and ST, and LVM than girls. They had also lower SV_{max} than girls. There were no gender differences for all the other variables.

Discussion/Conclusion
The major finding of the present study was that in healthy children, VO_{2max} increases after aerobic training as a result of an increase in SV_{max} only. Such an adaptive process was found, and this is a new finding, irrespective of gender. We are unaware of previous paediatric studies dealing with the effect of training on cardiac function according to gender. Our results were consistent with, to our knowledge, the only one longitudinal study which investigated in boys the effect of aerobic training on the Fick equation parameters and reported that SV_{max} was the only parameter that was modified after training [Eriksson and Koch, 1973]. SV depends on a complex interplay of many factors such as intrinsic left ventricular relaxation and contractility properties, internal chamber dimension, pre-load and after-load. In the present study, similar mechanisms including increase in pre-load (i.e. blood volume) and decrease in after-load (SVR) conditions as well as cardiac enlargement (LVEDd) seem to be involved in both boys and girls in order to explain SV improvement. These results have important health implications because they shows that a chronically instrumented physical exercise program in children results essentially in central cardiovascular adaptations.

References
Rowland TW, Boyajian, A (1995). Pediatrics, 96: 654-8.
Nottin S, Vinet A, Stecken F, N'Guyen LD, Ounissi F, Lecoq AM, Obert P (2002). Acta Physiol Scand, 175 : 85-92.
Eriksson BO, Koch G. (1973). Acta Physiol Scand 1973; 87:27-39.
Armstrong N, Williams J. (1991). Eur J Appl Physiol, 62:369-375

LEFT VENTRICULAR FUNCTION IN ENDURANCE-TRAINED CHILDREN BY TISSUE DOPPLER IMAGING

***Nottin Stephane*[1], *Nguyen Long-Dang*[2], *Terbah Mohamed*[2], *Obert Philippe*[1]**

[1] *Laboratory of Cardio-vascular Adaptations to Exercise, Faculty of Sciences, Avignon, France*
[2] *Cardiology Department, Regional Hospital Center, Orléans, France*

Keywords: left ventricular relaxation properties, trained children, tissue doppler imaging

Introduction
In young adults and children, the enhanced cardiac performance induced by endurance training is mainly due to the increase in left ventricular (LV) filling since LV systolic function is not altered. In adults, it is well established that the increase in LV filling induced by endurance-training results from several factors including in particular a cardiac hypertrophy and an increase in preload due to plasma expansion. However, whether LV relaxation properties is increased by endurance-training is controversial (Caso et al., 2000 ; Schmidt-Truckssass et al., 2001). In children, the underlying mechanisms responsible for the higher LV filling consecutive to endurance-training remain uncertain (Obert et al.,2001). Compared to adults, endurance-trained children exhibited only

moderate increase in LV internal diameter, without changes in interventricular septum and posterior wall thickness. Moreover, whether LV preload and/or LV relaxation properties are increased by endurance-training in children is unknown. Recently, a new Doppler application, based on tissue Doppler imaging (TDI) has been developed. This method provides additional information on LV relaxation properties by the measurement of LV regional wall motions. By using this new echocardiographic tool, the aim of the present study was to test whether LV relaxation properties are increased by training in prepubertal children and young adults.

Methods
Standard echocardiography (LV morphology and function) and tissue Doppler imaging (LV relaxation properties) were assessed at rest in 14 adult cyclists and triathletes, 13 age-matched sedentary controls, 12 child cyclists and 11 untrained boys. Standard Doppler echocardiography and TDI measurements were performed with the subjects in a partial left decubitus position using an HDI 5000 system (Phillips Ultrasound system). Doppler echocardiographic and TDI tracing were recorded digitally on hard drive for further analysis and all measurements were averaged on 3 to 5 measures obtained during end-expiratory of normal respiration. Standard echocardiograms consisted of 2-dimensional, M-Mode and Doppler blood flow measurements according to the recommendations of the American Society of Echocardiography. Wall motion velocities by TDI were assessed at the mitral annulus level, on the septal, lateral, inferior and anterior walls, from 2- and 4-chambers views. The pulsed TDI was characterized by the myocardial systolic wave (S_m) and 2 diastolic waves (Early, E_m and Atrial, A_m), expressed in $cm.s^{-1}$. Peak velocity of S_m was used as systolic index, and E_m, A_m peak velocities and E_m/A_m ratio were determined as diastolic measurements. Among these TDI diastolic measurements, E_m peak velocity can be considered as a good index of LV relaxation properties (Nagueh et al, 1997). Each variable was compared between the 4 groups by using a two-way analysis of variance (age group x training status). When an overall difference was found at $P<0.05$, a post hoc test of Fisher PLSD was performed.

Results
In adults, cyclists and triathletes exhibited both higher LV internal diameter, wall thickness and mass. However, no effect of training was obtained on E_m peak velocities recorded at the level of 4 walls of the mitral annulus, indicating that endurance-training did not improve the rate of relaxation of their myocardium. Moreover, no significant correlations were obtained between LV filling and morphologic parameters, showing that increased LV internal diameter was mainly due to structural alterations. As opposed to adults, child cyclists had a moderate increase in LV internal diameter without changes in wall thickness. Significantly higher E_m peak velocities were obtained at the level of the septal, inferior and anterior walls of the mitral annulus, indicating an increased rate of LV relaxation in child cyclists compared to untrained children. Moreover, significant correlations were found between both LV internal diameter and E_m recorded at the inferior ($P<0.05$, $R=0.46$) and the anterior ($P<0.001$, $R=0.65$) wall. SV was correlated with inferior E_m ($P<0.05$, $R=0.43$) and anterior E_m ($P<0.01$, $R=0.54$).

Discussion
In both children and adults, the present study confirmed the better cardiac performance (i.e. higher SV) as a result of endurance-training. The enhanced cardiac performance observed in endurance-trained children as well as young adults was mainly due to higher LV filling since no effect of training were observed on all systolic parameters. Our results mainly support that some mechanisms responsible for the increase in resting LV filling after endurance-training are partially age-related. In adults, the enhanced LV filling observed in our trained subjects was indeed mainly related to their cardiac hypertrophy, since neither LV relaxation properties, nor LV filling patterns accounted for differences in LV filling. In endurance-trained children, the LV morphological response to training was specific compared to that of adults, and included a moderate increase in LV end-diastolic diameter without changes in LV septal and posterior wall thickness. In children, LV relaxation properties were improved in the trained group, and correlated with LV internal diameter and SV, indicating that they played a major role in the increase in LV filling. However, in child cyclists, we could not exclude that LV filling was also improved by increased preload due to plasma expansion, but this hypothesis needs further investigation since effect of endurance training on blood volume has never been investigated in children.

References
Caso PA, D'Andrea M (2000). Am J Cardiol. 85:1131-1136
Nagueh SF, Middleton KJ (1997) J Am Coll Cardiol. 30:1527-1533.
Obert P, Mandigout S. (2001) Int J Sports Med. 22:90-96.
Schmidt-Trucksass A, Schmid A. (2001) Med Sci Sports Exerc. 33:189-195

THE REPRODUCIBILITY OF BLOOD PRESSURE FOLLOWING MAXIMAL EXERCISE IN 9-10 YEAR OLD CHILDREN

***Middlebrooke Andrew*[1]*, Armstrong Neil*[2]*, Ball Claire*[1]*, MacLeod Kenneth*[1] *and Shore Angela*[1]**

[1] *Peninsula Medical School, Exeter, UK*
[2] *Children's Health and Exercise Research Centre, University of Exeter, Exeter, UK*

Keywords: blood pressure, reproducibility, exercise

Introduction
An exaggerated increase in systolic blood pressure in response to acute exercise has been shown to be a stronger predictor of the future development of hypertension[1], stroke[2] and cardiovascular events[3] than resting measures of blood pressure and is an independent predictor of mortality[4]. An early prediction of increased cardiovascular risk in children is extremely attractive, however there is a lack of evidence regarding the reproducibility of blood pressure measurements during exercise in children. Therefore, the aim of the present study was to determine the reproducibility of the blood pressure response to maximal exercise in 9-10 year old children.

Methods
Ten healthy children (5 boys and 5 girls) were recruited from a

local Exeter school (age 9.9 ± 0.3y; body mass 37.1 ± 8.8kg; stature 1.39 ±0.07m). Systolic and diastolic blood pressure (Phase IV) were measured using a manual mercury sphygmomanometer (Dekamet Mk3, Accoson Ltd, U.K.) and stethoscope (Litmann Class II S.E., 3M Healthcare, Germany) at the site of the brachial artery at rest, immediately before and after a continuous incremental exercise test to exhaustion on a cycle ergometer (Lode Excalibur, Groningen, Netherlands) on three separate occasions. Respiratory gases were measured on a breath-by-breath basis throughout the test using an online mass spectrometer (Morgan Medical EX-670, Morgan Medical, Guildford, U.K.) and averaged over 15 seconds for analysis. Heart rate was measured continuously using a 12-lead electrocardiogram system integrated with the mass spectrometer (PC-ECG1200, Norav Medical Ltd. Israel). The subject was judged to have attained peak VO_2 when two of the following criteria had been satisfied; 1) heart rate within 10 $b.min^{-1}$ of age-predicted maximum heart rate; 2) respiratory exchange ratio greater than 1.0; 3) a plateau of VO_2 values.

Results
A repeated measures analysis of variance demonstrated that there was no significant difference in systolic or diastolic blood pressure over the three test occasions, at rest, pre-exercise and post-maximal exercise (Table 1). There was no significant difference in the change in blood pressure from rest to post-maximal exercise over the three test occasions (delta systolic: 36±11 v 30±11 v 33±10mmHg, p=0.481, delta diastolic: 7±10 v -1±12 v 9±6mmHg, p=0.1). The mean within-subject coefficient of variation over the three trials for systolic blood pressure post-maximal exercise was 3.4% and for diastolic blood pressure was 9.3%. There was no significant difference in peak VO_2 between the three test occasions (Table 1).

Parameter	Test 1	Test 2	Test 3	p-value
Systolic Rest	96 ± 7	98 ± 8	98 ± 7	0.81
Diastolic Rest	53 ± 9	56 ± 7	49 ± 6	0.12
Systolic Pre-exercise	99 ± 9	98 ± 7	98 ± 6	0.91
Diastolic Pre-exercise	59 ± 8	57 ± 7	55 ± 8	0.56
Systolic Post-maximal exercise	133 ± 12	128 ± 12	131 ± 15	0.79
Diastolic Post-maximal exercise	60 ± 7	55 ± 9	57 ± 5	0.33
Peak $\dot{V}O_2$ ($L.min^{-1}$)	1.39 ± 0.26	1.38 ± 0.29	1.42 ± 0.30	0.96

Table 1. Systolic and diastolic blood pressure response at rest, pre-exercise and post-maximal exercise and peak VO_2 over three test occasions.

Discussion/Conclusion
These data suggest that systolic and diastolic blood pressure at rest, pre-exercise and following maximal exercise are reproducible measures in 9-10 year old children. This is in contrast to a previous finding in adults[5]. If associations between the blood pressure response to exercise and cardiovascular events in adults are common to children[6], the blood pressure response to exercise could potentially be used as a non-invasive marker of cardiovascular risk at an early age.

References
1. Miyai N et al. (2000). J Am Coll Cardiol 36(5): 1626-31
2. Kurl S et al. (2001). Stroke 32(9): 2036-41
3. Moan A et al. (1995). Am J Hypertens 8: 268-275
4. Mundal R et al. (1994). Hypertension 24(1): 56-62
5. Sharabi Y et al. (2001). Am Heart J 141(6): 1014-7
6. Kavey RW et al. (1997). Am Heart J 133(2): 162-8

FITNESS, FATNESS AND FAT DISTRIBUTION DURING ADOLESCENCE AND LARGE ARTERY PROPERTIES IN ADULTHOOD. A PROSPECTIVE ANALYSIS WITHIN THE AMSTERDAM GROWTH AND HEALTH LONGITUDINAL STUDY

Ferreira I, Twisk JWR, van Mechelen W, Kemper HCG, Stehouwer CDA

Institute for Research in Extramural Medicine (EMGO) - VU University Medical Center, The Netherlands

Keywords: cardiopulmonary fitness, body composition, arterial properties

Low cardiopulmonary fitness (VO_{2max}), excessive body fatness and a central pattern of fat accumulation are major risk factors for cardiovascular morbidity and mortality. However, little is known to what extent this is related to the effects of cardiopulmonary fitness and body fatness/fat distribution on atherosclerosis and arterial stiffness, the underlying mechanisms of cardiovascular impairment and mortality. Moreover, the time course of these relationships needs to be elucidated. We therefore investigated the prospective relationship between levels of fitness, fatness and fat distribution during adolescence (13-16 years) on the one hand, and indicators of pre-clinical atherosclerosis (i.e. carotid intima-media thickness - IMT) and large artery stiffness (i.e. distensibility and compliance coefficients), at the age of 36, on the other.
Arterial properties were assessed by non-invasive ultrasound imaging. VO_{2max} was measured with a maximal running text on a treadmill with direct measurements of oxygen uptake. The sum of 4 skinfolds (ΣSKF) was used as an estimate of total body fatness, and the ratio between the subscapular+suprailiac and the ΣSKF (SS/ΣSKF) as an estimate of central fat accumulation. Analyses consisted of 159 subjects (84 girls) and data were analysed with multiple linear regression models.
After adjustment for smoking status, alcohol and nutrients intake, physical activity, biological age and current height, adolescent VO_{2max} were inversely associated with carotid IMT at age 36 (β=-0.32, p=0.03), in men. Adolescent ΣSKF and SS/ΣSKF were positively associated with carotid IMT at age 36 (β =0.32, p<0.01 and β =0.24, p=0.07), the latter in men only. As far as arterial stiffness is concerned, only SS/ΣSKF during adolescence was inversely associated with distensibility (β =-0.14, p=0.07) and compliance (β =-0.19, p=0.01) of the carotid artery. Further mutual adjustments of these relationships for VO_{2max}, ΣSKF and SS/ΣSKF, and other risk factors (cholesterol, blood pressure and resting heart rate) did not change the strength of these associations.
We concluded that low cardiopulmonary fitness, excess body fatness and in particular a central pattern of fat accumulation during adolescence may me critical for the onset of atherosclerosis and arterial stiffness later in life. Therefore promotion of a more active lifestyle starting already during adolescence may be an important tool for the primary prevention of cardiovascular disease.

COMPOSITION AND DENSITY OF FAT-FREE MASS IN ADOLESCENT ATHLETES BASED ON A FIVE-COMPONENT MOLECULAR MODEL OF BODY COMPOSITION: COMPARISON WITH LOHMAN'S AGE-ADJUSTED MODELS

Sardinha Luís B, Silva Analiza M, Minderico Claudia

Exercise and Health Laboratory, Faculty of Human Movement, Technical University of Lisbon, Portugal

Keywords: body composition, athletes, fat-free mass

Introduction

Estimates of body composition are used to assess nutritional status, disease risk, and physical fitness and to separate the body mass into metabolically active and inactive components [1]. In athletes, body composition measures are widely used to prescribe desirable body weights, to optimize competitive performance, and to assess the effects of training [2]. In addiction, there is an increased recognition of the need to measure body composition during growth and puberty, as preadolescent and adolescent years are a period of a rapid growth in the body fat and non-fat compartments.

Traditional indirect methods for evaluating body composition in humans, such as densitometry, hydrometry, and ^{40}k spectrometry, are based on a two-component model in which it is assumed that the body consists of fat and fat-free components [3]. For example, densitometry assumes that body mass consists of a fat mass component with a density of 0.9007 g/cm^3 and a fat-free mass (FFM) component with a density of 1.100 g/cc [4]. The FFM is assumed to be composed of 73.8% water with a density of 0.9937 g/cc, 6.8% mineral with a density of 3.038 g/cc, and 19.4% protein with a density of 1.34 g/cc [5]. However, these assumptions may not be the most accurate in children and adolescents because of the potential changes in the various inherent assumptions of the 2C model during growth and maturation, such as changes in the hydration and the density of FFM [6]. In order to overcome these methodological limitations, Lohman [6] developed age- and sex-specific constants to convert body density into body fat (BF) in children, based on the existing data in children from birth to 10 years of age [7] and the FFM composition of growing adolescents [7-9]. Even though this theoretical approach seems to improve the accuracy of BF prediction in children, it does not address the issue related with body composition changes, namely FFM density and respective fractions of water, protein, and mineral during growth and maturation in athletes.

Multi-compartment models such as the three-compartment (3C), 4C, and the recently 5C molecular model [10], take into account interindividual variability in the composition of FFM. The 5C molecular model divides body weight into fat, water, bone mineral, soft tissue mineral, and protein, and fewer assumptions are considered in the composition of FFM by accounting for variations in body water and mineral, which are among the most variable components of FFM [11,12]. Regarding the recognized chemical immaturity in growing children, Wells et al. [13], have used a 4C molecular model as the "gold standard" through which interindividual variability in the density and hydration of FFM was evaluated, indicating that FFM density was significantly lower and hydration higher, than the adult assumptions. Studies on some small groups of adults bodybuilders athletes [14,15], male football players and female swimmers have found systematic differences between estimates of %BF based on a 4C model and estimates from body density [16], indicating that FFM density was different than 1.100 g/cc, whereas studies with athletes involved in other sports have not [16-19].

Considering the inconsistence data on FFM density and composition in athletes and the required studies on an athletic population during growth and maturation, the purpose of the present study was twofold: to determine estimates of body composition from a 5C model in which body density, water, bone mineral, and soft tissue mineral were estimated in order to analyse FFM composition and its implications on FFM density, and to determine whether Lohman's [6] age- and sex-specific values for FFM density and composition are appropriate for adolescent athletes.

Methods

Sample

A total of 32 girls and 45 boys, Caucasian, pubescent and post-pubescent, volunteered for the study. Subjects were recruited from several sports clubs and were involved in a variety of sports (e.g. swimming, basketball, gymnastic, rugby and judo). According to the regulations of the Ethical Committee of the Faculty of Human Movement, Technical University of Lisbon, all subjects were informed about the research design and signed a consent form. All measurements were obtained with subjects fasted overnight (≥ 12 h).

Maturation

Subjects were grouped by puberty stage of development, determined by self-assessment according to Tanner [20] stage and adapted by Ross and Marfell-Jones [21]. A self-evaluation method, with figures, was used to identify the degree of development of the genital organs, breast and pubic pilosity.

Measurements of body composition

Measures of body volume assessed by air displacement plethysmography, bone mineral content by dual-energy x-ray absorptiometry (DXA) and total body water by deuterium dilution were used to estimate %BF. Briefly, body volume was estimated using the BOD POD® (Life Measurement Instruments, Concord, CA) as described elsewhere [22,23]. Bone mineral content was obtained by DXA (QDR-1500; Hologic, Waltham, MA) from the whole body scans and converted to total body bone mineral (as bone mineral content represents ashed bone) by multiplying it by 1.0436 [24]. Total body water (TBW) was assessed by the deuterium dilution technique using an isotope ratio mass spectrometer (PDZ, Europa Scientific, UK). After a completed 12 h fast, an initial urine sample was collected and immediately administrated a deuterium oxide solution dose (^2H_2O) of 0.1g/kg of body weight diluted in 150 mL of water. After a 4h period new urine sample was collected. Urine was prepared for $^1H/^2H$ analysis using the equilibration technique of Prosser and Scrimgeour [25]. The enrichments of equilibrated local water standards were calibrated against SMOW (Standard Mean Ocean Water). Based on delta SMOW, total body water was estimated by Schoeller et al. [26] method, including a 4% correction due to the recognized amount corresponding to deuterium dilution in other compartments.

The Wang et. al. 5C molecular model [10], was used as the reference method to estimate BF. Accordingly, BF was assessed with the following equation:

$$BF\ (kg) = 2.748xBV - 0.715xTBW + 1.129xMo + 1.222xMs - 2.051xBM$$

where BV is body volume (L), TBW is total body water (kg), Mo is total-body bone mineral (kg), Ms is total-body soft tissue mineral (kg) and BM is body mass (kg).

Statistical Analysis
Comparison of means was performed with a paired t-test. Considering that FFM density and respective water, protein and bone mineral fractions are age-dependent in Lohman's models, a one-sample t-test was used to assess if the differences between the selected variables from Lohman's models and the 5C model were different from zero at any given age. Statistical significance was set as $p < 0.05$. The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS inc., version 10.0, Chicago, IL).

Results
Table 1 depicts the means and standard deviations values of FFM density and composition, namely water, bone mineral, soft tissue mineral and protein.

Table 1 – Means and standard deviations values for the selected variables.

	Boys (n=45)	Girls (n=32)
	Mean ± SD	Mean ± SD
Age (y)	15.4 ± 1.1	15.1 ± 0.3
Weight (kg)	71.7 ± 12.4	56.2 ± 14.2
Stature (m)	1.80 ± 0.12	1.65 ± 0.13
BMI (kg/m²)	22.0 ± 2.6	20.2 ± 2.6
$FFM_{density}$ (g/cc)	1.100 ± 0.007	1.105 ± 0.004
Water/FFM (%)	72.4 ± 1.7²	70.9 ± 1.2²
Total Body Mineral/FFM (%)	6.1 ± 0.5²	6.3 ± 0.7²
Bone Mineral/FFM (%)	5.2 ± 0.5	5.4 ± 0.7
Soft tissue Mineral/FFM (%)	0.93 ± 0.02	0.92 ± 0.02
Protein/FFM (%)	21.5 ± 1.5²	22.8 ± 1.6²

¹ *Differences between FFM density estimated by the 5C model and by Lohman's age-adjusted values (p<0.001)*
² *Differences between FFM composition estimated by the 5C model and by Lohman's age-adjusted values (p<0.001)*

Differences between FFM hydration were different (p<0.05) in boys and girls (1.88 vs. 4.28%), respectively. Differences between FFM mineralization (0.33 vs. 0.33 %), and FFM residual/protein fraction (2.21 vs. 3.96 %) were also different (p<0.05) in boys and girls, respectively. Finally, FFM density was higher than Lohman's age-adjusted models [6] and differed (p<0.05) by 0.004 and 0.012 g/cc, in boys and girls, respectively. FFM density was underestimated (p<0.05) by Lohman's models [6], due to the lower water fraction and the higher residual/protein fraction, which has an assumed greater density than water (1.34 vs. 0.994 g/cc). The molecular composition of the FFM, water, total body mineral, and protein differed from Lohman's age-adjusted constants [6]. The implications of the FFM density and composition on %BF are shown in Figure 2.

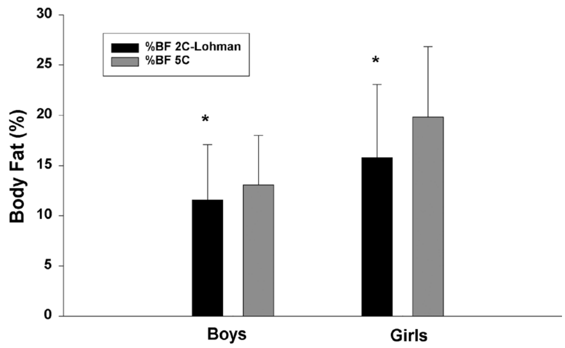


*Figure 1 – For boys and girls, means and standard deviations values of %BF estimated by the 5C model and $\%BF_{2C\text{-}Lohman}$. *p<0.001*

In boys, using Lohman's age-adjusted models [6] and the 5C molecular model yielded different (p<0.001) %BF values (11.6 ± 5.5 vs 13.1 ± 4.9). Similar differences were found in girls when these two models were used (15.8 ± 7.3 vs 19.8 ± 7.0). Therefore, as indicated in Figure 1, %BF was underestimated in relation to the reference 5C model when Lohman's age-adjusted models [6]were used in both genders.

Discussion/Conclusion
There is little information regarding exercise effects on FFM density and respective compartments as, so far, few studies have defined the variability in FFM density among different athletic groups [14-19]. In addiction these few studies were conducted in adult athletes and presented controversial results. The present data represents the first estimated values for FFM composition and density in adolescent athletes using a robust 5C model. The mean values for boys matched closely to the adults assumed FFM density (1.100 g/cc), but the mean values for the female young athletes were significantly greater, though the composition of the FFM in each of these groups differed somewhat from the assumed values (73.8% for water/FFM; 6.8% for mineral/FFM and 19.4% for protein/FFM) [5]. Conversely, FFM density from the present data was higher than the results obtained on non-athlete prepubescent children evaluated with a 4C molecular model in the study of Wells et al. [13] (1.102 ± 0.006 vs. 1.086 ± 0.007). Concerning the higher FFM density presented in the female adolescent sample, similar results were found in the female adult gymnasts from the study of Prior et al. [16], whereas female adults swimmers from the referred study had a significantly less FFM density than 1.100 g/cc. It is important to note that in the present work, fourteen girls were gymnasts, fourteen were basketball players and the remained four were swimmers and judo athletes. In line with the general findings of the current study, Penn et al. [17], Withers et al. [18], and Arngrímsson et al [19] using a sample of male and female runners showed that no differences were found between FFM density and the assumed value 1.100 g/cc. On the other hand, Modlesky et al. [14] and Withers et al. [15] using a sample with male bodybuilders, concluded that increased muscle development in the athletes may further decrease FFM density, primarily due to the higher water fraction and secondarily to the lower mineral and protein fractions of the FFM than the values found in men with average muscu-

loskeletal development. According to these studies, skeletal muscle hypertrophy appears to increase disproportionately the water fraction of the FFM, which dilutes the mineral and protein fractions [14]. As suggested by Prior et al. [16], these findings indicate that the FFM density may be higher or lower than the assumed values for adults and that generalization across athletes in different sports is not appropriate.

Concerning the use of the age-adjusted constants for changes in the composition and density of FFM developed by Lohman [6], lower values for FFM density were obtained compared with the FFM composition and density obtained by the reference method. The inability to reproduce Lohman's models [6] indicates that the values for the density of FFM were not appropriate for young athletes. These differences may be explained by the fact that the water fraction in the current study was lower and total mineral (bone mineral plus soft tissue mineral) and protein fractions were higher when compared with the Lohman's age-adjusted values [6]. Consequently, the relative contribution of the protein and mineral fractions, which have a higher density than water (respectively, 1.34 g/cc and 2.982 g/cc *vs.* 0.9937 g/cc) may justify the higher FFM density found in the present study compared with Lohman's age-adjusted constants [6] for both genders. Moreover, these findings may justify the significant underestimation of %BF when body density from Lohman's 2C model [6] was used.

In conclusion, these results suggest that some caution should be taken when using Lohman's age-adjusted models [6], which were developed on a sample of non-athlete children and adolescents, to estimate FFM composition in athletes during growth and maturation. Furthermore, more research is needed with young athletes performing specific sports to determine whether FFM density is affected by muscularity or musculoskeletal development. Since assumed constants, as well as FFM hydration, are the cornerstones of several body composition methods, further study is needed to identify relatively constant relationships between FFM components at any given age in growing athletes.

References

1. Forbes, G.B. (1987) Human body composition: Growth, aging, nutrition, and activity., Springer-Verlag
2. Sinning, W.E. (1996) Body composition in athletes. In Human Body Composition (Roche, A.F. et al., eds.), pp. 257-274, Human Kinetics Publishers
3. Siri, W.E., ed. (1961) Body composition from fluid spaces and density: Analysis of method, National Academy of Sciences
4. Going, S.B. (1996) Densitometry. In Human body composition (Roche, A.F. et al., eds.), pp. 3-23, Human Kinetics Publishers
5. Brozek, J., Grande, F.& Anderson, J.T. (1963) Densitometry analysis of body composition: Revision of some quantitative assumptions. Annals of the New York Academy of Sciences 110, 113-140
6. Lohman, T. (1989) Assessment of body composition in children. Pediatr. Exerc. Sci. 1, 19-30
7. Fomom, S.J. et al. (1982) Body composition of reference children from birth to age 10 years. Am J Clin Nutr 35 (5 Suppl), 1169-1175.
8. Haschke, F. (1983) Body composition of adolescent males. Acta Paediatr Scand (307 (suppl)), 1-20
9. Boileau, R.A. et al. (1984) Hydration of the fat-free body in children during maturation. Hum Biol 56 (4), 651-666.
10. Wang, Z. et al. (2002) Multicomponent methods: evaluation of new and traditional soft tissue mineral models by in vivo neutron activation analysis. Am J Clin Nutr 76 (5), 968-974
11. Bakker, H.K. and Struikenkamp, R.S. (1977) Biological variability and lean body mass estimates. Hum Biol 49 (2), 187-202
12. Lohman, T.G. (1992) Advances in body composition assessment, Human Kinetics Publishers
13. Wells, J.C. et al. (1999) Four-component model of body composition in children: density and hydration of fat-free mass and comparison with simpler models. Am J Clin Nutr 69 (5), 904-912.
14. Modlesky, C.M. et al. (1996) Density of the fat-free mass and estimates of body composition in male weight trainers. Journal of Applied Physiology 80 (6), 2085-2096
15. Withers, R.T. et al. (1997) Body composition changes in elite male bodybuilders during preparation for competition. Aust J Sci Med Sport 29 (1), 11-16
16. Prior, B.M. et al. (2001) Muscularity and the density of the fat-free mass in athletes. J Appl Physiol 90 (4), 1523-1531
17. Penn, I.W. et al. (1994) Body composition and two-compartment model assumptions in male long distance runners. Med Sci Sports Exerc 26 (3), 392-397
18. Withers, R.T. et al. (1998) Comparisons of two-, three-, and four-compartment models of body composition analysis in men and women. J Appl Physiol 85 (1), 238-245
19. Arngrimsson, S. et al. (2000) Validation of body composition estimates in male and female distance runners using estimates from a four-component model. Am J Human Biol 12 (3), 301-314
20. Tanner, J.M. (1962) Growth and adolescence, Blackwell Scientific
21. Ross, W.D. and Marfell-Jones, M.J. (1991) Kinanthropometry. In Phsysiological testing of the high-performance athlete (MacDougall, J.D. et al., eds.), pp. 224-305, Human Kinetics Publishers
22. Dempster, P. and Aitkens, S. (1995) A new air displacement method for the determination of human body composition. Med Sci Sports Exerc 27 (12), 1692-1697
23. McCrory, M.A. et al. (1995) Evaluation of a new air displacement plethysmograph for measuring human body composition. Med Sci Sports Exerc 27 (12), 1686-1691
24. Heymsfield, S.B. et al. (1990) Body composition of humans: comparison of two improved four-compartment models that differ in expense, technical complexity, and radiation exposure. Am J Clin Nutr 52 (1), 52-58.
25. Prosser, S.J. and Scrimgeour, C.M. (1995) High-Precision Determination of $^2H/^1H$ *in* H_2 *and* H_2O *by Continuous-Flow Isotope Ratio Mass Spectrometry. Anal Chem 67 (13(1)), 1992-1997*
26. Schoeller, D.A. et al. (1980) Total body water measurement in humans with ^{18}O *and* ^2H *labeled water. Am J Clin Nutr 33, 2686-2693*

BODY COMPOSITION AND CARDIORESPIRATORY FITNESS IN CHILDREN AND ADOLESCENTS

Santa-Clara Helena, Ornelas Rui, Sardinha Luís B

Exercise and Health Laboratory, Faculty of Human Movement, Technical University of Lisbon, Portugal

Keywords: body composition; cardiorespiratory fitness; children; adolescents

Introduction

The peak VO_2 of children and adolescents has been well documented and, data demonstrate a progressive, linear increase in peak VO_2 with chronological age in both genders. Mean value for

VO_{2peak} increase from about 1.0 L/min at age 6 years in all children to 2.0 and 2.8 L/min for girls and boys, respectively, at 15 years of age, and mean values for boys exceed those of girls at all ages (Rowland, 1996). When VO_{2peak} is expressed relative to body mass, with age different patterns of change occurs. However, using a log-linear scaling model, Armstrong et al. (1998) had demonstrated in 12-yr-old boys and girls a significant effect of maturation on peak VO_2 independent of body mass. More than total body mass, differences in body composition may partially explain gender differences in weight relative VO_{2max}, since males have a greater lean body mass than girls even before puberty (Rowland, 1996). Several studies have demonstrated gender differences at all ages when VO_{2max} values are related to lean body mass with the greater values to the boys (Anderson et al., 1974; Kemper et al., 1989; Rutenfranz et al., 1981). This study was designed to analyse the influence of total lean mass (TLM) and leg lean mass (LLM) on relative expression of peak oxygen uptake (VO_{2peak}) in healthy Portuguese children and adolescents.

Methods

Children were 445 (212 girls - 9.7±0.32 yrs; and 234 boys - 9.7±0.33 yrs), and adolescents were 120 (58 girls - 15.7±0.3 yrs; and 62 boys - 15.6±0.3 yrs). Cardiorespiratory fitness, defined as maximal power output per kilogram ($W_{max} \cdot kg^{-1}$), was assessed in a cycle ergometer test. The subjects performed a maximal graded exercise test on an electronically braked cycle ergometer. Initial and incremental workloads were 20 W for children weighing less than 30 kg and 25 W for children weighing 30 kg or more. For adolescent girls and boys the initial and incremental workloads were 40 W and 50 W, respectively. The workload increased every 3 minutes. Heart rate was controlled continuously (Polar Vantage, Finland) throughout the test until subject could no longer continue, and the criteria defined for maximal effort was heart rate ≥ 185 beat per minute. The cycle ergometer was electronically calibrated once every test day and mechanically calibrated after being moved. The equation (12*Wmax+5*weight)/weight was used to estimate VO_{2peak} relative to the weight of total body mass, TLM and LLM. Total body scans were performed by dual-energy x-ray absorptiometry (DXA) and analysed using an extended analysis program for body composition (model QDR-1500 Hologic, pencil beam, software version 5.67), to determinate total body mass, TLM and LLM. The same technician positioned the subjects, performed the scans, and completed the scan analysis according to the operator's manual using the standard analysis protocol. Quality assurance tests were performed each morning of assessment. Descriptive statistics were used for presentation of the data. Group differences were assessed by two-way analysis of variance (ANOVA). Statistical significance was set at $p<0.05$.

Results

Subject's physical characteristics and peak exercise data are presented in Table 1. Boys had higher values of TLM and LLM ($p<0.001$) than girls in all ages. In children, no differences were found between boys and girls in stature and total body mass. Adolescents boys were taller ($p<0.001$) and heavier ($p<0.01$) than girls. As compared with children, adolescents boys and girls had higher values of total body mass, lean mass and legs mass ($p<0.001$).

Table 1. Mean values of studied variables

	Girls		Boys	
	Children n = 212	Adolescents n = 58	Children n = 233	Adolescents n = 62
Age (years)	9.7 ± 0.3	15.7 ± 0.3*	9.7 ± 0.3	15.6 ± 0.3*
Stature (cm)	137.1 ± 6.4	160.3 ± 5.7*	137.0 ± 7.0	169.6 ± 7.5*#
Total body mass (kg)	34.1 ± 8.3	55.8 ± 8.4*	34.1 ± 8.0	60.7 ± 10.7*#
Total lean mass (kg)	23.1 ± 3.0	36.8 ± 4.0*	25.2 ± 2.9**	49.7 ± 7.7*#
Total legs mass (kg)	7.0 ± 1.1	11.1 ± 1.6*	7.6 ± 1.1**	16.5 ± 2.9*#
Maximal power(watts)	89.8 ± 14.8	150.4 ± 24.3*	99.2 ± 20.1	233.9 ± 43.2*#
VO_{2peak} $mL \cdot kg^{-1} \cdot min^{-1}$	37.7 ± 6.6	38.0 ± 6.7*	43.9 ± 7.8**	54.0 ± 7.4*#
VO_{2peak} $mL \cdot kgTLM^{-1} \cdot min^{-1}$	54.2 ± 6.3	56.9 ± 7.1*	58.1 ± 7.9**	65.3 ± 6.4*#
VO_{2peak} $mL \cdot kgLLM^{-1} \cdot min^{-1}$	181.1 ± 23.3	190.1 ± 27.5*	194.0 ± 27.6**	196.9 ± 19.8*#

*Values are mean ± SD. VO_{2peak} peak oxygen uptake; TLM, total lean mass, LLM, legs lean mass. * adolescents had higher values than children in both genders ($p<0.05$).** children: boys had higher values than girls ($p<0.001$). # adolescents: boys hah higher values than girls ($p<0.01$).*

Maximal power (watts), VO_{2peak} relative to total body mass, TLM and LLM were different ($p<0.05$) between children and adolescents and between both genders ($p<0.001$). The difference between children and adolescent boys was 23%, 12%, and 2% when VO_{2peak} was expressed relative to total body mass (43.94±7.84 *vs.*53.95±7.36 mL/kg/min $p<0.001$), TLM (58.11±7.94 *vs.*65.29±6.41 mL /kg of TLM/min, $p<0.001$) and LLM (194.03±27.55 *vs.*196.85±19.75 mL/kg of LLM/min, $p<0.05$), respectively. In girls the differences between children and adolescents for the same variables were 1% (37.72± 6.59 *vs.* 37.96± 6.73 mL/kg/min, $p<0.01$), 5% (54.16±6.29 *vs.* 56.87±7.12 mL /kg of TLM/min, $p<0.01$), and 5% (181.08±23.33 *vs.* 190.06±27.53 mL/kg of LLM/min, $p<0.05$). Cardiorespiratory differences between children and adolescent boys tend to decrease when total and regional functional mass such as TLM and LLM were considered. These results suggest that, differences in cardiorespiratory fitness between boys and girls during growth and development are largely dependent on TLM and LLM. Since differences in cardiorespiratory fitness between girls and boys were diminished relative to LLM, these data emphasize that differences in cardiovascular fitness between boys and girls were largely attributable to differences in body composition.

References

Andersen KL, Seliger V, Rutenfranz J, Mocelin R (1974). Eur J Appl Physiol 33:177-195

Armstrong N, Welsman JR, Kirby BJ (1998). Med Sci Sports Exerc 30: 165-169

Kemper HC, Verschuur R, De Mey L (1989). Pediatr Exerc Science 1: 257-270

Rowland TW (1996). Developmental exercise physiology

Rutenfranz F, Andersen KL, Seliger V, Klimmer F, Berndt I, Ruppel M (1981). Eur J Pediatr 136:123-133

IMPACT OF OBESITY AND DOWN SYNDROME ON MAXIMAL HEART RATE AND WORK CAPACITY IN YOUTH WITH MENTAL RETARDATION

***Fernhall Bo*[1]*, Pitetti Ken*[2]*, Guerra Myriam*[3]**

[1] *Exercise Science Department, Syracuse University, Syracuse, NY, USA*

[2] *Physical Therapy Department, Wichita State University, Wichita, KS, USA*

[3] *Physical Activity and Sports Sciences, Fundació Blanquerna, University Ramon Llull, Barcelona, Spain*

Keywords: heart rate, obesity, Down syndrome

Introduction

Individuals with mental retardation (MR) have low physical work capacity and thus low aerobic capacity, regardless of the form of testing (5). Both laboratory and field based studies show that physical work capacity is reduced in this population (1,3,5). The cause of the low levels of physical work capacity in individuals with MR is not clear. It has been suggested that low levels of motivation and task understanding influences the ability of persons with MR to perform, limiting their ability to produce true maximal effort (4). However, recent information suggests this is not case, and work capacity is reduced in persons with MR despite valid and reliable maximal efforts (5). Instead it is suggested that physical work capacity may be reduced because of low levels of physical activity, high incidence of obesity, low levels of leg strength and low maximal heart rates (5,7).

Individuals with Down syndrome (DS) have even lower levels of physical work capacity than their peers with MR without DS (2,5,8,14). Although there are many physiological perturbations associated with DS, it is frequently suggested that individuals with DS have low levels of physical work capacity because of a high incidence of obesity and low levels of physical activity (5,8). However, Fernhall et al, (2) have shown that a reduction in maximal heart rate is a major contributor to reduced physical work capacity in individuals with DS. Guerra et al, (14) recently showed that the low maximal heart rates in persons with DS are due to chronotropic incompetence which is physiologically based, probably as a result of altered autonomic function (13).

Obesity lowers physical work capacity in both children and adults without disabilities (11,15), as well as in children and adults with MR (1,6). This appears to be the case in individuals both with and without DS (2,6). In addition to lowering physical work capacity, obesity is associated with lower than normal maximal heart rates in non-disabled adults (11,12). Therefore, predicting maximal heart rate is less accurate in obese individuals, and the reduction in maximal heart rate can also contribute to the reduced work capacity, because of a reduction in cardiac output (5). However, it is unknown if obesity is associated with lower than normal maximal heart rates in children, particularly in children with MR, with or without DS. It is possible that maximal heart rate would also be lower in obese children with MR (with or without DS), and thus associated with lower physical work capacity. Since obesity is more prevalent in children with MR, especially in children with DS, this may be a larger problem in children with MR compared to their non-disabled counterparts. However, it is unknown if obesity alters maximal heart rates in children with MR, with our without DS. Since obesity is related to autonomic dysfunction (related to low maximal heart rates in non-disabled obese individuals(10), and adults with DS often exhibit autonomic dysfunction (13), it is possible that obesity may exacerbate the reduction in maximal heart rate in youth with DS, further reducing their work capacity. Because of the large potential impact of obesity and low maximal heart rate in this population, the purpose of this study was to evaluate the impact of obesity on maximal heart rate and physical work capacity in youth MR, both with and without DS.

Methods

Subjects

We recruited 89 subjects with DS. Of those, 47 were classified as obese (OB) and 42 were classified as non-obese (NOB). Their mean age was 14.5 years, mean height was 147, 5 cm and mean body weight was 53.9 kg. We also recruited 84 subjects with MR, but without DS, of which 22 were classified as OB and 62 were classified as NOB. Obesity was classified as a BMI of 25 or above. The BMI was similar between groups with (OB=28.9; NOB=20.2) and without DS (OB=28.6; NOB=19.2). Subjects were recruited from local organizations and schools, and all subjects lived at home with their parents or guardians. All subjects were classified with mild MR according to established criteria and all subjects with DS had been diagnosed with Down syndrome. All subjects were healthy, none were taking any medication which could affect heart rate or cardiovascular function, and none of the subjects with DS had congenital heart disease.

Protocol

Subjects were familiarized with the laboratory and the testing protocol prior to any data collection. The number of familiarization visits varied depending on the subject. Data collection commenced when subjects could comfortably walk on the treadmill with the mouthpiece and nose clip. We employed an individualized walking protocol, starting at a comfortable walking pace for each subject. Speed was increased until subjects walked at a fast waling pace, whereafter speed was maintained constant and grade was increased. During the last 1-2 minutes of the test, if possible, speed was again increased to bring the subjects to a jog. Metabolic data were collected using a metabolic cart (calibrated prior to each test) and heart rates were collected using a heart rate monitor. Tests were stopped when subjects could no longer keep up with the treadmill speed.

Statistics

Means and standard deviations were calculated for each variable. Group comparisons were made using a 2x2 ANOVA (DS vs no DS by OB vs NOB). To evaluate the potential impact of maximal heart rate on aerobic capacity, we used a 2x2 ANCOVA, with maximal heart rate as a covariate. Statistical significance was set at $p<.05$ for all comparisons.

Results

Age was not different between any of the groups, but BMI was higher in the OB groups ($p<.05$). The impact of obesity on maximal heart rate is shown in figure 1 below. Subjects with DS exhibited lower maximal heart rates in general and there was no difference between OB and NOB groups with DS. Obese subjects with MR without DS exhibited significantly lower maximal heart rates compared to their NOB peers ($p<.05$). Aerobic capacity was lower ($p<.05$) in the OB groups and in subjects with DS (figure 2). Controlling for maximal heart rate equalized aerobic capacity in the group with DS but not in the group without DS.

Discussion

The main finding of this study was that obese youth with MR, but without DS, have lower maximal heart rate than normal weight youth with MR without DS. Conversely, obese youth with DS exhibited similar maximal heart rate as the normal weight youth with DS, showing that obesity differentially

affects maximal heart rate in youth with MR with and without DS. Furthermore, aerobic capacity was higher in normal youth, regardless of presence or absence of DS, showing that obesity is associated with lower aerobic capacity in youth with MR.
It is not surprising that obesity lowers aerobic capacity expressed relative to body weight. This has been shown in many studies of non-disabled individuals (11,12,15) and it has also been shown in children and adolescents with MR (1). Although other methods of normalizing aerobic capacity may suggest less negative influence of obesity, from a practical perspective, obese individuals still need to move their entire body weight. Consequently, obesity negatively impacts aerobic capacity in persons with MR, consistent with data on both children and adults without MR.
Several studies have shown that individuals with MR exhibit lower maximal heart rates than non-disabled individuals (1,2,5,7), but most of these studies have been done on adult populations. Recent data (6) show smaller differences in maximal heart rate between children with MR and their non-disabled peers. Our current data are in agreement with these findings, as the normal weight youth with MR (without DS) in this study exhibited close to normal maximal heart rates. Interestingly, the obese youth with MR (without DS) exhibited significant reductions in maximal heart rate, consistent in magnitude with other reports (5). This may suggest that previous studies of individuals with MR may have included many obese subjects, artificially skewing the data, and providing lower than expected maximal heart rates. Studies on maximal heart rate in adult, obese non-disabled individuals show maximal heart rates are between 10-15 beets lower than expected (11,12), which is similar to the magnitude of the difference observed compared to expected maximal heart rates in adults with MR, without DS (5).
Youth with DS exhibited lower maximal heart rate compared to their peers without DS, consistent with many previous reports (1,2,5,7,8,9,14). Interestingly, obesity had no impact on maximal heart rate in youth with DS, as the mean heart rate was almost identical in obese and normal weight subjects. This was somewhat unexpected, and suggests that obesity impacts the cardiovascular system differently in persons with DS. Our data also suggest that DS per se affects maximal heart rate, independent of obesity. It is likely that individuals with DS have lower than expected maximal heart rates due to autonomic dysfunction as recently shown by Fernhall and Otterstetter (13). Consequently, developing strategies to combat autonomic dysfunction should be an important future consideration in this population.

References

1.Fernhall B (1997). Mental retardation. In: ACSM, ed. Exercise Management for Persons with Chronic Disease and Disability. Champaign, IL: Human Kinetics; 221-226
2.Fernhall B, Pitetti K, Rimmer JH, McCubbin JA, Rinatala P, Millar AL, Kittredge J, Burkett LN. (1996). Medicine and Science in Sports and Exercise, 28:366-371
3.Fernhall B (1993). Medicine and Science in Sports and Exercise, 25:442-450
4.Seidl L, Reid G, Montgomery DL (1987). Adapted Physical Activity Quarterly, 4:106-116
5.Fernhall B, Petitti K (2001). Clinical Exercise Physiology, 3:176-185
6.Pitetti KH, Millar AL, Fernhall B (2000). Adapted Physical Activity Quarterly, 17:322-332.
7.Fernhall B, McCubbin J, Pitetti K, Rintala P, Rimmer J, Millar AL, de Silva A (2001). Medicine and Science in Sports and Exercise, 33:1655-1660
8.Guerra M, Roman B, Geronimo C, Violan MA, Cuadrado E, Fernhall B (2000). Adapted Physical Activity Quarterly, 17:310-321
9.Guerra M, Cuadrado F, Llorens N, Fernhall B (2000). Medicine and Science in Sports and Exercise, 32:S235
10.Lauer MS, Okin PM, Larson MG, Evans JC, Levy D (1996). Circulation. 93:1520-1526
11. Hulens, M, G, Vasant, R, Lysens, L, Claessens, E. Muls. (2001). Scand. J. Med Sci Sports, 11:305-309
12.Miller, WC., Wallace, JP, Eggert, KE (1993). Med Sci Sports Exerc, 25:1007-1081
13. Fernhall, B., Otterstetter, M (2003). J. Appl. Physiol., 94:2158-2165
14.Guerra, M., Llorens, N., Fernhall, B (2003). Arch. Phys.Med. Rehabil. (In Press)
15.Rowland, T (1991). Am. J. Dis. Child. 145:764-768

EFFECTS OF TENNIS-INDUCED MECHANICAL STRAINS ON MUSCULAR AND BONE TISSUES

Ducher Gaële, Tournaire Nicolas, Prouteau Stéphanie, Jaffré Christelle, Courteix Daniel

Laboratory of Muscular Exercise Physiology, Faculty of Sport Sciences, University of Orléans and Inserm ERIT-M0101, Regional Hospital of Orléans, France

Keywords: bone mineral content, lean tissue mass, young tennis players

Introduction

Large differences in muscular mass and bone mineral content have been reported between dominant and non dominant arms in adult tennis players. These differences are attributed to the mechanical loads encountered by the dominant arm during the tennis stroke. It is assumed that the genetic, hormonal and nutritional influences are similar in both arms. Few studies have investigated the effects of unilateral loading on the arms of young tennis players (Haapasalo et al., 1998).
The aim of this study was to compare the bone mineral content and lean tissue mass of both forearms of young tennis players.

Methods

Twenty-six tennis players, aged 11.8±1.6 years, were recruited. All subjects have been playing tennis at least twice a week. They started their career at 6.5±2.1 years. Lean tissue mass (LTM, g) and bone mineral content (BMC, g) of the forearms and hands were determined by DXA. A Wilcoxon non parametric test was used to compare the measures on the dominant and non dominant arms. An analysis of covariance was used to test the influence of LTM on the forearm BMC. The LTM and BMC side-to-side differences were expressed as percentage (D%) of the non dominant value. The association between these two variables was analysed by the Spearman ranked correlation coefficient (r_{Sp}).

Results

Significant correlations ($p<0.0001$) were observed between LTM and BMC in the dominant ($r_{Sp} = 0.95$) and non-dominant forearms ($r_{Sp} = 0.90$). LTM and BMC were significantly higher in the dominant forearm ($p<0.0001$). The D% LTM was 10.4 ± 6.3 % in the dominant arm. Similarly the BMC values (19.4 ± 18%, $p<0.01$) were significantly higher in the dominant arm. When LTM was covaried, this difference was no longer significant.

Discussion
This study demonstrated greater LTM and BMC values in the dominant forearm of young tennis players, even though their training history was relatively short. Results suggest that the side-to-side difference is influenced to a great extent by the higher muscular activity and increased bone stress loading encountered in the dominant extremity during tennis play.

Reference
Haapasalo H., Kannus P., Sievanen H., Pasanen M., Uusi-Rasi K., Heinonen A., Oja P. and Vuori I. (1998). J. Bone Miner. Res. 13(2): 310-19

THE EFFECT OF STIMULANT MEDICATION ON SUBMAXIMAL EXERCISE RESPONSES IN BOYS WITH ATTENTION DEFICIT/HYPERACTIVITY DISORDER (ADHD)

Mahon Anthony D, Stephens Brooke R

Ball State University, USA

Keywords: stimulant medication, heart rate, VO_2

ADHD is characterized by inattentive, hyperactive and impulsive behaviors and is usually treated with stimulant medication. Previous studies have suggested that this type of medication may augment the typical increases in heart rate (HR) and blood pressure brought on by exercise. However, the effects of this type of medication on other physiological and perceptual responses during exercise are not well understood. Thus, this study was designed to examine the effect of stimulant medication on the physiological and perceptual responses during submaximal exercise in 12 boys (10.9 ± 1.0 yrs) with ADHD. Each child completed two exercise protocols on a cycle ergometer on separate days. On one day exercise was performed after the child was treated with his usual morning dose of medication. On the other day exercise was conducted without prior medication on the day of testing. Exercise was performed at three intensities (25W, 50W and 75W) for 3 minutes each with short rest periods interspersed. HR, VO_2, the ventilatory equivalent for VO_2 (VE/VO_2), respiratory exchange ratio (RER) and ratings of perceived exertion (RPE) were assessed at each level of exercise. The data were analyzed with a 2-way (day by intensity) ANOVA. The day by intensity interaction was not significant for any of the analyses. A significant main effect for HR was observed with HR on medication (159.3 bpm) higher than the HR off medication (149.0 bpm). Treatment with medication had no effect on VO_2, VE/VO_2, RER, or RPE. In addition, pre-exercise medication dose (absolute and relative to body weight) was not related ($r = -0.08$ to -0.25; $P>0.05$) to the individual differences in HR at each level of exercise between the two days. In conclusion it appears that the systemic effect of the stimulant medication, used in the treatment of ADHD, is restricted to the cardiovascular system. However, a medication dose-HR response relationship was not observed. RPE and other physiological responses during submaximal exercise in children with ADHD appear to be unaffected by the use of this type of medication.

EFFECTS OF AN ORAL GLUCOSE CHALLENGE ON METABOLIC AND HORMONAL RESPONSES TO EXERCISE IN ACTIVE PREPUBERTAL GIRLS

Foricher Jean-Marc, Boisseau Nathalie, Ville Nathalie, Berthon Phanélie, Bentué-Ferrer Dominique, Gratas-Delamarche Arlette, Delamarche Paul

Laboratory of physiology and biomechanic of muscular exercise, France

Keywords: substrate mobilization, challenge in glucose, insulin sensitivity

To examine hormonal and metabolic effects of an oral challenge in glucose (16 g), fifteen prepubertal girls, age 9-12 yr, were randomly divided in two groups according to the oral challenge in glucose.
Each girl performed a 30min ergocycle test at 60% of Wmax. Among them, 8 ingested an oral glucose challenge between 2 and 3 minutes after the beginning of the exercise whereas the other 7 girls received no fluid intake. During this test, blood samples were collected using a venous catheter, in seated position on the bicycle. In the group without oral challenge (Gw) the measures were made at rest and every 15min. In the group with oral challenge (Go), the measures were made at rest, at the 3rd, 5th, 10th, 15th and 30th minute of the test.
Plasma glucose was significantly different according to the oral challenge at the 15th minute and 30th minute, where Go was higher than Gw ($p<0.001$ and $p<0.01$ respectively). In Go, a significant increase in plasma glucose concentration appeared between rest and the 30th minute and between the 15th and 30th minute ($p<0.01$). Concerning plasma FFA, a problem occurred, so the statistics between groups were not realised. Plasma norepinephrine was not influenced significantly by the challenge in glucose. Concerning plasma epinephrine, a significant difference appeared at the 15th minute ($p<0.05$) between Go and Gw, the value obtained in Go was higher than the value of the Gw group. At last, concerning plasma insulin, no challenge effect was encountered.
In conclusion, the effects of an oral challenge in glucose ingested after the beginning of an exercise test at 60% of Wmax in active prepubertal girls confirm previous results well established in adults. Many studies show that, in adults, plasma glucose can be maintained at steady state when the exercise intensity is not higher than 70-80% of VO_{2max} during one hour. Indeed, in prepubertal girls plasma glucose is relatively stable during a 30 minutes exercise test. Besides, the non-significant different values of FFA found in the group Go confirm the phenomenon of insulino-resistance in prepubertal children and their capacity to perform prolonged exercise compared to adults. These results suggest that prepubertal girls receiving an oral challenge in glucose at the beginning of a prolonged exercise could longer maintain this exercise, by avoiding a hypoglycaemia.

EFFECTS OF EXERCISE AND CALCIUM SUPPLEMENTATION ON BONE HEALTH IN PRE-MENARCHEAL GIRLS: A LONGITUDINAL STUDY

Courteix Daniel, Prouteau Stephanie, Jaffré Christelle, Lespessailles Eric, Carlson John S.

IPROS Inserm ERIT-M and Laboratoire de la Performance Motrice, Regional Hospital and University of Orleans, France

Keywords: calcium, exercise, premenarcheal girls

Background
Childhood activity and high calcium intake each improve bone mass accrual, but their synergistic action has not yet been clarified. This study investigated the combined effects of calcium supplementation and exercise on bone density and further examined the residual effects of the intervention on bone health twelve months following the intervention.

Method
Two milk-powder products containing either 800 mg of calcium phosphate or placebo were randomly allocated to 113 healthy premenarchal girls on a daily basis for 1 year. The group was composed of 63 weight bearing exercise (7.2 ± 4 hours of exercise/week) and 50 sedentary (1.2 ± 0.8 hours of exercise/week) children. There were 4 experimental groups: exercise/calcium (n=12), exercise/placebo (n=42), sedentary/calcium (n=10), and sedentary/placebo (n=21). Areal bone mineral density (BMD) (6 skeletal sites) and body composition were determined by DXA. Radiographic measures determined bone age and the daily spontaneous calcium intake was assessed by questionnaire. Measurements were taken at baseline, following the one-year of intervention and 1 year following the cessation of the treatment.

Results
No differences were observed between groups in bone age, body height and weight at any stage of the study. At baseline there was no significant difference in the calcium intake between the groups. After 1 year of intervention, the total body BMD gains of the exercise/calcium group (6.3 %, $p<0.05$) were significantly greater than the gains of all other groups. There was no significant difference between the three other groups. Specific site significant gains were observed in the exercise/calcium group at lumbar spine (11 %, $p<0.05$), femoral neck (8.2 %, $p<0.02$), and Ward's triangle (9.3 %, $p<0.01$).
One year following the intervention, there were no significant differences observe in any of the bone accrual measures between the groups. However, the exercise/calcium group maintained the significantly higher BMD values at the total body ($p<0.01$). The two exercise groups (exercise/calcium and exercise/placebo) produced greater BMD values than the two sedentary groups at the femoral neck ($p<0.02$), Ward's ($p<0.03$), and the subregions of the radius (mid: $p<0.02$, U distal: $p<0.001$, 1/3 distal: $p<0.05$).

Conclusions
These data reveal that calcium supplementation when combined with physical exercise produces greater gains in bone health that just exercise or calcium intake alone. In addition the calcium supplementation without physical activity did not improve the BMD acquisition in this group of pre-menarcheal girls.

TRAINING IN 10-11 YEAR OLD BOYS: A COMPARISON OF STEADY STATE AND INTERVAL TRAINING AT TWO DIFFERENT INTENSITIES, WHILST KEEPING TOTAL WORK CONSTANT

McManus Alison[1], Cheng Chi Hong[1], Leung Maurice[2], Yung TC[2]

[1] *Institute of Human Performance, University of Hong Kong, Hong Kong*
[2] *Division of Paediatric Cardiology, Department of Paediatrics, University of Hong Kong, Hong Kong*

Keywords: training, cardiopulmonary, boys

Introduction
Previous studies with young people have indicated that the magnitude of change in cardiopulmonary function is primarily dependent on the intensity of the training (Shephard, 1992). Although there have been attempts to compare the effectiveness of differing intensities using steady state and interval training protocols (McManus et al., 1997; Williams et al., 2000), little attempt has been made to keep total work constant. In this experiment we attempted to keep total work constant while comparing steady state cycle ergometer training at 70-75% of maximum heart rate with interval cycle ergometer training at 85-90% of maximum heart-rate in 10-11 year old Chinese boys. The study utilized a randomized between-group design to test the hypothesis that when total work is held constant, the magnitude of change in cardiopulmonary function is not significantly different between higher intensity interval training and lower intensity steady state training.

Methods
Thirty-six boys were randomly assigned to one of three groups: control, steady state or interval training. Both the steady state and interval groups trained 3 times per week for 8 weeks. The control group continued with normal physical activity. Similar total work was confirmed during pilot work, modeling the interval protocol (interval and rest times) on the total cardiovascular work achieved during a continuous 20-minute cycle with heart rate 70-75% maximum. Cardiopulmonary function was assessed pre- and post-training in all three groups from respiratory gas analysis and heart rate response. Mean differences in submaximal and peak cardiopulmonary responses were examined using a one-way ANOVA. Differences between the post-training and pre-training values were compared, with the pre-training value of each of the variables as the covariate, and main effects being tested for using the Bonferroni post-hoc test. Significant differences were accepted at the .05 level.

Results
A significant difference in submaximal heart rate existed. This was lower in the interval group compared to the control group [interval: 145(4); steady state: 152(4), control: 160(3)]. At peak exercise significant differences were found in peakVO_2 (l/min) between the control group and interval group, as well as between the steady state group and interval group [control: 1646(31); steady state: 1736(38), interval: 1867(38)]. Significant differences were also apparent between the control and interval group in peakVO_2 (ml/kg/min), but not however, between the interval and steady state groups. Similarly the intensity of exercise at peak was significantly higher in the interval group (99w) compared to the control group (78w), but not between the steady state (88w) and interval (99w) groups.

Table 1: Descriptive Data

		Steady-state	Interval	Control
Hgt	Pre	1.40 (.43)	1.45 (.29)	1.40 (.43)
(m)	Post	1.41 (.37)	1.45 (.35)	1.41 (.44)
Wgt (kg)	Pre	35.9 (7.3)	38.9 (5.6)	36.3 (7.2)
	Post	34.7 (7.1)	39.1 (5.1)	35.2 (6.9)
VO_2 (l/min)	Pre	1.65 (.16)	1.80 (.22)	1.58 (.20)
	Post	1.74 (.38)	1.87 (.38)	1.65 (.31)
VO_2 (ml/kg/min)	Pre	47.0 (6.5)	46.6 (4.9)	44.7 (6.5)
	Post	50.7 (6.9)	51.6 (4.5)	48.9 (6.6)

Discussion/Conclusion
This study has provided evidence that when total work is held constant, interval training at a high intensity elicits improvement in some cardiopulmonary markers when steady state training can fail to do so. However, a comparison of the magnitude of change in peakVO_2 (ml/kg/min) shows only a small, non-significant difference exists between the steady state group (7.5% increase) and the interval group (9.8% increase).

References
Shephard RJ (1992). Sports Med 13:194-213.
McManus AM, Armstrong N, Williams CA (1997). Acta Paediatr 86:456-9.
Williams CA, Armstrong N, Powell J (2000). Br J Sports Med 34: 168-73.

THE VALIDITY OF THE JONES & PEARSON ANTHROPOMETRIC METHOD TO DETERMINE THIGH VOLUMES IN YOUNG BOYS: A COMPARISON WITH MAGNETIC RESONANCE IMAGING

Winsley Richard, Armstrong Neil, Welsman Joanne

Children's Health & Exercise Research Centre, University of Exeter, Exeter, UK

Keywords: MRI, Lean leg volume, Jones & Pearson

Introduction
Anthropometric techniques of assessing leg muscle volume have found popularity with child based research due to their non-invasive nature, ease of use, low cost and fast completion times (Knapik et al., 1996). The development of Magnetic Resonance Imaging (MRI) now allows for a more precise, non-invasive determination of muscle volume rather than just lean tissue volume. However, the high scanning costs and restricted access to MRI scanners *per se* has meant that the use of this equipment in research is limited outside the clinical setting. The use of anthropometric techniques therefore appears to be more feasible for child based research, but studies have consistently reported a large differences in measured leg volume between the two measurement techniques; 7.1-17.7% (Housh et al., 1994), 22% (Knapik et al., 1996). The Jones & Pearson (1969) technique in particular has been frequently used in paediatric exercise physiology research, yet there remains the question of the suitability of this method to accurately predict the quantity of lean leg tissue in children. Therefore, the purpose of this study was to compare the Jones & Pearson anthropometric and Magnetic Resonance Imaging methods in determining thigh volumes in young boys.

Methods
Sixteen boys with a mean (± SD) age of 9.9 ± 0.3y volunteered to participate in the study. All boys were classified as prepubertal (pubic hair rating 1) (Tanner, 1962). Stature was measured using a Holtain Stadiometer (Crymych, Dyfed, UK) to the nearest 1cm. Body mass was measured using an Avery beam balance (Avery Berkel, Birmingham, UK) to the nearest 0.1kg. Leg volume measures for each child were collected according to the procedures of Jones & Pearson (1969), using Holtain skinfold callipers and anthropometric tape measure (Crymych, Dyfed, UK). The same investigator took all measures at the same time of day for each child. All children remained inactive prior to measurement. The right leg was measured in all cases. All children were subsequently taken to the Somerset MRI centre (Bridgwater, Somerset, UK) to undergo scanning of the thigh region. Scans were performed using a Philips Gyroscan T5 II (0.5 Tesla). The right thigh was scanned from medial to lateral in 6mm thick, contiguous, longitudinal slices. The number of slices ranged from 22 to 27 depending on the size of thigh. T2 weighted gradient echo images were produced (20° flip angle, field of view = 450mm, scan matrix = 256 x 256) using a multiple spin-echo sequence (echo time = 20ms, repetition time = 50ms). The region of interest on each scan was measured from the head of femur to the distal femur below the medial and lateral condyles. For each scan, total area, muscle area and bone area were calculated by tracing around the specific area with a mouse controlled cursor, from which the computer generated an area measurement using built-in algorithms. Total slice, bone and muscle volumes were calculated by multiplying the slice areas by slice thickness (6mm). Total thigh volume, total bone volume and total muscle volumes were calculated by summing all the individual slice volumes. Fat volume was taken to be the residual quantity when bone and muscle volumes were subtracted from total thigh volume. To enable comparison with the Jones & Pearson (1969) technique, lean thigh volume was also calculated by summing muscle and bone volumes for each subject. Statistical analyses were performed using SPSS computer statistics package (Version 9) (SPSS Inc., Chicago, Illinois, USA). Paired t-test analyses were used to determine significant differences between measurement techniques. Relationships between variables were investigated through Pearson product moment correlation coefficients. Limits of agreement between the data were calculated according to the recommendations of Bland & Altman (1986). Statistical significance was accepted at $p \leq 0.05$.

Results
Mean stature and body mass of the boys was 1.40 ± 0.08 (m) and 31.5±5.2 (kg) respectively. Pearson correlation coefficients between the thigh volume measures calculated by the two methods were high; r=0.95 (total thigh volume (TTV)), r=0.79 (lean thigh volume (LTV)) and r=0.90 (fat thigh volume (FTV)), yet there was a significant difference in all mean values between the two methods (see Table 1). Table 1 indicates that the anthropometric technique under estimates total, lean and fat thigh volume in young children. This represents an underestimation for TTV of 36%, LTV of 31% and for FTV 52%.

	Jones & Pearson method	MRI method	Level of significance
Total thigh volume (L)	2.71 ± 0.59	4.23 ± 0.83	p≤0.05
Lean thigh volume (L)	1.96 ± 0.33	2.83 ± 0.37	p≤0.05
Fat thigh volume (L)	0.75 ± 0.32	1.49 ± 0.60	p≤0.05

Table 1: A comparison of lean and fat thigh volume measures calculated by anthropometry and MRI techniques. Values are mean ± SD.

A calculation of the limits of agreement between the two measures (±1.96 SD) (Bland & Altman, 1986) are shown in Table 2. The figures show that there is a consistent bias towards an underestimation of actual thigh volume by the Jones & Pearson (1969) method.

	Mean difference	Standard deviation of the differences	Limits of agreement (±1.96 SD)
Total thigh volume (L)	-1.53	0.35	–0.84 to –2.22
Lean thigh volume (L)	-0.85	0.23	-0.40 to –1.30
Fat thigh volume (L)	-0.77	0.35	-0.08 to –1.46

Table 2: Differences and limits of agreement between thigh volume measures as measured by anthropometry and MRI.

The range of potential underestimation by using the Jones & Pearson technique represents between 19-52 % for TTV, 14-46% for LTV and 5-98% for FTV.

Discussion/Conclusion

The simplicity and non-invasive nature of using anthropometric techniques to estimate lean or muscle volume has allowed these techniques to be widely employed in child based research. However, the specificity of the Jones & Pearson (1969) technique for use with children has not been previously questioned. These data indicate that using this particular anthropometric technique with child subjects greatly underestimates the volume of all leg tissue components. Although the strong positive correlations between the thigh volumes measured by the two methods suggest that one is a valid predictor of the other, the significant difference in the measured thigh volumes raises questions as to the ability of correlation coefficients to indicate agreement between two methods. The limits of agreement data presented in Table 2 demonstrate that the size of this underestimation of lean thigh volume ranges from 0.4 – 1.3 L, which represents a significant proportion of a child's thigh volume. Scrutiny of the original Jones & Pearson (1969) paper reveals that the original methods were validated against water displacement and X-ray methods. The correlation coefficients between the two methods ranged from r=0.84-0.90, but anthropometry was seen to underestimate the quantity of adipose tissue even in these original adult subjects. Indeed it has been reported previously that anthropometry underestimates cross-sectional areas in comparison to MRI (Housh et al., 1994; Knapik et al., 1996). Why should anthropometry produce this underestimation? The technique assumes the limb is a cylinder and that the subcutaneous fat is evenly distributed. In reality, the leg is not a perfect cylinder (Knapik et al., 1996; Malina, 1986) and there are individual differences in fat distribution, which cannot be catered for by the in-built general regression equations. The MRI method included sections of the thigh that were omitted from the Jones & Pearson (1969) method. The region of interest on the MRI scans was classified as being from the head of femur to the bottom of the femoral bone. Inevitably part of the gluteal muscles and the adjacent buttock fat were included into the thigh volume measurement, something omitted using the anthropometric method. The gluteal inclusion does answer the criticism voiced by Winter et al., (1991) who argued that the Jones & Pearson (1969) method was at fault for not including these muscles, but this extra tissue may have inflated the MRI measures. Fundamentally, such a difference between the two methods may have arisen because the original Jones & Pearson (1969) method was validated for use with adults and not children. The regression equations fundamental to the prediction capabilities of the method are not specific for use with children and therefore will inevitably produce an error in prediction for this population. The beauty and simplicity of the method makes it very attractive for child based research and so it may be unwise to dismiss the method outright. Indeed, the Jones & Pearson (1969) method may be used if, as suggested by Bland & Altman (1986), the appropriate correction factors are applied (see Table 2).

In conclusion, the Jones & Pearson (1969) method of determining thigh volumes in children greatly underestimates the true volume. As the use of MRI is both expensive and unfeasible for many research projects, the Jones & Pearson (1969) method may be utilised with young children if the appropriate correction factors are included into the estimates of leg volume provided.

References

Bland JM and Altman DG. (1986). The Lancet, February 8th: 307-310.
Housh D et al. (1994). Isokinetics Ex Sci, 4(1): 3-7
Jones PRM and Pearson J. (1969). J Phys, 204: 63-66.
Knapik JJ et al (1996). Med Sci Spts Ex, 28(1): 1523-1530.
Malina RM. (1986). Human growth; a comprehensive treatise.
Tanner JM (1962). Growth at adolescence.
Winter EM et al.(1991). J Spts Sci, 9(1): 3-13

ARE BEDSIDE TECHNIQUES ACCURATE AND SUITABLE TO ESTIMATE BODY FAT IN ADOLESCENT ATHLETES?

Silva Analiza, Minderico Claudia, Sardinha Luís B

Laboratory of Exercise and Health, Faculty of Human Movement, Technical University of Lisbon, Portugal

Keywords: body composition, athletes, body fat

Introduction

Accurate assessment of body composition (BC) during growth and maturation is important in many areas of nutrition-related research including clinical assessment, obesity-related research, and research into the regulation of growth and development (Goran, 1996). In addiction, BC assessment in adolescent athletes has an important role when prescribing desirable body weights, in optimising competitive performance, and in assessing the effects of training [1].

Despite a recent raise of interest in BC techniques, relatively few studies have specifically addressed methodological aspects in the paediatric population [2,3]. Thus, a small number of specif-

ic equations for estimating BC from skinfold-thickness measurements were developed for use in children and adolescents [4-7]. Also, several body fat analysers based on the bioelectrical impedance analysis (BIA) principles have been widely used in the clinical setting to estimate percent body fat (%BF) in different populations, including the infancy and the youth period. Even do it is recognized the need to assess body composition in paediatric groups, it remains difficult to measure with accuracy and precision, particularly in young athletes.
Although ch anges in fat-free mass (FFM) density have been described during puberty [8-11], the validity of specific equations developed for children and adolescents when applied to young athletes, concerning other potential alterations in FFM density is not yet clarified. Thus, the validation of those specific models in other laboratories is needed to assess their generalizability. Due to chemical immaturity in growing children, multicomponent models should be used as the "gold standard", against which other body composition techniques should be evaluated [2]. Multi-compartment models such as the three-compartment (3C), 4C, and the recently 5C molecular model [12], are more robust to interindividual variability in the composition of FFM. The 5C molecular model divides body weight into fat, water, bone mineral, soft tissue mineral, and protein.
Considering the need of accurate data on body composition assessment during growth and maturation, specifically concerning the athletic population, this study was designed to assess the performance of the specific skinfold-thickness equations of Slaughter et al. [4], Deurenberg et al. [6], Sardinha et al. [7], and two body fat analysers based on BIA principles to estimate %BF in adolescent athletes, using the 5C molecular model as the reference [12].

Methods

Sample

A total of 32 girls (age: 15.1 ± 0.3 y; weight: 56.2 ± 14.2 kg; stature: 1.65 ± 0.13 m; BMI: 20.2 ± 2.6 kg/m^2) and 46 boys (age: 15.3 ± 1.2 y; weight: 71.5 ± 12.3 kg; stature: 1.80 ± 0.12 m; BMI: 22.0 ± 2.5 kg/m^2), Caucasian, pubescent and postpubescent, volunteered for the study (Table 1). Subjects were recruited from several sports clubs and were involved in a variety of sports (e.g. swimming, basketball, gymnastic, rugby and judo).
According to the regulations of the Ethical Committee of the Faculty of Human Movement, Technical University of Lisbon, all subjects were informed about the research design and signed a consent form. All measurements were obtained with subjects fasted overnight (≥ 12 h).

Maturation

Subjects were grouped by puberty stage of development, determined by self-assessment according to Tanner [13] stage and adapted by Ross and Marfell-Jones [14]. A self-evaluation method, with figures, was used to identify the degree of development of the genital organs, breast and pubic pilosity.

Measurements of body composition

Measures of body volume assessed by air displacement plethysmography, bone mineral content by dual-energy x-ray absorptiometry (DXA) and total body water by deuterium dilution were used to estimate %BF. Briefly, body volume was estimated using the BOD POD® (Life Measurement Instruments, Concord, CA) as described elsewhere [15,16]. The bone mineral content was obtained by DXA (QDR-1500; Hologic, Waltham, MA) from the whole body scans and converted to total body bone mineral (as bone mineral content represents ashed bone) by multiplying it by 1.0436 [17]. Total body water (TBW) was assessed by the deuterium dilution technique using an isotope ratio mass spectrometer (PDZ, Europa Scientific, UK). After a completed 12 h fast, an initial urine sample was collected and immediately administrated a deuterium oxide solution dose (^2H_2O) of 0.1g/kg of body weight diluted in 150 mL of water. After a 4h period new urine sample was collected. Urine was prepared for $^1H/^2H$ analysis using the equilibration technique of Prosser and Scrimgeour [18]. The enrichments of equilibrated local water standards were calibrated against SMOW (Standard Mean Ocean Water). Based on delta SMOW, total body water was estimated by Schoeller and colleagues [19] method, including a 4% correction due to the recognized amount corresponding to deuterium dilution in other compartments.
The Wang et al. [12] 5C molecular model, was used as the reference method to estimate BF. Accordingly, BF was assessed with the following equation:

$$BF\ (kg) = 2.748xBV - 0.715xTBW + 1.129xMo + 1.222xMs - 2.051xBM$$

where BV is body volume (L), TBW is total body water (kg), Mo is total-body bone mineral (kg), Ms is total-body soft tissue mineral (kg) and BM is body mass (kg).
To assess %BF from the morphological models, ten skinfolds were measured, according with Lohman´s [20] procedures, with a Lange Caliper: abdominal horizontal, abdominal vertical, biceps, triceps, subscapular, suprailiac anterior, suprailiac medial, mid thigh, and calf. Also, two body fat analysers, BF300 and Tanita based on BIA principles were used to estimate %BF.

Statistical Analysis

The statistical analyses included examination of the coefficient of correlation (R), standard error of estimation (SEE), pure error (PE) and coefficient of variation (CV). Agreement between models was assessed with the Bland-Altman [21] method. Comparison of means between %BF methods was performed with a Paired t test. A one-sample t-test was used to assess if the differences were different from zero. Statistical significance was set as $p < 0.05$. The statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS inc., version 10.0, Chicago, IL) and the MedCalc Statistical Software (MedCalc Software, Mariakerke, Belgium).

Results

For both genders, table 1 depicts the means and standard deviations values of %BF from the morphological models, BF300, Tanita and the reference method. Means and standard deviations values are also presented in table 1 for the density and composition of the FFM, namely water, bone mineral, soft tissue mineral and protein.

Table 1 – Means and standard deviations values of %BF from the morphological models, BF300, Tanita and the reference method (%BF_{5C}) for boys and girls. Means and standard deviations values for the density and composition (water, bone mineral, soft tissue mineral and protein) of FFM for boys and girls

	Boys (n=46) Mean ± SD	Girls (n=32) Mean ± SD
%$BF_{Slaughter}$ [4]	16.7 ± 6.7*	24.7 ± 7.6*
%$BF_{Deurenberg}$ [6]	15.8 ± 4.1*	24.4 ± 6.9*
%$BF_{Sardinha}$ [7]	10.0 ± 4.9*	23.9 ± 6.6*
%BF_{BF300}	17.0 ± 5.1*	20.8 ± 4.2
%BF_{Tanita}	14.0 ± 4.6	21.6 ± 7.4*
%BF_{5C}	13.1 ± 4.9	19.8 ± 7.0
$FFM_{density}$ (g/cc)	1.100 ± 0.00[illegible]	1.105 ± 0.00[illegible]

**Differences between %BF estimated by the 5C model and the other techniques (p<0.001).*

For boys, %BF from the morphological models and the device BF300 was higher than the reference method ($p<0.05$), and was lower than %BF from Sardinha's model [7]. However, %BF using Tanita did not differ from %BF_{5C} ($p>0.05$). For girls, all the morphological models and Tanita presented higher %BF estimations in relation to the reference method ($p<0.05$), with the exception for the device BF300 ($p>0.05$).
For boys and girls, FFM density is similar to the reference man (1.100g/cc) but higher than Lohman's age-adjusted models [22] based on a non-athlete sample of children and adolescent, a widely used procedure to estimate body fat from 2-component models during growth and maturation. In addiction, the molecular composition of the FFM, water, bone mineral, soft tissue mineral, and protein are presented in table 1.
The performance criterias used to validate the above equations in the present study are shown in table 2.

Table 2 – Performance of predictive equations validated using the 4C model as reference.

%BF techniques	Sex	r	r^2adj	SEE (%)	CV (%)	PE (%)	Bias (%)	Limits of Agreement
Slaughter et al. [4]	M	0.78	0.61	3.08	18.4	5.40	–3.4*	4.9 - (-11.7)
	F	0.89	0.79	3.20	13.0	5.94	–4.9*	1.9 - (-11.6)
Deurenberg et al. [6]	M	0.79	0.62	3.01	19.1	3.92	–2.6*	3.3 - (-8.4)
	F	0.88	0.77	3.39	13.9	5.77	–4.6*	2.1 - (-11.3)
Sardinha et al. [7]	M	0.78	0.61	3.30	31.1	4.52	3.2*	9.5 - (-3.2)
	F	0.82	0.67	2.95	16.8	5.71	–4.1*	3.8 - (-12.0)
BF300	M	0.45	0.20	4.39	25.8	6.44	–3.9*	6.3 - (-14.1)
	F	0.52	0.27	6.06	29.1	5.98	–1.0	10.7 - (-12.7)
Tanita	M	0.48	0.23	4.34	31.0	4.87	–1.0	8.5 - (-10.4)
	F	0.77	0.59	4.57	21.2	5.19	–1.8*	7.9 - (-11.5)

**Significant differences from %BF_{5C} (p<0.001).*
Abbreviations: *r, correlation coefficient; r^2, coefficient of determination; adj, adjusted; SEE, Standard error of estimation; PE, pure error; CV, coefficient of variation; FM, fat mass; M, male; F, female.*

For boys and girls, a reasonable precision was found for the Slaughter et al. [4], Deurenberg et al. [6] and Sardinha et al. [7] models as presented by the high coefficients of correlation (r) and lower standard errors of estimation (SEE). When the SEE value of each equation was standardized for the mean value of %BF for each equation, the so-called coefficient of variation (CV) was obtained. This parameter indicates that the lowest is the CV, the better is the performance of the predictive equation. Considering this fact, morphological models presented a better performance for girls. Conversely, the pure errors were higher for both genders, which means that the performance of these morphological equations when applied in the present sample of adolescent athletes were poor. The devices, BF300 and Tanita showed a reduced precision as indicated by the lower r and the higher SEE and CV. And also a poor performance was found for these devices when applied to a sample of young athletes, as indicated by the PE.
All the models differed from the line of identity, which means that the slope differed from 1 ($p<0.05$) and the interception differed from 0 ($p<0.05$), with the exception for the Deurenberg et al. [6] models for both genders ($p>0.05$) and Sardinha et al.'s [7] equation and BF300 for girls ($p>0.05$).
All the equations and BIA devices overestimated %BF as indicated by the bias ($p<0.05$), with the exception of the Sardinha et al. [7] equation for boys that underestimated %BF in relation to the reference method ($p<0.05$). No bias was found between the differences of the 5C model with Tanita for girls and with BF300 for boys ($p>0.05$).
Agreement between the 5C model and all the bedside techniques were large, particularly for BF300 and Tanita, indicating a poor performance of these techniques to estimate %BF on an individual basis. However, the Sardinha et al. [7] equation for boys presented the smaller limits and no tendency was found between the difference of the methods and the mean of both methods. On the other side, a correlation was found in the Slaughter et al. [4] and Deurenberg et al. [6] models for boys and BF300 for girls, which means that the differences between these techniques and the reference method were related with body fatness.

Discussion/Conclusion
During growth and maturation of athletes two sources of variation in the composition of FFM may occur, which are the biological maturity and the changes in body composition due to exercise. Thus, the biological variability increases the methodological problems in %BF estimation in growing athletes. Therefore, in the development of new body composition methods a multicomponent model regarding the composition of FFM is required as reference. For this reason, the 5C molecular model emerged as the most robust methodological process to validate bedside techniques. This study revealed that the morphological models and BIA devices were not precise and accurate to estimate %BF in this population.
The poor performance obtained may be explained by the reference method used in the development of the predictive equations, the characteristics of the skinfold caliper and the sample characteristics. As a result, the models developed by Sardinha et al. [7] were developed using DXA as reference overestimated %BF in girls and underestimated %BF in boys. Several studies demonstrated that this method overestimates %BF in relation to the 4C molecular model [2,23,24], which may explain the obtained overestimation in the predictive equation for girls. However, for boys the greater body fatness of the male sample used to developed

Sardinha et al.'s [7] model may explain the obtained underestimation of the equation when applied in the young athletes.
The results obtained by the Slaughter et al. [4] models presented a greater adiposity for boys and girls in relation to the 5C molecular model. Although these models were developed using a 4C molecular model as reference (body density by underwater weighing, bone mineral by single photon absorptiometry and total body water by deuterium dilution), the Harpenden caliper used in the skinfold measurement of the non-athletic children and youth sample that provided the development of the Slaughter et al. [4] equations are known to underestimate skinfold measurements from 1 to 4mm comparing to the Lange caliper used in the present study [25]. The poor performance of the Deurenberg et al. [6] models in estimating %BF in this sample are related with the reference method used in the development of the Deurenberg et al. [6] equations. These equations were developed in a non-athletic sample of children and adolescents against a 2C model (body density by underwater weighing), assuming that density of the FFM slowly increases with age, from 1.080 g/cc at 7 years [26] to 1.100 g/cc at 18 years [27] in both sexes [5]. Concerning that the density of FFM of the adolescent athletes in the present work was similar to the adults (1.100 g/cc) the reference method used in the prediction equations of Deurenberg et al. [6] was not appropriate for the present sample. Furthermore, a Harpenden caliper was used to measure skinfold thickness in the Deurenberg et al. [6] sample, which is known to underestimate skinfold measurements from 1 to 4mm comparing to the Lange caliper, used in the present study [25].
The solutions provided by the bioelectrical impedance method using the devices BF300 and Tanita, were not accurate and suitable in %BF estimation for this population. Effectively, the coefficients of correlation were lower and standard errors of estimation were higher. In addiction, the regression lines between %BF from the reference method and %BF from BF300 and Tanita differed from the line of identity for both genders. To estimate FFM and to calculate BF from the difference of total body mass and FFM, the bioelectrical impedance method assumes the constancy of FFM hydration. In the manual of both equipments this value is not refered. However, whichever the used value, the measurement of the impedance and respective derivation of total body water, FFM and BF, these equipment are inadequate to be used in young athletes.
In conclusion, the morphological models based on skinfold-thickness and the two body fat analysers based on BIA principles were not enough precise and accurate to estimate %BF in adolescent athletes. Based on a five-component model, these data illustrate the need for the development of more accurate models regarding the molecular composition of FFM to estimate body composition in adolescent athletes.

References

1. Sinning, W.E. (1996) Body composition in athletes. In Human Body Composition (Roche, A.F. et al., eds.), pp. 257-274, Human Kinetics Publishers
2. Fields, D.A. and Goran, M.I. (2000). J Appl Physiol 89 (2), 613-620
3.Sardinha, L.B. et al. (2003). Acta Diabetol 40(1) (58-63.)
4. Slaughter, M.H. et al. (1988). Hum Biol 60 (5), 709-723.
5.Weststrate, J.A. and Deurenberg, P. (1989). Am J Clin Nutr 50 (5), 1104-1115.
6. Deurenberg, P. et al. (1990). Br J Nutr 63 (2), 293-303.
7. Sardinha, L.B. et al. (2000). Arq Med 14 (2), 68-77
8. Boileau, R.A. et al. (1984). Hum Biol 56 (4), 651-666.
9. Lohman, T.G., Boileau, R.A. & Slaughter, M.H. (1984) Body composition in children and youth. Advances in Pediatric Sports and Sciences. Champaign, I.L:Human Kinetics, 29-57
10. Lohman, T.G. (1986). Exerc Sport Sci Rev 14, 325-357
11. Lohman, T.G. (1992) Advances in body composition assessment, Human Kinetics Publishers
12. Wang, Z. et al. (2002). Am J Clin Nutr 76 (5), 968-974
13. Tanner, J.M. (1962) Growth and adolescence, Blackwell Scientific
14. Ross, W.D. and Marfell-Jones, M.J. (1991) Kinanthropometry. In Phsysiological testing of the high-performance athlete (MacDougall, J.D. et al., eds.), pp. 224-305, Human Kinetics Publishers
15. Dempster, P. and Aitkens, S. (1995). Med Sci Sports Exerc 27 (12), 1692-1697
16. McCrory, M.A. et al. (1995).Med Sci Sports Exerc 27 (12), 1686-1691
17. Heymsfield, S.B. et al. (1990). Am J Clin Nutr 52 (1), 52-58.
18. Prosser, S.J. and Scrimgeour, C.M. (1995). Anal Chem 67 (13(1)), 1992-1997
19. Schoeller, D.A. et al. (1980). Am J Clin Nutr 33, 2686-2693
20. Lohman, T.G. et al., eds (1988) Anthropometric standardization reference manual, Human Kinetics Publishers
21. Bland, J.M. and Altman, D.G. (1986). Lancet 1 (8476), 307-310.
22. Lohman, T. (1989) Assessment of body composition in children. Pediatr. Exerc. Sci. 1, 19-30
23. Roemmich, J.N. et al. (1997). J Appl Physiol 83 (3), 927-935
24. Wong, W.W. et al. (2002). Am J Clin Nutr 76 (2), 384-389
25. Pollock, M.L. et al. (1995) The measurement of body composition. In Physiological assessment of human fitness (Maud, P.J. and Foster, C., eds.), pp. 167-204, Human Kinetics Publishers
26. Fomom, S.J. et al. (1982). Am J Clin Nutr 35 (5 Suppl), 1169-1175.
27. Siri, W.E., ed. (1961) Body composition from fluid spaces and density: Analysis of method, National Academy of Sciences

BODY FAT IS MORE RELATED TO BLOOD PRESSURE THAN BODY MASS INDEX IN ADOLESCENTS

Minderico Claudia, Marques-Vidal Pedro

Superior Institute of Health Sciences South – Lisbon, Portugal

Keywords: hypertension, adolescent, body fat

Introduction
Cardiovascular diseases (CVD) are a leading cause of death in most industrialized countries including Portugal [1]. The development of cardiovascular disease, obesity and other chronic diseases in adulthood is thought to be the result of lifelong processes having origins in childhood [2]. This pathology is the result of a complex interaction among a variety of risk factors in which hypertension hypercholesterolaemia and inactivity are common [3]. According to the National Institute of Health [4], blood pressure values in childhood can predict what they will be 15 years later; this marking is important to evaluate this parameter in children. It is now common to regard obesity in children as an indicator of future CVD risks during adulthood [5,6]. In adults, the body mass index (BMI) represents a good parameter to describe overweight and obesity, as it estimates body fat by simple means[7] and predicts cardiovascular risk and mortality [8]. In children it is not known which of the available obesity

parameters can best predict the increased risk for obesity-related diseases and mortality. In the present study was examined the relationships between body composition parameters, namely, anthropometrics measurements (BMI and waist/hip ratio – WHR) and percent of body fat (%BF) using the body fat analyser BF300 based on the bioelectrical impedance analysis (BIA), with blood pressure levels (systolic and diastolic, SBP and DBP, respectively) in a sample of adolescents.

Methods

Sample

A transverse study was conducted in a sample of 511 secondary school adolescents (mean age: 16.5 ± 1.1 years) who volunteered for the study.

Measurements

In each child, blood pressure (SBP and DBP), height and weight, BMI, waist, hip, WHR and %BF were determined. Body weight was measure by a digital scale (SECA, Hamburg, Germany) to the nearest 0.1kg, and body height was determined by a stadiometer to the nearest 0.1cm, as indicated by the standard anthropometrics methods (Council of Europe, 1988). According to the procedures described by Lohman et al.[9], waist circumference was measured to the nearest 0.1cm, at the smallest circumference of the torso, which is at the level of natural waist and hip circumference was measured at the level of maximum extension of the buttocks to the nearest 0.1cm. The device BF300 (BF300, OMRON Healthcare Europe, Hoofddorp) based on the bioelectrical impedance analysis (BIA) was used to assess %BF.
After resting 5 minutes, blood pressure was obtained in the sitting position in the left arm once by an automated device (OMRON M-4).

Statistical Analysis

The statistical analysis was performed using Spearman correlation and stepwise multivariate regression. Statistical significance was set at $p<0.05$.
The statistical analysis was assessed using the Statistical Package for the Social Sciences (SPSS inc., version 10.0, Chicago, IL).

Results

For boys and girls, means and standard deviations (SD) values of age, weight, height, BMI, waist, hip, WHR, %BF, SBP, and DBP, are presented in Table 1.

Table 1 – Means and standard deviations (SD) values of age, weight, height, BMI waist, hip, WHR, %BF, SBP, and DBP, for boys and girls

	Boys (n=299) Mean ± SD	Girls (n=212) Mean ± SD
Age (y)	16.5 ± 1.2	16.5 ± 1.1
Weight (kg)	67.9 ± 11.4	58.7 ± 10.4
Height (cm)	173 ± 6	161 ± 6
BMI (kg/m^2)	22.8 ± 3.4	22.5 ± 3.7
Waist (cm)	76.9 ± 9.4	71.2 ± 9.0
Hip (cm)	96.3 ± 9.3	96.0 ± 8.8
WHR	0.80 ± 0.07	0.74 ± 0.05
%BF	17.8 ± 6.7	25.2 ± 5.6
SBP (mm/Hg)	123 ± 15	111 ± 16
DBP (mm/Hg)	69 ± 13	69 ± 13

For boys, significant correlations were found between SBP and DBP with: BMI ($r=0,31$ and $r=0,17$, respectively, $p<0,01$), WHR ($r=0,22$ and $r=0,1$, respectively, $p<0,01$), and %BF ($r=0,26$ and $r=0,17$, respectively, $p<0,01$). In girls, similar findings were obtained between SBP and DBP with BMI ($r=0,13$ and $r=0,30$, respectively, $p<0,01$). However, WHR presented a significant correlation just with SBP ($r=-0,16$, $p<0,05$), and %BF presented a significant correlation only with DBP (0,29, $p<0,01$).
Finally, stepwise multivariate regression analysis adjusting for age showed that %BF was more related to DBP than BMI or WHR. In addiction, %BF was also related to SBP in boys, whereas WHR was related to SBP in girls.

Discussion/Conclusion

The significant correlations found between BMI and blood pressure levels in the adolescent males and females support the results of Boucherd et al. [4,10] that pointed out stature and weight overload to have an enormous influence on blood pressure values. These data is also in line with the studies conducted by Macedo et al. [1], which revealed that heavier and/or taller adolescent tend to have higher blood pressure in comparison to lighter and/or shorter adolescent of the same age, despite the fact that, stature and weight were analysed as isolated obesity-parameters. The significant correlations found between BMI and blood pressure levels in the adolescent males and females support the findings of previous studies which have indicated that in adults and children [11,12] BMI and cardiovascular morbidity and cardiovascular mortality are correlated with each other [8,12-14]. Therefore, BMI has been recommended as an appropriate parameter to define obesity in adults and, more recently, in children and adolescents [11,12]. However, it was also shown that adolescents obesity defined by the excess of subcutaneous fatness has been associated with elevated BP [15], demonstrating that high levels of CVD risk factors often accompany excess body fat in youth. The regression analysis of the present work showed that %BF was related to blood pressure according with the findings of Williams et al. [16] which suggested that measurement of both total and regional fatness may be informative of CVD risk factors, especially for adolescent health screenings.
In conclusion, these results suggest that body fat is more related to BP levels than BMI or WRH in healthy adolescents. Therefore, body fat might be of interest in the assessment of adolescents at risk of developing hypertension.

References

1. Macedo, M.E. et al. (1997). Rev Port Cardiol 16 (9), 679-682, 663
2. Berenson, G.S. et al. (1992). Am J Cardiol 70 (9), 851-858
3. Raitakari, O.T. et al. (1997). Med Sci Sports Exerc 29 (8), 1055-1061
4. NIH. (2000). The Practical Guide Identification, and treatment of overeight and obesity in adults
5. Clarke, W.R. and Lauer, R.M. (1993). Critical Reviews in Food Science and Nutrition 33, 423-430
6. Porkka, K.V. et al. (1994). Am J Epidemiol 140 (12), 1096-1110
7. Bray, G.A. (1987). Ann N Y Acad Sci 499, 14-28
8. Calle, E.E. et al. (1999). N Engl J Med 341 (15), 1097-1105
9. Lohman, T.G. et al., eds (1988) Anthropometric standardization reference manual, Human Kinetics Publishers
10. Bouchard, C. et al. (1993). Endocrine Reviews 14, 72-93
11. Barlow, S.E. and Dietz, W.H. (1998). Pediatrics 102 (3), 1-19
12. Bellizzi, M.C. and Dietz, W.H. (1999). Am J Clin Nutr 70 (1),

173S-175S
13. Gunnell, D.J. et al. (1998). Am J Clin Nutr 67 (6), 1111-1118
14. Must, A. et al. (1992). New England Journal of Medicine 327, 1350-1355
15. Gortmaker, S.L. et al. (1987). Am J Dis Child 141 (5), 535-540
16. Williams, D.P. et al. (1992). Am J Public Health 82 (3), 358-363

INCREASED BONE MASS IN THE FINGERS OF ELITE ADOLESCENT ROCK CLIMBERS

Kriemler Susi, Schlegel Christian

Dept of Pediatrics, Triemli Hospital, Zurich, Switzerland

Keywords: bone, physical activity, rock climbing

Objectives
Sport activities that are characterized by high magnitudes of skeletal loading such as weightlifting or tennis have been associated with a higher regional bone density in adolescent athletes. It is not clear however, whether an activity where skeletal loading is purely through muscle contractions without any compressive forces might also lead to bone mass accumulation. The purpose of this study was therefore to determine whether high volume rock climbing was associated with greater than normal bone mass in the fingers of elite adolescent rock climbers.

Methods
Twenty-nine 10- to 17-year-old nationally ranked rock climbers took part in the study. Climbing history was assessed by interview, followed by an anterior-posterior radiograph of both hands. Age-and sex-matched control subjects were selected from the Zuerich longitudinal study. Cortical thickness of the second and third proximal (PP) and middle phalanx (MP) of the 2^{nd} and 3^{rd} finger of the right hand was assessed at the junction of the distal third and proximal two-thirds (2^{nd}MP-A and 2^{nd}PP-A, 3^{rd}MP-A and 3^{rd}PP-A) and at the middle of the phalanx (2^{nd}MP-B and 2^{nd}PP-B, 3^{rd}MP-B and 3^{rd}PP-B). Cortical thickness was then expressed as percentage of the total width.

Results
Climbers and controls did not differ in age (14.7±1.6 vs. 14.6±2.3 years), height (162.3±25.0 vs. 161.1±14.5 cm) and weight (52.1±12.1 vs. 49.3±12.3 kg). The climbers were able to perform a UIAA climbing grade of 8.2±0.56, they trained 5.9±3.3 hours per week during at least a year and they started their regular climbing career 26.3±16.9 months prior to the study. Cortical thickness was significantly higher in the climbers compared to controls at all sites: 2^{nd}MP-A: 37.7±4.7 vs. 33.8±4.7%, $p<0.005$; 2^{nd}PP-A: 51.7±5.6 vs. 46.9±3.9%, $p<0.0005$; 3^{rd}MP-A: 32.4±4.7 vs. 29.5±4.4%, $p<0.05$; 3^{rd}PP-A: 50.7±4.2 vs. 46.5±2.7%, $p<0.0001$; 2^{nd}MP-B: 53.6±5.4 vs. 49.1±5.8%, $p<0.005$; 2^{nd}PP-B: 43.0±4.5 vs. 39.3±5.2%, $p<0.01$; 3^{rd}MP-B: 49.0±5.5 vs. 45.4±4.5%, $p<0.01$; 3^{rd}PP-B: 42.5±3.8 vs. 39.9±4.3%, $p<0.05$. The relative cortical thickness of all sites but 3^{rd}PP-A correlated significantly with the duration of the active climbing career (r=0.48-0.56, $0.05>p>0.005$).

Conclusion
High level rock climbing during adolescence might lead to an increased bone mass in the fingers by simple muscle contractions without any impact loading. Longitudinal studies have to be performed, however, to exclude selection bias.

RELATIONSHIPS OF LEPTIN AND ANDROGENS TO BONE MASS IN PREMENARCHEAL SPORTIVE GIRLS

Jaffré Christelle, Collomp Katia, Courteix Daniel

Laboratoire de la Performance Motrice, Université d'Orléans, France

Keywords: bone mass, leptin, androgens

Introduction
In young girls, physical activity increases the bone mass by a direct effect of the mechanical loading on the skeleton. A potential effect by way of hormonal activity remains unclear. Some studies have reported that leptin and androgens concentrations are associated with bone mass in non active women. The aim of thi study was to analyse the relationship between serum leptin levels, urinary androgens concentrations and bone mass in premenarcheal sportive girls.

Methods
Serum leptin and urinary androstenedione and DHEA-S levels were measured by RIA in 113 premenarcheal girls, includind 63 actives (7.2 ± 4.1 hr/week) and 50 non actives (1.2 ± 0.8 hr/week) subjects. Bone age, Tanner's stages and anthropometric characteristics were determined in each subject. Bone mineral content (BMC) and density (BMD) were measured by DXA at the total body and 5 skeletal sites.

Results
Except at the whole body, bone mineral content and bone mineral density were significantly higher in the active as compared with the non active girls. There were no differences between the two groups for serum leptin levels and urinary androstenedione and DHEA-S concentrations. A positive correlation has been found between androstenedione and BMC (r = 0.241 to 0.570, $p < 0.05$) as well as BMD (r = 0.286 to 0.583, $p < 0.05$) at all sites in controls. By contrast no relationship was noticed in sportive girls. In the same way, serum leptin levels were related with femoral neck and mid radius bone mass (r = 0.210 to 0.487, $p < 0.05$) as well as density (r = 0.444 to 0.565, $p < 0.05$) in non active girls. No relationship was found in active girls.

Conclusion
Our results show a positive relationship between leptin, androgens and bone mass only in non active girls suggesting a role of these hormones on the bone mass. The lack of relationship between leptin, androgens and bone mass in active subjects could suggest that physical activity acts as a modulator of the hormonal influence.

GENDER DIFFERENCES IN VENTILATORY RESPONSES OF YOUTH ARE RELATED TO EXERCISE INTENSITY

Murray Robert G[1], *Baggett Chris*[2], *Pennell Michael*[3], *Bangdiwala Shrikant*[3], *Harrell Joanne*[4]

[1] *Department of Exercise & Sport Science,* [2] *School of Public Health, University of North Carolina,* [3] *Department of Biostatistics,* [4] *School of Nursing, University of North Carolina, Chapel Hill, NC, USA*

Keywords: respiration, ventilatory equivalent, sex

Introduction

The early works of Robinson (1938) have shown that minute ventilations (V_E) during submaximal exercise declines, while absolute oxygen uptake (L/min) increases, as males aged from 6 to 25 years of age. This results in an improvement in ventilatory efficiency for oxygen (V_E/VO_2 ratio). In addition, we know from the work of Rowland and Cunningham (1997) that at a given V_E, tidal volume (V_T) increases with a simultaneous decrease in respiratory frequency (f_R) with age. Although these changes occur, there appears to be little data comparing gender specific development of these respiratory patterns. In adults, we know from the research of Aitken et al. (1986) and White et al. (1983) that gender differences in ventilatory responses and ventilatory control do exist. However, Rowland and Cunningham (1997), using 9 girls and 11 boys, ages 8 to 14 years, have suggested that no gender differences exist. Therefore, the purpose of the present study was to determine the trajectories of gender differences in the evolution of the respiratory pattern as it relates to rest and exercise intensity.

Methods

The subjects consisted of 326 youth aged 8 to 18 years who were participating in the Energy Expenditure of Physical Activity in Youth Study (EEPAY). They were similarly dispersed by age and gender such that there were at least nine subject of each gender per year of age. The data used for this study were obtained from rest, while walking at 4 and 5.6 km/h, running at 8 km/h and cycling at 22.4 km/h. Ventilatory measures and oxygen uptake (VO_2) were obtained from breath-by-breath measurement using a COSMED K2b4 portable metabolic system (COSMED, Rome, IT). The subjects were given time to become comfortable breathing through the mask. Resting measurement were taken in a quiet room, with the subject in a supine position, and a minimum of 3 hours post prandial. Measurements were taken for 15 minutes, with the first 5-min and the last minute of measurement eliminated from analyses. Ventilation and VO_2 were obtained during 10-min of walking and running at each speed. All subjects were habituated to walking and running on the treadmill. For analyses, the first 2-min and final minute was eliminated. If the participant could not run for a minimum of five minutes, giving us 3 min of steady state response, there data were excluded. Cycling was completed using a standard bicycle and a set of training rollers, simulating cycling on a flat, asphalt road. The children were not allowed to change the gears. Attainment of steady state was verified from plots of the data in which there was <1.5 ml/kg/min variation in VO_2. The breath-by-breath measures were averaged over the steady-state time interval to obtain a mean for each subject for each activity.

Results

There were significant differences in all measures by age ($p<0.01$). VO_2 (mL/min) increased with age at rest and for all four activities ($p<0.0001$). No gender differences for VO_2 were noted at resting, during walking, running ($p>0.065$), but males had a higher VO_2 during cycling ($p=0.046$). Minute ventilation (V_E), tidal volume (V_T) and $P_{ET}CO2$ increased with age ($p<0.01$). There were no significant gender or gender-by-age interactions for V_E at rest or during the four activities ($p>0.088$). In addition, V_E per kilogram weight declined by approximately 50% at rest and during exercise as the youth aged from 8 to 18 years. V_T was higher for the older males than aged-matched females at rest, during walking and running ($p<0.05$). $P_{ET}CO_2$ was similar between the genders ($p>0.11$) and there were no significant age-by-gender interaction ($p<0.26$). Respiratory frequency (f_R) declined with age ($p<0.0001$). There were no significant main effect for gender but there were gender-by-age interactions for walking and cycling ($p<0.02$), with the older females (16-18 y) having a higher f_R than the males. Ventilatory efficiency for oxygen (V_E/VO_2) declined with age and was similar between the genders at rest and walking. During the higher intensity exercises (cycling and running) the V_E/VO_2 of the females was higher than males ($p<0.004$).

Discussion

These data indicated that gender difference in V_E were note evident; however, it is interesting to note that V_E for all exercises continued to increase as the males aged until age 17 yrs, while in the females, V_E increased to age 15 then appeared to level off. Similarly, body mass increased as the males aged, whereas body mass tended to level off about age 15 years for the females. Thus growth, or attainment of adult mass, appears an important determinant of ventilatory responses. In support, we found a good correlations between VE, height and weight ($R^2 \sim 0.7$). Although there were good correlations between V_E, height and mass, other factors besides these, such as ventilatory neural drive or mechanical factors, may be important (Rowland and Cunningham, 1997).

Although V_E and V_E/kg appeared similar, V_E/VO_2 ratio, in general, tended to be lower for males than females, in agreement with Rowland and Cunningham (1997). These differences in V_E/VO_2 were not related to changes in body mass or stature, as the R^2 for these relationships were low ($R^2 = 0.09$-0.36). VO_2 at rest and during the four activities, although not significantly different among the genders, did show a trend with the females being slightly less than the males ($p \sim 0.051$-0.088). In addition, the V_E of the females, in general, was slightly higher than for the males. The combination of these two small differences, neither of which in itself are significant, resulted in the changes in V_E/VO_2.

Gender differences in V_T and f_R were evident particularly during late adolescence, and particularly during high intensity exercise. Aitken et al. (1986) and White et al. (1983) have suggested that in adults, these gender-differences may be related to differences in the sensitivity to CO_2. This may not be the complete explanation for our youth, as we noted no differences in CO_2 production, as indicated by respiratory exchange ratio, or $P_{ET}CO_2$; however, we did not measure CO_2 sensitivity. We did notice that height was highly correlated to V_T and f_R, and that the late adolescent females were generally shorter than the males. It is possible that the shorter height of the females

resulted in a higher stride frequency, which concomitantly modified neural respiratory drive. This relationship between stride frequency and respiration rate has been previously shown in adults (Dejours, 1967; McMurray 1985).
The ability of the younger participants (8-9 y) to increase V_T was quite limited, as V_T only increased by approximately 100% from rest to running (high intensity) exercise. In contrast, the V_T in the late adolescents was approximately 400% from rest to running. These differences were probably related to the size of the youth, as the V_T/kg was similar during running for 8 and 18 year olds (mean = 20.3 vs. 22.0 ml/kg, respectively) and not different by gender. The limited ability of the young children to increase V_T appears to be compensated by increase f_R, and, consequently, a lower $P_{ET}CO_2$ (Cooper et al., 1987).
In adults, the typical ventilatory response to increasing exercise intensity is for V_T to level off at moderate intensities of exercise and further increases during high intensity exercise to occur by increasing f_R. The adult response maximizes ventilatory efficiency (West, 1979). This V_T/f_R pattern was not evident in our youth aged less than 15 years. Since the ability to increase V_T was limited in our younger sample, as noted above, attempts to increase V_E must occur via f_R. Although this response is inefficient compared to adults, it allows small children with limited lung capacity to effectively increase V_E in relation to metabolic rate. As our sample aged, and V_T increased more, then changes in V_E could be met with less an increase in f_R, increasing the ventilatory efficiency. In support of our point, our V_E/VO_2 ratios declined as age increased. Thus, our results do not totally agree with those of Boule et al. (1989), who found that in the untrained child (aged 6-15 y), V_T and f_R increased in proportion to oxygen uptake.
In conclusion, the data suggests that there are minimal gender differences in ventilatory pattern during rest and low-intensity exercise; however, as the intensity of the exercise increases, gender differences in tidal volume, respiratory frequency and V_E/VO_2 become evident. These results also suggest that there are no gender differences in ventilatory pattern of pre-adolescents and that the development of the adult ventilatory response to exercise occurs during mid-adolescence, with males developing a more efficient ventilatory pattern then females. The difference between children and adults could be related at differences in CO_2 sensitivity, but appear to be more highly correlated with height and weight of the child.

References

Aitken ML, Franklin JL, Pierson DJ, Schoene RB (1986) J Appl Physiol 60:1894-1899
Boule M, Gaultier C, Girard F (1989) Respir Physiol 75:225-234
Cooper DM, et al. (1987) Pediatr Res 21:568-572
Dejours P (1967) Circ Res 20:Suppl 1:146-153
McMurray RG, Smith LG (1985) Respira Physiol 62:117-124
Robinson S (1938) Arbeitsphysiol 10:318-323
Rowland TW, Cunningham LN (1997) Chest 111:327-332
West JB (1979) Respiratory Physiology
White DP, et al (1983) J Appl Physiol 54:874-879

EIGHT WEEKS OF HIGH INTENSITY RUNNING INTERVAL-TRAINING INDUCE AN IMPROVEMENT IN SPIROMETRIC AND MAXIMAL FLOW-VOLUME VALUES IN HEALTHY PREPUBERTAL CHILDREN

Mucci Patrick[1], Nourry Cédric[1], Baquet Georges[2], Deruelle Fabien[2], Guinhouya Comlavi[2], Fabre Claudine[2], Berthoin Serge[2]

[1] *Laboratoire d'Analyse Multidisciplinaire des Pratiques Sportives, University of Artois, France*
[2] *Laboratoire d'Etudes de la Motricité Humaine, University of Lille II, France*

Keywords: lung, boys and girls, pulmonary capacity

Introduction
Several studies showed that respiratory muscle strength may be improved by aquatic physical activities in adults. This fact seems to be involved in the alterations of airway resistance or maximal expiratory flow-volume in prepubertal girls who have followed one year of intensive swimming training ***[1]***. However, swimming need specific breathing pattern during exercise. Therefore, we questioned if a short training period in running, as it could be used in school physical activities ***[2]***, may induce an alteration in maximal expiratory flow volumes. The aim of this investigation was to study the effect of an eight-weeks period of running interval-training in prepubertal children.

Methods
Eighteen prepubertal children (age = 10.0 ± 0.8 yrs, Tanner's stade 1) participated to this study. The subjects were divided into two groups: one Experimental group (n = 9; age = 9.7 ± 0.7 yrs; height = 135.3 ± 8.6 cm; weight = 34.6 ± 12.2 kg) who followed an high-intensity interval-training programme associated with school physical education lessons (2 sessions.wk^{-1} for a period of 8 wk ***[2]***); and one Control group with untrained children who followed their habitual activities during the same period (n = 9; age = 10.4 ± 0.5 yrs ; height = 141.9 ± 10.4 cm; height = 40.9 ± 14.2 kg). All the children performed spirometric and maximal flow-volume tests before and after the 8-week period. All the children were preliminary familiarised with the apparatus and the tests. At each investigation time, three maximal flow-volume tests was performed and the best values were retained as recommended by American Thoracic Society.

Results
Following the 8-week period, Experimental group showed a significant increase in forced vital capacity (FVC: +7%), in forced expiratory volume in l.$^{-s}$ (+11%), in peak expiratory flow (+17%) and in maximal expiratory flow at 75% of FVC (+15%) and at 50% of FVC (+18%). None of these changes was noted in Control group.

	ExpG (n = 9)		CG (n = 9)	
	Pre-training	*Post-training*	*Pre-training*	*Post-training*
FVC (L)	1.87 ± 0.36	2.00 ± 0.38*	1.94 ± 0.44	2.38 ± 0.50
FEV_1 (L)	1.58 ± 0.23	1.76 ± 0.27*	2.29 ± 0.57	2.00 ± 0.50
PEF ($L.s^{-1}$)	3.00 ± 0.76	3.52 ± 0.90**	3.63 ± 0.87	3.68 ± 0.93
$MEF_{75\%}$ ($L.s^{-1}$)	2.85 ± 0.69	3.42 ± 0.79**	3.35 ± 0.94	3.28 ± 0.79
$MEF_{50\%}$ ($L.s^{-1}$)	2.11 ± 0.51	2.49 ± 0.71*	2.59 ± 0.68	2.52 ± 0.62
$MEF_{25\%}$ ($L.s^{-1}$)	1.16 ± 0.40	1.34 ± 0.43	1.39 ± 0.40	1.49 ± 0.44

*Values are means ± SD. ExpG, experimental trained group; CG, untrained control group; FVC, forced vital capacity; FEV_1, forced expiratory volume in 1 s; PEF, peak expiratory flow; $MEF_{75\%}$, maximal expiratory flow at 75% of FVC; $MEF_{50\%}$, maximal expiratory flow at 50% of FVC; $MEF_{25\%}$, maximal expiratory flow at 25% of FVC. Significant difference between pre- and post-training period *P < 0.05, **P < 0.01.*

Table 1: Change in spirometric and maximal flow-volume parameters after eight-week period in trained and untrained groups.

Discussion/Conclusion

We concluded that the high-intensity interval-training programme during eight weeks seemed to be sufficient to observe alterations in pulmonary volume and maximal flow-volume parameters. Improvement in respiratory muscle strength and/or contractility may be hypothesised ***[3]***, nonetheless specific studies on these parameters need to be performed in order to explain this rapid increase in resting pulmonary function.

References

1. Courteix D et al (1997). Eur J Appl Physiol 76: 264-69
2. Baquet G et al (2002). Int J Sports Med 23: 439-44
3. Farrel P (1981). J Sports Med 21:145-149

AGE RELATED CHANGES IN THE TIME CHARACTERISTIC OF VENTRICULAR PERFORMANCE

AberbergaAugskalne Liga

Department of Physiology, Riga Stradins University, Riga, Latvia

Keywords: systolic time interval, heart rate, exercise

Introduction

Systolic time intervals (STI) reflect the left ventricle's hemodynamic environment as well as its contractile status and are used as criteria of left ventricular contractility [3,7,8]. In normal individuals ejection time varied inversaly with HR and directly with stroke volume [10]. The aim of the present study was to perform a longitudinal analysis of 1041 observations of the time charasteristic of ventricular performance on a cohort of females and males between the ages of 7 to 16 years.

Methods

This study represents the analysis of age related changes in the time characteristic of ventricular performance when more than 100 schoolchildren-volunteers of the same cohort were observed yearly over a ten-year period. Tetrapolar impedence cardiography was used measuring systolic volume, ECG and carotid pulse were recorded at rest and immediately after bicycle exercise. Blood pressure was measured by auscultation.

Heart rate (HR - beat/min), left ventricular ejection time (LVET in ms), LVET related to data at rest (LVET rel.), LVET index (LVETI in ms), duration of cardiac output (LVET· HR in s), mean systolic ejection rate (MSER in ml/s) were determined. Exercise test in supine reperesented standard work load and after 4 min. rest submaximal gradually increasing work load till subjective refusal. The parameters obtained in all subjects under study were computed and statistical analyses were made using the SAS statistical analysis programme. Statistical differences were calculated by Student's criteria, the normal regression equations relating HR and LVET, expressed in ms were calculated [Weisler]: LVET = LVETI – b · HR and used as a criteria for contractility of myocardium.

Results

During growth and development from 7 to 16 years age related changes in heart rate and time characteristic of ventricular performance are represented in Table 1. From age 11, gender differences in HR appear as lower values in boys if compared with girls. At the age of 13, gender differences became signifficant (P<0.05-0.01). Age related changes in the time characteristic of ventricular performance were the same for both genders and manifested in prolonging LVET corresponding to the duration of the cardiac cycle. The stabilization of LVET rel. was observed, which constituted, on average, 0.34 of the duration of the cardiac cycle for females and 0.33 for the males.

Age	Gender	HR	LVET	LVETI	LVETrel.	LVET· HR
7	F	92.3 ± 15.3	240±19	311.5± 19.2	0.37± 0.05	22.1± 3.3
	M	98± 12.8	233± 18	304.2± 14.8	0.38± 0.04	22.8± 2.6
8	F	91.2 ±23.4	235±18	261.9± 17.4	0.35± 0.09	21.3± 5.2
	M	92.5± 13.5	232± 17	273.8± 16.5	0.36± 0,05	21.4± 3
9	F	81.3± 12	239± 20	300.6± 17.2	0.32± 0.04	19.6± 2.6
	M	81.4±12.9	242± 16	289.8± 13.5	0.33± 0.04	19.6± 2.6
10	F	74.6± 9.5	251± 17	299.5± 15.7	0.31± 0.04	18.7± 2.2
	M	73.3± 9.3	251 ±15	300.9± 14.4	0.31± 0.04	18.4± 2.2
11	F	78.1± 12.3	272±27	372.5± 21.3	0.35± 0.04	21.2 ±2.7
	M	74.6± 11	277±23	370.1± 18.2	0.34± 0.04	20.6± 2.4
12	F	76±12.4	280±24	350.4± 19.4	0.35± 0.05	21.2± 2.9
	M	73.9± 10.1	281±24	380.3± 19	0.34± 0.04	20.7± 2.2
13	F	75.7± 10.2	267± 18	325± 16.3	0.34 ±0.04	20.2± 2.7
	M	69.9± 9.3	271± 19	332.4± 17.3	0.31± 0.04	18.9± 2.3
14	F	77.3± 14.1	265± 23	338± 18	0.34± 0.05	20.3± 3.1
	M	69.8± 11.9	274± 18	342.6± 14.1	0.32± 0.04	19± 2.6
15	F	74.1± 11.5	270± 21	366.9± 14.9	0.33± 0.04	19.9± 2.2
	M	67.4± 9.4	278± 14	331.3± 14.1	0.31± 0.04	18.7± 2.2
16	F	71.3 ±12.7	280±20	363.2±19.7	0.33±0.04	19.8± 2.6
	M	60.8±6.5	286± 12	302.1± 18	0.3± 0.03	17.4± 1.8

Table1. Longitudinal data for systolic time intervals at the ages 7-16. Values are mean ± SD.

High significant correlation took place between the LVET and HR (r = - 0.61) during the observed period. The relationship between LVET and HR with increasing age of the subjects became more pronounced and at the ages 14-16 the slopes LVET-HR became steeper and LVETI increased. Relatively stable values of LVET· HR for boys and girls corresponded to age related increase in MSER. In addition, mean values for MSER varied highly in all age and sex groups (c.v. > 30%).
Regression equations relating HR and LVET are represented in Table 2.
Average values for LVETI and b during the observed period were: 342.6± 5.1 and – 1.04± 0.06 for females (n = 536); 351.2 ±4.8 and – 1.17± 0.06 for males (n = 482).

Age	Regression equations relating HR and LVET	
	Female	Male
7	LVET= 311 – 0.81	LVET= 304 – 0.72
8	LVET= 262 – 0.32	LVET= 274 – 0.45
9	LVET= 301 – 0.76	LVET= 290 – 0.59
10	LVET= 299 – 0.66	LVET= 300 – 0.69
11	LVET= 372 – 1.26	LVET= 370 – 1.25
12	LVET= 350 – 0.93	LVET= 380 – 1.34
13	LVET= 325 – 0.77	LVET= 332 – 0.86
14	LVET= 338 – 0.93	LVET= 342 – 0.99
15	LVET= 367 – 1.29	LVET= 331 – 0.8
16	LVET= 363 – 1.15	LVET= 302 – 0.3

Table 2. Calculated regression equations relating HR and LVET, expressed in ms.

Restructuring in the time characteristic of ventricular performance took place due to bicycle exercise of different intensity (standard and submaximal). Age related tendency to reduce LVET and relatively stable LVET rel. and LVET· HR were observed during the standard bicycle exercise. The relationship between LVET and HR became weaker and there were decreases in LVETI due to exercising. At ages 14-16, when there existed greately pronounced gender differences in relationship between the LVET and HR, higher values for LVETI resulted and relationships were more pronounced. Average values for LVETI and *b* during the whole observed period were: 268.6± 17.5 and – 0.47± 0.14 for females; 270.4± 20.4 and – 0.47± 0.23 for males. The relationship between HR and the last level of submaximal load of the bicycle exercise with increasing age became steeper, more pronounced, at ages 14-16 in girls and 13-16 in boys. With every 50 watt increase boys revealed lower HR if compared with girls. Restructuring of the cardiac cycle caused by bicycle exercise of different submaximal intensity revealed shortening of LVET by 15 -30% and LVET rel. represented 0.50 of the duration of the cardiac cycle. Duration of the cardiac output prolongated by 30-50% if compared with data at rest. Revealed decrease in LVET with age did not combine with significant changes in LVET rel. Correlation between LVET and HR at the last load of increased exercising was weak, regression coefficient (*b*) and LVETI decreased during the observed period. Gender differences revealed higher regression coefficient and LVETI in males if compared with females.

Discussion/Conclusion

Age related changes during 7 to 16 years revealed a decrease in HR ($r = -0.46$; $p<0.01$) and gender differences characterised by lower values for boys. Gender differences at the age of 13 became significant. The time characteristic of ventricular performance was the same for both girls and boys and manifested in prolonging LVET corresponding to the duration of the cardiac cycle with age. Statistically no significant differences were found not between STI in girls and boys aged 3-16, as reported by [2]. According to our data high significant correlation took place between the LVET and HR at rest during the whole observed period. This agreed with [8] considering that HR influenced all of the STI. The relationship between LVET and HR with increasing age of the subjects became more pronounced and at the ages 14-16 there was a steeper rise in LVETI. However they did not reach the level observed in adults [10].

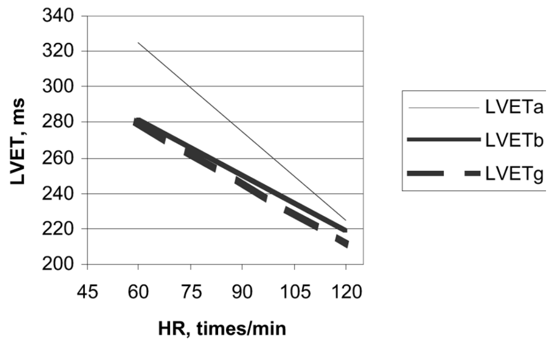


Figure 1. Relationship between left ventricular ejection time and heart rate (HR) in boys (LVETb) and girls (LVETg) as compared with adults (LVETa).

Close correlation between the STI and HR, less striking than in adults were demonstrated too by [9]. Our data, based on cardiointervalometry of the same subjects at the ages 15-16 when magnitude of HR reached that in adults, suggested that changes in the variables indicated to the incomplete formation of the endogenic structure of the cardiac rhythmus. However, the development of the control mechanisms of the mean HR and its endogenic structure were relatively independent and heterochronic. Beside it, the age related changes in time characteristic of ventricular performance and relatively stable values of LVET· HR for boys and girls associated with age related increase in MSER. This gave evidence of strengthening of the pumping function of heart with age. MSER as a valid indicator of left ventricular function with greater sensivity since calculation corrects LVET for the size of stroke volume was reported by [11]. Increase in HR due to exercise was accompanied by shortening of LVET. LVET varied with enhanced ventricular filling, stroke volume as well as with HR and myocardial inotropy [11]. Duration of systole should be affected due to findings [6] by an increse in afterload during ventricular relaxation. Our data in relation to standard exercise revealed age related tendency to reduce LVET, relatively stable values for LVET rel. and LVET· HR accompanied by increased MSER and blood pressure. This adaptive response due to observed parameters were related not only with increasing HR but also with increased contractility of the myocardium as there was age related increase in systolic volume. The relationship between LVET and HR with increasing age became less pronounced and there was a decrease in LVETI.

During exercise with stepwise increased workloads, mechanical systole at first decreased lineary with increasing HR, but at high HR demonstrated a significant curvilinearity with successively smaller decrease of mechanical systole [4]. In our study relationship between HR and the last level of submaximal workload of the bicycle exercise with increasing age became steeper, more pronounced, at the ages 14-16 in girls and 13-16 in boys. With every 50 watt increase boys revealed lower HR if compared with girls. Similar findings that girls had higer HR in submaximal exercise was reported by [1, 5]. Thus increasing HR due to intensity of submaximal exercies depended on age and gender. Restructuring of the cardiac cycle caused by bicycle exercise of different submaximal intensity revealed shortening of LVET by 15 -30% and LVET rel. represented 0.50 of the duration of the cardiac cycle. Duration of the cardiac output prolongated by 30-50% if compared with data at rest. Revealed decrease in LVET with age did not combine with significant changes in LVET rel. Weak correlation between LVET and HR at the last workload of exercising, lowered regression coefficient (*b*) and values for LVETI during observed period disagreed with submaximal exercising data for man demonstrated by [4] when higher correlation coefficients were present. In our study gender differences revealed relatively higher regression coefficient and LVETI in males if compared with females over the observed period.

In conclusion, the gradual increase of duration of the cardiac cycle with age at rest was followed by the corresponding prolongation of ejection period of left ventricle and a tight relationship between left ventricular ejection time and heart rate not reaching the level for adults. Adaptive response to bicycle exercise in supine was characterized with less pronounced dependence of left ventricular ejection time from heart rate if compared with adults. The results of the present investigation suggested that subjects of higher cardiovascular fitness displayed slightly longer ejection times, larger systolic volumes and faster mean systolic ejection rates at the rest as well as at the same exercises heart rate.

References

1. Gutin B et al (1997). Children and exercise XIX: 460-4
2. Kasih EN, Hofman W (1984). Klin Padiatr196:360-6
3. Lewis RP et al (1977). Circulation
4. MaherJT et al (1974). Am Heart J 87:334-42
5. Mahon AD et al (2001). Pediatric Exercise Science 13: 319
6. Mobert J et al (1997). Children and exercise XIX: 429-33
7. Solomon SB et al (1999). Am J Physiol277: H 262-7
8. UlmerHE et al (1982). Basic Res Cardiol 77:197-212
9. Vitolo E et al (1991). Acta Cardiol 46:631-40
10. WeisslerAM et al (1961). Am Heart J 62:367-78
11. Wolf LA et al (1978). J Appl Physiol:Respirat Environ Exercise Physiol 44:55-8

WHOLE BODY PROTEIN TURNOVER IN YOUNG TRAINED GYMNASTS AS COMPARED TO NON ACTIVE GIRLS MEASURED WITH [^{15} N] GLYCINE

***Boisseau Nathalie*[1]*, Persaud Chandarika*[2]*, Jackson Allan*[2]*, Poortmans Jacques R*[3]**

[1] *Laboratoire de la Performance Motrice, UFRAPS de Poitiers, Poitiers, France*
[2] *Institute of Human Nutrition, University of Southampton, Southampton, United Kindon*
[3] *Institut Supérieur d'Education Physique et de Kinésithérapie, Université Libre de Bruxelles, Bruxelles, Belgium*

Keywords: children, exercise, protein turnover

Introduction

Nowadays, health professionals encourage children and adolescents to increase physical activity to prevent the emergence of obesity linked to inactivity in this population. Although the positive effects of increased physical activity are well known in adults, most of the physiologic consequences of regular exercise in young subjects are still unexplored. Childhood and adolescence is a time of important growth and development which induce elevated energy intake and nutrients needs (National Research Council Food and Nutrition Board 1989). Protein metabolism play here an important role. It has been shown in adults that protein oxidation increases with exercise and training (Gontzea et al. 1974, Poortmans 1993, Lemon 1994) and acute changes in activity may be associated with differences in protein kinetics in childhood (Bolster et al, 2001), but there is a lack of information concerning the habitual protein needs in children and adolescents regularly involved in physical activity. The purpose of this study is to estimate if regular intensive physical activity may alter protein turnover in children. To this end, whole body protein turnover was measured non invasively in competitive young gymnasts and non active girls of 7-12yr using the end product method with [^{15} N] glycine.

Methods

Twenty young girls participated in this study. The subjects were classified into two groups comprising 10 competitive gymnasts and 10 non active girls. All the gymnasts had been training from 5 to 9 h a week for at least 6 months. Ethical approval for the study was received from the Ethical Committee of the Université libre de Bruxelles.

Protein turnover: Nitrogen flux (Q), whole body protein synthesis (PS), protein breakdown (PB), and net protein balance (NB) were determined in young gymnasts and control girls from a single oral dose of [^{15}N] glycine and collecting total urine output (Jackson et al. 2000). Enrichment was measured in urinary ammonia and urea. This method is non invasive and does not induce any risk for the children.

Protein turnover studies started at night to minimise the effect of physical activity. The following day, all the subjects were predominantly non active and food intake were all recorded. Just before bedtime, children provided a baseline "spot" urine sample for ^{15}N-ammonia and ^{15}N-urea background and then emptied their bladders. Then, the procedure required the ingestion of a single oral dose of ^{15}N-glycine (2mg/kg body; 98 + atom % enrichment; Cambridge Isotope Laboratories, Andover, USA) dissolved in orange juice or water. The rate of nitrogen excretion and the total amount of ^{15}N excreted either as ammonia or as urea, for a period of 12h. Labelled ammonia is completely excreted after 12h. For labelled urea, that excreted as 12h is taken as that available for excretion over 12h although some has been retained within the body pool at 12h and is only excreted more slowly over the next 12h. For this reason, and to avoid having to take a sample of blood, the urine collection was thus performed up to 24h after the initial dose of tracer. The urine was acidified with 10ml HCL, 6mol/L, the volume measured and an aliquot was stored at -20°C.

Diets: The habitual dietary intake of each subject was assessed using a 7 day food record collected by questionnaires and interviews. Nutritional intakes were obtained using a computerised dietary analysis (Prodiet 5.2, France). Nitrogen balance was calculated from daily protein intake and urine nitrogen excretion (micro-Kjeldhal method, Fleck et Munro 1965) a week before the protein turnover protocol.

Calculations: Flux was calculated by the method of Waterlow et al. 1978 and Fern et al. 1985:

Q = rate of nitrogen excretion x (dose of 15N / amount of 15N excreted over 12h)

Q was determined from urinary ammonia and urea. Results from both ammonia and urea were averaged.

Rates of protein synthesis and breakdown in the whole body were derived from the expression:

Q = E + PS = I + PB, where E is the rate of excretion of total nitrogen in urine, PS is the rate of whole-body protein synthesis, I is the rate of intake from the diet and PB is the rate of whole-body protein breakdown. All units are expressed as g of nitrogen/24h. A factor of 6.25 was used to convert g of nitrogen into g of protein. The net protein balance (NB) corresponds to PS-PB.

Statistics: Statistical analysis to compare the control group and the gymnasts was performed using the Wilcoxon-Mann-Whitney *U*-test. All data were presented as means and standard errors of the mean (SEM). P values < 0.05 were considered statistically significant.

Results

The morphological data of the two groups are shown in table 1.

Table 1. Morphological characteristics of the subjects. Values are mean ± SEM.

Subjects	Age (yr)	Height (cm)	Body mass (kg)	Fat free mass (kg)	Fat mass (%)	BMI ($kg.m^{-2}$)
Gymnasts (n = 10)	**10.3** (0.5)	**136** (2)	**30** (1.8)	**25.6** (1.4)	**14.3** (0.6)	**16.0** (0.6)
Controls (n =10)	**9.4** (0.6)	**138** (4)	**32.6** (2.5)	**26.6** (1.9)	**18.2 *** (0.6)	**17.0** (0.8)

**: p< 0.01between controls and gymnasts.*

Diets: The results showed that most of the nutritional status of the two groups was similar. The average energy consumption was insufficient in all subjects to cover the energy expenditure (±1650 kcal/day). Their diet was near to the recommended allowances for total carbohydrate intake (53% instead of 55-60% in the gymnast group) but widely inappropriate for simple sugar fraction (26% of total energy intake instead of 10% recommended). As well, lipid fraction was too high (35% of total), in addition to inadequate polyunsaturated acid fraction. The protein distribution was lower in the gymnast group and appeared less (11.5%) than the recommended value (15%). Insufficient intakes were registered for several minerals and vitamins (calcium, phosphorus, magnesium, iodine, zinc, vitamins B5, A, E) and fibres in controls and gymnasts. Both groups showed a positive nitrogen balance with a mean protein intake of 1.39 $g.kg^{-1}.day^{-1}$ in all subjects (1.34 $g.kg^{-1}.day^{-1}$ and 1.43 $g.kg^{-1}.day^{-1}$ in gymnasts and controls respectively, p =NS) (Figure 1).

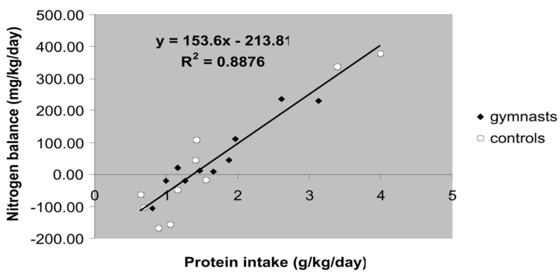
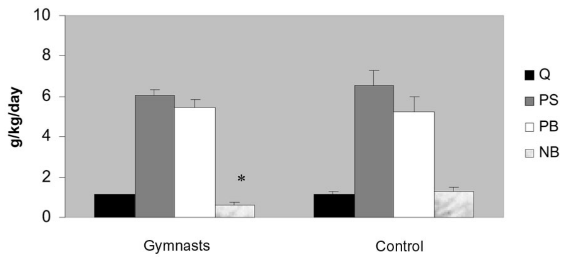


Fig. 1: Daily nitrogen balance ($mg.kg^{-1}.day^{-1}$) and protein intake ($g.kg^{-1}.day^{-1}$) relationship in gymnasts and controls.

Protein turnover (figure 2)**:** Q was 1.13 (± 0.05) and 1.15 (±0.12) g $N.kg^{-1}.d^{-1}$ in gymnasts and control girls, respectively (p = NS between the groups). PS was calculated at 6.06 (± 0.27) in gymnasts and 6.53 (± 0.74) g $N.kg^{-1}.d^{-1}$ in controls. PB was estimated to 5.45 (± 0.38) and 5.27 (± 0.74) g $N.kg^{-1}.d^{-1}$ in gymnasts and in controls, respectively. Despite no statistical differences for PS and PB between the two groups, the net protein balance in controls (expressed in $g.d^{-1}$, g. d^{-1} per $kg.BW^{-1}$ and $kg.FFM.^{-1}$) was twice as compared to gymnasts (p< 0.01).

*Fig. 2: Protein metabolism in gymnasts and controls. *: p <0.01 between both groups.*



Conclusion

Based on 7 day food record questionnaire, the present study indicate that the total daily energy intake and the nutritional status of the two groups were not appropriate to cover growth, maturation and exercise needs. Specific recommendations should be addressed to children, parents and coaches who are aware of the dietary rules of individuals involved in physical practice.

The amount of food consumed by our subjects indicates a protein need of 1.39 $g.kg^{-1}.day^{-1}$ in non-active girls and competitive female gymnasts. This result suggests a higher protein need (± 35%) than the usual Recommended Dietary Allowances proposal. As already stipulate by Boisseau et al. (2002) in adolescent soccer players of 15 yr, growth, development and exercise could increase the real protein requirement in a young well fed population. However, in our study, the higher protein need does not seem to be strictly related to the energy expenditure imposed by the exercise training in competitive female gymnasts, rather than a higher need for protein for metabolism, as shown by similar protein turnover in both groups. Indeed, whole body protein turnover in young trained gymnasts as compared to non active girls indicated no significant difference in nitrogen flux, protein synthesis and protein degradation. The only difference between both groups appears in the net protein balance which was twice in controls as compared to gymnasts. The lower accretion in gymnasts could be due to a significant protein oxidation induced by physical activity and/or to a higher nitrogen ingestion in control subjects the day of the protocol.

The present study postulates that despite their specific training status, young gymnasts do not need extra protein intake as compared to non active girls to meet growth, maturation and exercise needs.

References

Boisseau N, Le Creff c, Loyens M, Poortmans JR (2002). Eur J Appl Physiol, 88, 288-293.

Bolster DR, Pikosky MA, McCarthy LM, Rodriguez NR (2001). J

nutr 131: 2659-2662.
Fern EB, Garlick PJ, waterlow JC (1985). Clin Sci, 271-282.
Fleck A, Munro HN (1965). Clinica Chimica Acta, 11, 2-12.
Gontzea I, Sutzescu R, Dumitrache S (1974). Nutr Reports Int 10: 35-43.
Jackson AA, Duggleby SL, Grove G (2000). Eur J Clin Nutr 54, 329-336.
Lemon PW (1994). J Sports Sci 12: S17-S22.
National Research Council Food and Nutrition Board (1989) Commission on Life Sciences Recommended Daily Allowances (RDA), 1Oth ed. National Academy Press, Washingthon, DC.- Poortmans JR (1993) Protein metabolism. In Principles of Exercise Biochemistry, Poortmans JR (ed), 2nd, rev ed. Med Sports Sci Basel: Karger, vol 38, pp 186-229.
Waterlow JC, Golden MHN, Garlick PJ (1978). Am J Physiol, E165-E174.

STABILITY AND CHANGE OF 3000M RUNNING PERFORMANCE IN YOUNG WELL TRAINING MALE MIDDLE DISTANCE RUNNERS

***Bragada José*[1]*, Santos Paulo*[2]*, Maia José AR*[2]**

[1] *Higher School of Education, Polytechnic Institute of Bragança, Portugal*
[2] *Faculty of Sport Sciences and Physical Education, University of Porto, Portugal*

Keywords: performance, distance runners, tracking

The study of changes in performance over time can be made by identification of the occurred alterations in the average values and researching aspects of the stability or tracking. Some available research in literature, although appreciating the evolution of the performance in the 3000m does not appreciate its stability. Therefore the purpose of the present study was to document changes in 3000m running performance in well trained distance runners throughout two following seasons.
18 Portuguese male well trained distance runners showed at beginning of the study the following characteristics: over 2 years regular training; 20(3) years old; 64,1(6,2) Kg of body mass; 175(5) cm of height; VO_2max =70,4(9,0) ml/kg/min; 3000m running performance was evaluated in each runner 6 times throughout 2 following years. A multivaried statistical procedure was used (General Linear Model – repeated measures, SPSS 10,0), for asserting the alterations in function of time. The index Kappa (k) of Cohen was used for the study of the tracking (Longitudinal Data Analysis software).
The results indicate that there was no significant change in mean values of 3000m running performance, during six evaluations accomplished over two following seasons [lambda of Wilks =0,55; $F(5,13)=2,146$, $p=0,124$]. This means the absence of variation of the average values in this period. The study of the tracking of performance was made by determination of index Choen's k. The value of k for the group was excellent (k=0,79), i.e., the subjects had strong probability of keeping in the same distribution track along the time. This result is in agreement with Houmard e col (1991) who found a relative stability in running performance over time. However, in other studies there was observed significant changes in middle distance running competitions (Tanaka e col 1984, 1986; Svedenhag J, Sjodin 1985; Jones 1998). A global analysis of the results of these researches allows us to emphasize that an increase in performance can happen but, generally, is associated with an improvement in training loads. However, after some years of training, this increment can't be kept systematically but only in determined phases of the year or an athlete's career.
In present study the greater number of subjects show alterations in 3000 running time lower than 3% (~15s), in agreement with above values of different rankings. This value, even so relatively low if considered in statistical terms, can be substantial in terms of classification in the ranking performance.
In conclusion we found that: (i) the average values of 3000m running performance remain stable over six time points; (ii) there occurred a strong stability of the running performance in function of time.

PEAK BLOOD LACTATE AND MATURATION IN 11-13 YEAR-OLD MALE SWIMMERS

Alves Francisco, Noronha Cecília, Vieira Filomena, Fragoso Isabel

Faculty of Human Kinetics, Technical University of Lisbon, Portugal

Keywords: lactate, testosterone, swimming

Changes in peak blood lactate concentration with age may provide an indication of how children's glycolityc capacity changes with growth and development. Metabolic response to exercise during adolescence are thought to be closely related to the elevated levels of circulating androgen hormones. Eriksson et al., (1974) suggested that the evolution of glycolytic capability is linked to hormonal changes. Recent studies, however, failed to confirm this hypothesis. The aim of this study was to determine the influence of maturity on peak blood lactate concentration and short distance performance in circum-pubertal swimmers.
11 well trained male swimmers participated in this study (Agec: 12.77±0.66 years, height: 156.49±10.549 cm, body mass: 49.72±10.03 kg, %FAT: 20.76±10.50). Each subject performed 3 x 200 m front crawl repeats with 15 min of rest, at a velocity corresponding to 70%, 80% (v95) and 100% (Vmax) of best performance in the 200 m freestyle race. The last repeat was broken in 4 x 50 m with 10" rest to ensure for maximum effort. Two minutes after the completion of each repeat a blood micro sample was drawn from the earlobe for lactate concentration measurement, using the Accusport™ Portable Lactate Analyzer. Values obtained after the last bout was considered as peak lactate concentration (LaPeak). Serum levels of total testosterone (Tes) were determined by a immunoanalysis technique (enzyme linked fluorescent assay, Vidas®/Biomérioux). Skeletal age (AgeS) based on radiographs of the hand and wrist bones was assessed acording to Tanner-Whitehouse III Method (TW3). LacPeak was lower than the usually found in adult swimmers (10.08±1.46 $mmol.l^{-1}$) and showed a strong correlation ($r = 0.656$; $p < 0.03$) only with Vmax. However Vmax was slightly related to penis size and very significantly to chronological age. Tes (1.71±1.61 $nmol.l^{-1}$), as expected, was well correlated with AgeS ($r = 0.619$; $p < 0.04$) and also with height, arm span and biacromial breadth. This group of 11 swimmers included 5 late-maturing boys (Tes: 0.98±1.15 $nmol.l^{-1}$; LaPeak: 9.94±1.58 $mmol.l^{-1}$) e 2 early-maturing boys (Tes: 3.62±0.92 $nmol.l^{-1}$; LaPeak: 10.35±0. 64 $mmol.l^{-1}$), categories defined as,

respectively, 1 year behind or ahead AgeS for Agec.
Factors other than maturation during puberty seem to influence peak blood lactate responses, perhaps linked to the amount of active muscle mass which increases throughout childhood into adulthood and is strongly activated by chronic exercise.

USING DATA FROM THE CRITICAL VELOCITY REGRESSION LINE FOR THE ESTIMATION OF ANAEROBIC CAPACITY IN INFANT AND ADULT SWIMMERS

Soares Susana, Vilar Sónia, Bernardo Carla, Campos Ana, Fernandes Ricardo, Vilas-Boas João P

Faculty of Sport Sciences and Physical Education, University of Porto, Portugal

Keywords: swimming, aerobic capacity, anaerobic capacity

Introduction
Comparatively with estimations made over the aerobic system, the evaluation of the anaerobic energetic system, namely in pre-pubertal athletes, is rather difficult and the results produced are limited (Rowland, 1996). Evaluation of anaerobic response to the effort of young ages brings us methodological and, especially, ethical problems. So, controlling the changes that occur in anaerobic system due to the training is very difficult in any sport. The best measures for the best results are the ones obtained in real ecological conditions and, most of the times, its very difficult to work with the evaluation instruments both along the swimming pool or inside the water. Therefore, easy and non invasive reliable methods are needed for training evaluation and advice, and are permanently searched by scientists and coaches.
According to Wakayoshi et al. (1992a,b; 1993) the maximal velocity that can be sustained without significant participation of the anaerobic system (critical velocity) and the maximal distance that can be swam using anaerobic system can be determined from the regression line computed between competition distances and the correspondent swimming times. This regression is defined by an equation type: $y = ax + b$. The "a" value, or the slop of the line, or the critical velocity (CV) value, has been successfully used and is accepted as an indicator of individual swimmers aerobic capacity (Wakayoshy, 1992a, b; Vilas-Boas et al.,1997; Fernandes and Vilas-Boas, 1998; Rodríguez et al., 2002). The "b" value, or the y–intercept, has been pointed out as a possible indicator of swimmers anaerobic capacity (Jenkins and Quigley, 1991; Hill et al., 1995). Despite some authors defend that "b" value is not a useful tool for anaerobic training control (Dekerle et al., 2002) that possibility deserves to be very well and fully explored, once considered the difficulties in studding swimmer's anaerobic performance, especially for the youngest ones.
The purpose of this work was to analyse "b" values in swimming as indicators of individual swimmers anaerobic capacity, relating: the "b" distance to the correspondent maximal blood lactate (b[La$^-$]) values and with the b[La$^-$] after a 100 m maximal swimming test (Study one); the "b" value with two anaerobic tests performed on *Biokinetic Swim Bench* (*BSB*) - one arm pull and 45 sec arm pull (study two); the changes in "a" and "b" values with the training process of infant and adult swimmers (study three).

Methods
We performed three studies over a general sample of 39 swimmers of two age groups, infants (10-12 years old) and adults (15-21 years old), of both genders.
The maturational status of the infant swimmers was determined using Tanner scales for sexual maturation (penis and breast size) (Tanner, 1962) and all the children were classified as pre-pubertal.

Study one
For the determination of the individual "b" value, 37 subjects (12 infant males, 6 infant females, 11 adult males and 8 adult females) performed two maximal efforts of 50 m and 400 m front crawl swimming (youngest group) and 50 m and 800 m (older group). The tests were performed in the same day, infants in short course and adults in long course swimming pools. The subjects perform each test starting within water. The individual distance values used in tests and the correspondent times were plotted in a regression mode.
On day after, rest b[La$^-$]) were firstly determined. After that, each swimmer performed the "b" predetermined distance using maximal front crawl swimming. The start jump was cross out again, and the "b" distance start to be measured only after the swimmers foot cross over the 5 m swimming pool mark, in order to have real maximal swimming over the total "b" distance performed. b[La$^-$]) after swimming were collected from finger tip at 1, 2, 3 and 5 min after effort, for determining maximal value. All the lactate values pre and post efforts were determined using an automatic analyser *Accusport*, from *Boehringer Mannheim*.
Each swimmer has even performed a single bout of 100 m front crawl swimming for determination of post effort maximal b[La$^-$]) value, starting within water. Blood collections were obtained and analysed as described.
All the tests were performed after a light aerobic warm up and each swimmer was informed of the importance of swim all the distances at the maximal velocity.

Study two
For the determination of the individual "b" value, 21 subjects (10 infant males, 4 infant females, 2 adult males and 5 adult females) performed three maximal efforts of 50 m, 100 m and 400 m front crawl swimming (youngest group) and 50 m, 200 m and 800 m (older group). The tests were performed in two consecutive days (short and long distance in first day and median distance in second day), in short course swimming pool. The subjects performed each test starting within water. The individual distance values used in tests and the correspondent times were plotted in a regression mode. The first test was performed 10 min after a light aerobic warm up and each swimmer was informed of the importance of swim all the distances at the maximal velocity. The rest time between the two tests performed in the first day was of, approximately, 7 min. After a minimum interval of 48 hours, each swimmer performed, two anaerobic tests on a *Biochinetic Swimming Bench (Sport Fahneman, Germany)*. The first one consisted on a maximal 45 sec effort performed in simulated front crawl swimming to determine individual mean power. The second test consisted on an isolated maximal simultaneous arm pull to determining the

individual peak power. The first test was preceded by a 2 min warm up at 60% of maximal 100 m front crawl stroke rate. The level of resistance of the machine was established in level 3 for infant group and level 4 for adults. The rest time between the warm up and the first test was of 10 min, and between the two *BSB* tests was not inferior to 7 min. All the swimmers were informed of the necessity of apply the maximal force during the tests. The results showed on machine digital display have been video recorded for posterior registration of the data. The start and the end of the tests were signed by voice. Voice was always used for motivate the swimmers during the 45 min test.

Study three
For the determination of the individual "b" value, 39 subjects (15 infant males, 8 infant females, 8 adult males and 8 adult females) have performed three maximal efforts of 50 m, 100 m and 400 m front crawl swimming (youngest group) and 50 m, 200 m and 800 m (older group). The tests were performed in two consecutive days (short and long distance in first day and median distance in second day). Test distances were performed in short course (infant) and long course (adults) swimming pools. The subjects performed each test starting within water. The individual distance values used in tests and the correspondent times were plotted in a regression mode. The first test was performed 10 min after a light aerobic warm up and each swimmer was informed of the importance of swim all the distances at the maximal velocity. The resting time between the first day tests was of, approximately, 7 min.
The swimmers were evaluated, as described, in four moments during the second training macro cycle of the season. The first evaluation was conducted during the transition period that occurred between the first and the second macro-cycle (M1). The second, third and fourth evaluations were made, respectively, after the general preparation period (M2), the specific preparation period (M3) and the competitive period (M4).
In all three studies chronometric data was obtained using a manual chronometer.
Statistical procedures were performed on *SPSS 11.0* for *PC* computers and consisted, firstly, on an exploratory analyse of the data collected. All the variables, in all studies, have a normal distribution. The means and standard deviations were determined. For means comparisons ANOVA tests were used and *Bonferroni pot-hoc* tests were performed. The level of significance was established at 5%. For correlation studies *Pearson coefficient* (*r*) was determined.

Results

Study one
The results of this study are presented in table I.

Table I. Mean value and standard deviation of "b" distance ("b") and r values obtained between "b" distance and b[La^-] correspondent to "b" (r "b" / [La^-]$_b$), "b" distance and net b[La^-] correspondent to "b" (r "b" / [La^-]$_{netb}$), "b" distance and b[La^-] correspondent to 100 m (r "b" / [La^-]$_{100}$), and "b" distance and net b[La^-] correspondent to 100 m distance (r "b" / [La^-]$_{net100}$), for each group studied.

	"b" (m)	r "b" / [La^-]$_b$	r "b" / [La^-]$_{netb}$	r "b" / [La^-]$_{100}$	r "b" / [La^-]$_{net100}$
Adult males	11.17 ± 1.59	0.600*	0.796**	0.085	0.119
Adult females	8.81 ± 2.49***	0.877**	0.549	0.192	-0.335
Infant males	12.62 ± 2.08	0.474	0.634*	0.438	0.525
Infant females	13.16 ± 1.65	-0.343	-0.279	-0.330	-0.312

** Significant for $p \leq 0.05$; **Significant for $p \leq 0.01$.; ***Significantly different from infant males and females.*

The results show that the mean "b" distances are higher for infant groups, comparatively with adults. The differences are significant between infant and adult female groups. The infant female group is the one who presents the highest registered mean value.
The most interesting correlation results were found for adult male and female subgroups between "b" and [La^-]$_b$. [La^-]$_{netb}$ seams to reveal a good correlation with "b" distance for adult and infant male groups.
For studding the results of each age group, independently of the gender, we correlated the "b" values with [La^-]$_b$. The results showed a very low value for infants ($r = 0.29$), and a higher one for adults ($r = 0.69$). In what concerns the [La^-]$_{net100}$, the values obtained for both groups were very lower ($r = 0.28$ for the older and $r = 0.30$ for the youngest ones).

Study two
Table II shows the mean estimated "b" values and the results of the correlations computed between those values and the two anaerobic BSB tests performed by the swimmers.

Table II. Mean "b" values and r-values of "b" individual values with performance on one arm pull and 45 sec arm pull tests for each age group.

Correlations	Infant swimmers "b" = (14.83 ± +2.29)	Adult swimmers "b" = (14.06 ± 4.22)	Total
One arm pull and "b"	r = - 0.553*	r = 0.528	r = 0.075
45 sec pull and "b"	r = - 0.121	r = 0.426	r = 0.109
One arm pull and 45 sec pull	r = 0.659*	r = 0.967*	r = 0.968*

**Significant for $p \leq 0.05$.*

The mean "b" value of the older swimmers its of the same magnitude as the one of the infant and there was a higher variability of the adult group values. No significant differences were found.
The two anaerobic tests performed on BSB are highly and significantly correlated for adults than for infant swimmers.
The infant swimmers show a negative and significant correlation between the "b" distance and the one arm pull anaerobic test. The same negative relation, but non-significant, as been observed for the 45 sec test. The adult swimmers have positive but non-significant correlations, with the same tests.

Study three
Figure 1 show the CV and the "b" variation observed along the training macro-cycle for each age and gender groups.

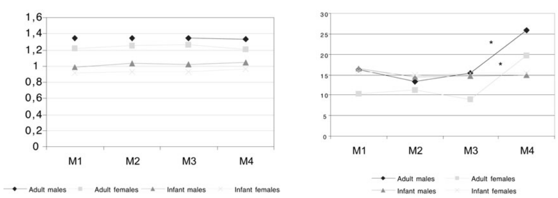


*Fig. 1. CV and "b" changes for each age group and gender during the studied macro cycle. * significant for $p \leq 0.05$. Legend: M1- Moment one; M2 – Moment two; M3 – Moment three; M4 – Moment four.*

The results showed very smooth alterations in CV mean values along the training macro cycle. "b" mean values changed considerably more and tended to be higher for infant group comparatively with adults, exception made for the fourth moment of evaluation. The variability tend to be higher in adult groups.

Discussion

Study one

Once "b" value could gave us some information about anaerobic capacity of swimmers it is not strange to expect to find any relation between this "b" distance values and the post exercise b[La$^-$]. "b" distances have revealed good correlations with [La$^-$]$_b$ and [La$^-$]$_{netb}$ for adult groups, but not for children. This pattern does not maintained for correlations with b[La$^-$]100 m front crawl. Such inconsistent results leads us to think that this method could not be the best one for the determination of anaerobic capacity, at least for children. Is it admissible that the possibly higher difficulty of the infants in pacing maximal swimming rhythms and its lower capacity for accumulate higher b[La$^-$] after exercise (Rowland, 1996) can explain these results. It is possible, too, that the distances used for regression were not the better ones for children. Balonas et al. (2002) and Soares (2002) have already showed that the "b" distances alter accordingly to the regression method used. In face of the results we can hypothesise that the use of "b" as an indicator of anaerobic capacity would be only possible for adult swimmers.

Study two

Just as we stated before, a positive correlation between "b" distance and anaerobic tests performed on BSB would be expected. However, results of this study were very inconsistent too. The two anaerobic tests performed on BSB revealed a surprisingly negative correlation with "b" distances for infant swimmers. It could be, again, a problem related with the method used for the determination of "b" in children, since adults revealed higher correlations between "b" distance and BSB tests. "b" seams to be, again, nearest of anaerobic potential of adults. Other factor that could influenced the results is the use of a BSB test of 45 sec. That may be not so well mastered by the youngest swimmers.

Study three

The CV results obtained in this study are very consistent and are in accordance to a similar study conducted by MacLaren and Coulson (1999), inclusively the non-increments in CV of older swimmers that could reflect a higher training level. The low variation of the CV for infant swimmers along to the fourth moments of the studied macro-cycle is quite unexpected once it is traditional to emphasise the aerobic training of the infant swimmers. Contrarily to CV results, "b" distances and the evolution profile during the macro-cycle were very variable. Just as has already happen in studies one and two, "b" values of infant tend to be higher than those of adults, except at the end of the macro-cycle, when competition takes place. This results are not similar to those found by MacLaren and Coulson (1999). This is an interesting result and seams to show, once again, that the "b" is more sensitive to changes in adult swimmers, when results are compared with infants.

As general discussion, its interesting to note that the different distances used in our three studies for regression lines determination produced quite similar "b" values despite previous studies have already showed that the use of different distances in regression influences "b" results (Balonas, 2002; Soares, 2002). In all the studies the "b" distances tend to be higher in infants, with the highest values observed in infant females group.

The higher "b" values for infants, specially the ones obtained for the girls, are strange when we consider the developmental physiology knowledge. Several authors (for references see Rowland, 1996) refer the lower anaerobic capacities of the children in comparison with adults and the smaller values of the females, when compared with male subjects. Our "b" results are also somewhat different from those of literature. In fact, the results found in other studies are somewhat inconsistent. Wilson and Sleivert (1996) have obtained "b" values ranging from 10 to 25 m for top-level swimmers. Wakayoshi at al. (1993) in a study with trained swimmers found values ranging between 17 and 31 m and Vilas-Boas et al. (1997) found a mean value of "b" of 19,33 m. The most similar values to those obtained in our studies are the ones published by Hill et al. (1995). Nevertheless, these authors registered a mean value of 10,2 and 15,7 for young and older swimmers, respectively, exactly in opposition to our findings on age group differences.

Conclusion

In study one, results pointed out that the "b" distance is correlated with the correspondent b[La$^-$] for the older swimmers. A very low correlation has been found with the 100 freestyle b[La$^-$] values for adult and infant swimmers. In study two the higher correlation result between "b" and BSB tests was found for adult groups and only for one arm pull test. In study three, results showed that during the training macro cycle, "b" values seem to change considerably in opposition with "a" values. The "b" values have risen at the end of the macro-cycle for the adult swimmers and were kept stable for infants.

In general, "b" values seem not to provide consistent information's about the anaerobic performance of swimmers, irrespectively of the age group considered. Although, results of older swimmers seams to be more coherent than those obtained for infants.

References

Balonas A et al (2002. Congresso Desporto, actividade física e saúde.
Dekerle J et al (2002). Int. J. Sports Med., 23: 93-98.
Fernandes R, Vilas-Boas JP (1998). Biomechanics and Medicine in Swimming VIII: 233-238.
Hill DW et al (1995). Paediatric Exercise Science, 7: 281-293.
Jenkins DG, Quigley BM (1991). Ergonomics, 34 (1): 13-22.
MacLaren D, Coulson M (1999). Biomechanics and Medicine in Swimming VIII: 227-231.
Rodríguez F et al (2002). Biomechanics and Medicine in Swimming.
Rowland TW (1996). Human Kinetics.
Soares S et al (2002). Congresso Desporto, actividade física e saúde..
TannerJM (1962). Blackwell Scientific Publications.
Vilas-Boas JP et al (1997). 9th European Congress on Sports Medicine.
Wakayoshi K et al (1992a). Eur. J. Appl. Physiol., 64: 153-157.
Wakayoshi K et al (1992b). Int. J. Sports Med., 13: 367-371.
Wakayoshi K et al (1993).Eur. J. Appl. Physiol., 66:90-95.
Wilson B, Sleivert G (1996). New Zealand Swimming Academy High Performance Centre.

ANAEROBIC PERFORMANCE ON PRE AND POST-PUBERTAL BASKETBALL PLAYERS

Santos Amândio, Batista RCJ, Fontes Ribeiro CA

Laboratory of Biokinetics, Faculty of Sport Science and Physical Education, University of Coimbra, Portugal

Keywords: anaerobic, peak power, force velocity test

Documentation about the development of short-term power output in young people is scarce compared with the abundant literature describing the development of aerobic power. There are intrinsic problems with determining peak power from the Wingate test, particularly with regard to optimal braking force, which was originally set to optimise mean power. The force velocity test (FVT) overcomes this problem as several sprints are completed against different braking forces. By plotting the highest power achieved for each of these bouts against the respective braking force the resulting parabola enables peak power (PPopt) to be calculated accurately for each subject. The aim of this study was to characterise the anaerobic performance obtained through FVT, vertical jump test and velocity running test in a pre and pos-pubertal basketball players population compared with a control group.
Written informed consent to participate was obtained from 132 boys subdivided in four groups (pre and post-pubertal basketball athletes and control groups). Basketball players ages are: 10.7 ± 0.8 and 17.1 ± 1.0 yrs old; control groups ages are: 10.8 ± 0.5 and 17.4 ± 1.0 yrs old. Basketball players body masses are: 43.06 ± 10.41and 74.28 ± 11.80 kg; control groups masses are: 37.35 ± 4.58 and 64.94 ± 8.61kg. Basketball players stature are: 147.59 ± 7.64 and 181.44 ± 8.12 cm; control group statures are: 142.45 ± 4.22 and 171.84 ± 4.46 cm. The FVT consisted of 4 to 6 sprints (on a Monark 824E cycle ergometer) lasting 5 to 8s against a range of randomly presented resistances (75 to 155 g·kg-1). PPopt was determined according to the procedures described by Winter et al. (1991).
FVT PPopt (in w) squat jump height (in cm) and 10 meter velocity running (in m/s) were the followings for pre and post-pubertal basketball players / control groups. FVT: 333.71 ± 74.91 and 928.88 ± 157.12 W / 315.15 ± 57.95 and 806.26 ± 139.97 W ; squat jump height: 23.3 ± 2.1 and 37.6 ± 4.3 cm / 21.2 ± 2.0 and 31.2 ± 3.1cm; 10 meters velocity running: 4.26 ± 0.45 and 5.19 ± 0.33 m/s / 3.98 ± 0.29 and 5.07 ± 0.27 m/s).
Basketball players are significantly heavier and taller than control groups (pre and post-pubertal). In relation to FVT PPopt, post-pubertal basketball players are significantly powerful; in squat vertical jump height basketball players group jump significantly higher (pre and post-pubertal); and in 10 meter velocity running, only pre-pubertal basketball players are significantly faster.

TIME TO PEAK TORQUE FOR KNEE AND ELBOW EXTENSORS AND FLEXORS IN CHILDREN, TEENAGERS AND ADULTS

De Ste Croix Mark, Deighan Martine, Armstrong Neil

University of Exeter, UK

Keywords: isokinetic, time to peak torque, muscle

The aim of this study was to examine the age and sex associated development in muscle contraction time of the knee and elbow extensors and flexors using time to peak torque data. 137 subjects participated in this study consisting of three groups aged 9/10 y, 16/17 y and 21+y. Isokinetic concentric knee and elbow extension and flexion were measured using a calibrated Biodex system 3 and time to peak torque determined. ANOVA identified significant ($p<0.05$) interaction effects for stature and body mass. A main effect for group for knee extension (range 0.20-0.26s) and elbow flexion (range 0.33-0.40s) was identified. For elbow flexion the 16/17 y-olds demonstrated significantly faster time to peak torque than the 9/10 y-olds and adults. No significant interaction or main effects for knee flexion (range 0.0.19-0.23s) or elbow extension (range 0.40-0.44s) were observed. Pearson product moment correlation coefficients identified no significant relationship between time to peak torque and peak torque for knee and elbow extensors and knee flexors in all groups. A significant negative correlation ($p<0.05$) was found for the elbow flexors for both 9/10 y-olds and adults for females but not males. To conclude, no sex differences in contractile speed of the knee and elbow extensor and flexor muscles were found. Age related changes in contractile speed appear to be muscle group and muscle action specific and highlight the insecurity of making assumptions between muscle groups and actions.

PREDICTION OF SKATING PERFORMANCE WITH OFF-ICE TESTING IN MALE AND FEMALE ICE HOCKEY PLAYERS

Bracko Michael, Fellingham Gilbert

Institute for Hockey Research, Canada

Keywords: ice hockey, fitness, gender

Introduction
Investigations to find the predictors of skating performance have been done with males and females separately, in different studies (Bracko and George, 2001 and Bracko and Fellingham, 1997). No research has examined predictors of skating performance with the sexes combined. This can useful information because at young ages, males and females will play together, or against each other. Bracko and Fellingham (1997) found that vertical jump height and push-ups predicted acceleration and speed in young male ice hockey players age 10 - 14 years. Bracko and George (2001) found 40-yard (36.5-m) dash time to predict speed in 8 - 16 year old female ice hockey players. The purpose of this study was to find the off-ice fitness variables that predicted skating performance in male and female ice hockey players.

Methods
Eighty-three male and female (38 males and 45 females) ice hockey players were tested. Average age of subjects equals 12.04 years. Regression analysis was used to find the predictors of skating performance. Demographic data included: age and playing experience. Off-ice fitness was measured with the following evaluations: body mass, standing height, vertical

jump height, maximum push-ups and sit-ups per minute, sit and reach flexibility, and percent body fat. Skating performance was measured with the following tests: 6.10-m acceleration, 44.80-m speed, and agility.

Results
Regression analysis found the following prediction equations to be significantly ($p<.05$ for each variable) related to the outcome variables: Acceleration = 2.00565 - 0.00186 x height (cm) - 0.00361 x vertical jump (cm) (adjusted R-Squared = 0.2232), Speed = 10.44921 - 0.01471 x height (cm) - 0.02180 x vertical jump (cm) (adjusted R-Squared = 0.4950), and Agility = 16.08844 - 0.02739 x height (cm) - 0.84075 x gender (males) (females = 1, males = 2) (adjusted R-Squared = 0.4288). These results indicate that a subjects' standing height, and vertical jump height, predicted skating acceleration and speed. Standing height and gender predicted skating agility.

Conclusions
Standing height, and vertical jump height, predicting acceleration and speed indicate taller players, who have a higher vertical jump, can accelerate faster from a static start and skate faster over 44.80-m. Standing height and gender predicting agility indicate taller males have better skating agility. Although no cause-and-effect can be established, the results suggest vertical jump may be important when training young male and female hockey players on the same team. Once predictor variables are established, training studies can be designed to evaluate the effect of off-ice training on skating performance. The importance of conducting evaluations that are related to skating is because professional coaches, general managers, and scouts consider skating ability a significant factor when selecting players for a team (Hansen and Reed, 1979).

THE INFLUENCE OF A 20 WEEK EXERCISE TRAINING PROGRAMME ON AEROBIC FITNESS AND SUBMAXIMAL BLOOD LACTATE LEVELS IN 13-14 YEAR OLD GIRLS

Stoedefalke Kerstin, Armstrong Neil, Welsman Joann

University of Exeter, UK

Keywords: exercise training, adolescent girls, blood lactate

This study examined the effect of a 20 week exercise training programme on aerobic fitness and blood lactate levels in 13-14 year old girls (experimental group =22, control group =19). Peak oxygen uptake (peak) and submaximal blood lactate levels were measured at baseline and following the 20 week programme. Training for the experimental group included three aerobic exercise sessions per week for 20 minutes at an exercise intensity of 75-85% of peak heart rate. Training sessions were rigorously monitored by all subjects wearing heart rate monitors throughout each session. The controls were instructed to continue with their daily lifestyle patterns. There were no significant ($p>0.05$) differences over time between the groups for peak. A Significant ($p<0.05$) decline in submaximal blood lactate levels was observed in the experimental group after the 20 week programme. These findings suggest that a 20 week aerobic training period produces no significant changes in peak aerobic fitness however a significant decline in submaximal lactate levels was observed.

MEASUREMENT OF LOWER LIMB MUSCLE POWER OF ADOLESCENT BOYS WITH MODERATE INTELLECTUAL DISABILITY

Chia Michael YH

Physical Education and Sports Science Academic Group, National Institute of Education, Nanyang Technological University, Singapore

Keywords: muscle power, dual-energy X-ray absorptiometry, moderate intellectual disability

Introduction
Research has established the reliability and validity of laboratory and field tests for appraising cardiovascular fitness (Fernhall *et al*, 1998) and muscular strength (Stadler & Pitetti, 1996) of young people with mild intellectual disabilities (ID). Subsequent comparative studies show that young people with moderate ID have inferior cardiovascular fitness (31) and also higher levels of body fat than people without ID (Wondra, 2000). Studies of isokinetic muscle strength also show that young people with moderate ID are significantly weaker than their peers without ID (Horvat *et al*, 2000). While there are research data on the cardiovascular fitness and muscle strength of young people with moderate ID, there are apparently none on their capability to perform all-out intensity cycling exercise such as that which characterizes the WAnT. This paucity of such data might be due in part, to the lack of an establishment of a reliable test to assess this sort of exercise in young people with moderate ID. Additionally, the general perception that young people with moderate ID might not have the motivation or the ability to accomplish intense exercise also explain the lack of research attention in the area (Cormack *et al*, 2000). Nonetheless, these views might not be tenable they have not be confirmed or refuted by research data. Contrarily, it appears that young people with moderate ID are able to perform intense exercise since many of them engage in power-type training and intense exercise when they prepare for competitive events such as those featured in the Special Olympics. Previous steady-state exercise data show that boys and girls with moderate ID demonstrate greater variability in their exercise performance than their counterparts without ID (Wondra *et al*, 2000). Consequently, the reliability and short-term stability of the exercise measure (e.g. peak oxygen uptake) will be affected in repeated performances of the same test. However, the situation as it pertains to all-out intensity exercise or non-steady state exercise of young people with moderate ID needs to be examined and elucidated. High intensity exercise data are insightful as they complement the available steady-state exercise data and provide a more complete picture of the exercising person with moderate ID. Importantly, assessing the all-out intensity exercise of participants with moderate ID provides information about individuals who might be in need of remediation or intervention to address areas of deficiency. Such data also provide a reference upon which appropriate goals for improvements can be formulated for boys with moderate ID. The Wingate Anaerobic Test (WAnT) (Inbar *et al*, 1996) is by far the most popular all-out exercise intensity test.

Comprehensive reviews of the test are available (Chia, 2000). Essentially, the test involves pedalling or arm cranking for 30 seconds at an all-out intensity effort, against a constant applied force using commonly available cycle ergometers. These ergometers have be instrumented and customised to be more sensitive in many laboratories. The outcome variables of interest are PP- a power that is equivalent to two to four times that which elicits peak oxygen uptake in young people (Blimkie *et al*, 1986), and MP, a surrogate measure for local muscle endurance (Chia, 2000). Despite the WAnT being the test of choice for populations with various needs, the test has apparently not been used to assess boys with moderate ID. The reasons for this might be that researchers have not considered that young people with moderate ID are capable of performing exercise that requires an all-out effort. Therefore the purpose of the study was to examine the agreement, reliability and variation of PP and MP achieved in the WAnT in adolescent boys with moderate ID.

Methods

Participants: Participants were 19 male adolescents with ID. Both participant and parent/guardian informed consents were obtained prior to testing. The University Institutional Review Board approved the study. The sampling design was purposive (Sherill & O'Conner, 1999) in that the participants had to meet the criteria of moderate ID and come from two MINDS (Movement For The Intellectual Disabled Of Singapore) schools in Singapore. Classification of ID was determined according to the model for diagnosis by Luckasson *et al* (1992) and was determined by educational psychologists at the MINDS schools. Other criteria for inclusion in the study were: (a) participants were male between the ages of 15 and 17 years; (b) participants were free from any known physical disabilities and chronic disease; (c) participants were not taking medications affecting heart functions; and (d) participants were adept at cycling. Boys with Down Syndrome were excluded from the study since this category of intellectual disability has its own unique set of physical and mental characteristics.

Anthropometric measurements and determination of sexual maturity status: Age was computed from the date of birth and date of examination. Stature, body mass and skinfold thicknesses over the triceps and sub-scapular regions were measured by techniques described by Weiner and Lourie (1981). A male physician assessed the sexual maturity status of the participants in accordance to the criteria that are popularised by Tanner (1962). The method of Tanner involved a visual inspection of pubic hair development, with a rating of 1-5. A rating of 1 indicated pre-pubertal status and a rating of 5 indicated the attainment of sexual maturity.

Habituation to the test procedures and the test procedures: All participants reported to the laboratory on four different days, over a two-week period accompanied by two teachers from the MINDS schools. The WAnT was conducted on a friction loaded cycle ergometer (Monark 834E; Monark-Crescent AB, Varberg, Sweden) that was interfaced to a microcomputer. The ergometer was calibrated in accordance to the manufacturer's instructions immediately prior to the test series and the same ergometer was used throughout for all tests. The seat height and handle bars were adjusted appropriately for each participant, and the test resistance was set at 0.74N per kilogramme of body mass (Chia, 2000).

On the first day, participants practised maintaining a pedal cadence of 50-60 rpm, over three attempts. Participants were also taken through the warm-up protocol that was standardized as four minutes of pedaling at 50-60 rpm against a minimal applied force (with the load basket supported). This was interspersed with three, all-out intensity sprints of 2-3 seconds against the test resistance, at the end of the 1st, 2nd and 3rd minutes. After the warm-up, the participant performed two minutes of stretching that involved the quadriceps, hamstrings and groin muscles. The entire practice session took about 40 minutes.On the second day, when the standardised warm-up was completed, participants performed a15-second WAnT twice, with a recovery period of 20 minutes separating the two sprints. The WAnT was initiated from a rolling start (i.e. 50-60 rpm). Throughout the all-out cycle sprint, participants remained seated and were verbally encouraged to give a maximum effort. Immediately after the test, participants completed a cool down that involved continuous light pedaling against minimal resistance and at a self-selected pedal cadence for three minutes. On the third day, the procedures of the second day were repeated, except that the test duration was increased to 30 seconds. On the fourth day, participants completed another 30-second WAnT, and duplicate fingertip blood samples were taken at two minutes after the WAnT (Chia *et al*, 1997). The sample was immediately assayed for blood lactate (BL) concentration using a YSI 2300 Stat Plus whole blood analyzer (Clandon Scientific, Farnborough, Hampshire, UK). The analyser self-calibrated with a known concentration of lactate every five samples, and the calibration was checked regularly against commercially prepared standards of verified concentrations. Inertial corrected power data-namely, peak power (PP), and mean power (MP) that were computed over 1-second time periods (Chia *et al*, 1997) over the two 30-second WAnTs were obtained.Throughout the familiarisation sessions, the boys' teachers were present to motivate and encourage to the participants. Importantly, both the teachers and the researcher were able to elicit a maximum effort from the participants when they performed the test. The participants were deemed to be adequately habituated to the WAnT when the PP achieved in successive familiarization sessions was not significantly different between repeated WAnT trials.

Statistical analyses: Data were stored and analysed using a SPSS software programme (SPSS version 10.0). Descriptive statistics-means and standard deviations-for anthropometric variables, PP, MP and BL concentration were generated. Intra-class reliability coefficients, the 95% limits of agreement, and the co-efficients of variation for PP and MP, over the third and fourth test sessions were computed to determine the reliability, levels of agreement and variation of the variables in the WAnT. The intra-class reliability co-efficient is a correlation coefficient that takes into account the relationship between two data sets. The reliability co-efficient is sensitive to the means of the two data sets, and also takes into account the actual change in scores in the data. The 95% limits of agreement provide information about the test-retest differences of the scores in the two data sets for 95% of the cases. The co-efficient of variation provides variability information with regard to how the spread of scores compares with the mean. For all analyses, statistical significance was established at $p<.05$.

Results

Participant and WAnT performance characteristics

Table 1 presents descriptive anthropometric data, WAnT performance, and blood lactate concentration measured after the test. In terms of the sexual maturity status of the participants, 86% were Tanner Stage 2 or 3 in their pubic hair development. The other 14% were adjudged as Tanner Stage 4 in pubic hair development.

Table1: Descriptive and WAnT performance characteristics of the boys

Variable	Boys (N=19)
Age [y]	15.5 ± 1.0
Body mass [kg]	47.4 ± 12.6
Stature [m]	1.59 ± 0.07
Sum of triceps & sub-scapular skinfolds (mm)	23.5 ± 9.2
Degree of ID	Moderate (30-50)
Peak power [W]	219 ± 87
Relative peak power [W/kg BM]	5.2 ± 1.9
Mean power [W]	155 ± 74
Relative mean power [W/kg BM]	3.5 ± 1.8
Post-WAnT blood lactate [mM/L]	3.8 ± 2.2

Data are means and standard deviations.

Reliability and level of agreement of PP and MP for adolescent boys with moderate ID

Table 2 presents the intra-class reliability co-efficient, indicators of agreement and coefficients of variation for PP and MP in the WAnT for adolescent boys with ID. The intra-class reliability co-efficients for PP and MP are significant at $p<.05$.

Table 2: Agreement, reliability and variability of PP and MP of adolescent boys with moderate ID.

Variable	Intra-class reliability coefficient	95% limits of agreement	Co-efficient of variation
Peak power	0.93*	-51W to –5W	55%
Mean power	0.95*	-23W to 16W	42%

** Significant at p<.05*

Discussion

The intellectual disability descriptions of the participants are consistent with the diagnosis of moderate intellectual impairment (Luckasson *et al*, 1992). The stature, body mass and sum of two-site skinfold thicknesses of boys with moderate ID are in general agreement with their peers without ID for that age group (Chia, 1998), even though some studies have shown that the body mass index (BMI) of females with ID were significantly higher than their peers without ID (Wondra, 2000). In terms of the sexual maturity status, the male adolescents with moderate ID do not appear to be ahead or delayed in their sexual maturity in comparison to their peers without ID (Chia, 1998). The significance of assessing sexual maturity status as it relates to anaerobic performance is that there appears to be a positive maturity effect on WAnT-type performance in some but not in all studies in normal young people without ID (Armstrong *et al*, 2001). Intra-class reliability coefficients were high for MP and PP at 0.95 and 0.93, respectively. The results are comparable to those reported for young people without ID (Inbar *et al*, 1996), and also in physically disabled populations and in young patients with chronic disease (26), where correlation coefficients for peak and mean power are in excess of 0.90. It is of interest that test-retest correlation coefficients in healthy young people in repeated WAnTs are 0.96 for PP and 0.92 for MP (Unithan *et al*, 1998). By this manner of comparison, it appears that the reliability of all-out intensity exercise efforts of boys with moderate ID is comparable to that of boys without ID. Researchers have debated the appropriateness of the use of inter-class and intra-class correlations, in test-retest computations to establish reliability (Bland & Altman, 1995) of the test instrument for various subject populations. The 95% limits of agreement (4) has been proposed as the more appropriate alternative to establish reliability and agreement between two data sets, as the method is less affected by sample heterogeneity, compared to the use of intra-class correlations (Atkinson & Nevill, 1998). In essence, the 95% limits of agreement represent the test-retest differences for the variables reported for 95% of the sample cohort tested. However, the method has yet to take on prominence as few researchers report on the 95% limits of agreement as an indicator of reliability. Some researchers in sports science have used the 95% limits of agreement in studies of body composition (Clasey *et al*, 1999) and also in studies on the aerobic fitness of adults with mental retardation (Draheim *et al*, 1999) but to date, apparently only Chia (1998) has apparently used it to substantiate the reliability or agreement between data sets of WAnT performance in young people without ID. Chia (1998), reported that the 95% limits of agreement for a 20s WAnT were (i)-57W to 63W for PP and (ii)-40W to 44W for MP, in twenty-five 10 year-old boys without ID. The 95% limits of agreement for PP (-51W to –5W) and MP (-23W to 16W) in the present study on boys with moderate ID were well in agreement with the results reported by Chia (7). In other words, in the case of MP, when the test is repeated, there is a 95% chance that the difference between the first MP score and the second MP score was between –23W and 16W. This is within the range of differences identified by Chia (1998) for boys and girls without ID. This demonstrated the 95% levels of agreement between repeated WAnT performances in male adolescent s with ID were comparable to those of normal young people without ID. The coefficients of variation for PP and MP (55% and 42%, respectively) were considerably higher than the 6-7% reported by Naughton *et al* (1992) for MP, for six to 12 year old boys and girls who were skilled at cycling. The present results were also higher than the 21% to 27% for WAnT power in 10-year-old boys and girls (8). Like their peers without ID, PP was far less stable as a measure than MP in the participants with ID. The results demonstrated that boys with ID were more variable and less consistent in their power performances as a cohort compared to trained young people and young people without ID. In the present study, every attempt was made to habituate the participants to the WAnT and the test environment, and for the participants to give an all-out effort throughout the 30-second test. It is therefore unlikely that the variability of the WAnT performances was due to a lack of motivation on the part of the participants since both the participants' teachers and the researcher were confident that participants did give an all-out effort based on their subjective evaluations (facial flushing, accelerated ventilation, and PP in the test was not significantly different from the warm-up and the final familiarisation session) of the participants' capabilities. Since PP during the warm-up phase was not significantly different to that of the actual test, this was taken as evidence that all the participants gave a maximum effort during the test. Moreover, all the participants were sufficiently practiced at sprint cycling during the familiarisation sessions (i.e. no significant difference in PP between that of the practice trials and during the actual WAnT). Researchers reported that WAnT performances in populations with disabilities are not only inferior to that of populations of people without ID, they are also more variable (Inbar *et al*, 1996). The present result supported this view. Although, the 95% limits of agreement for repeated WAnT performances of the adolescent males with moderate ID are in concord with those reported for young people without ID (e.g. Chia, 1998), their means for PP and MP of 219W and 155W, respectively were about 35% and 34% of the PP and MP attained by their peers without ID, using a similar WAnT protocol (Chia, 1998). This is in agreement with published norms that were established for healthy untrained male adolescents, albeit using a dissimilar WAnT protocol (Inbar *et al*, 1996). The present results of low peak muscle power (as indicated by PP) and local muscle endurance (as indicated by MP) were also buttressed by the low post-exercise lactate values taken at two minutes following the WAnT. Some researchers have used the post-exercise blood lactate value as an indicator, albeit a blunted one, of the extent of anaerobic metabolism that has taken place during exercise, and there appears to be a positive correlation between the high power outputs in the WAnT and post-exercise lactate concentration (9), however it should be noted that interpretation of post-exercise BL concentration is fraught with difficulties because it is a function of not only lactate production in the muscle cell, but also its release into the circulation, its distribution in total body water, and its removal and uptake by other tissues (Chia, 1998). There are apparently no data on the post-exercise blood lactate values in people with moderate ID but the values in the present study are substantially lower than those found for in people without ID of the same age range (Chia, 1998). The low blood lactate concentration should not be taken to mean that the participants did not produce a maximum effort since the teachers and researchers were confident that maximum efforts were elicited (i.e. facial flushing, heavy breathing and PP in the test was not significantly different to that achieved in the warm-up and familiarization trials). Moreover, the low blood lactate concentrations after the test could reflect a physiological deficiency in this group of participants with moderate ID. The present result of low PP and MP achieved by the boys with moderate ID is consistent with findings in the extant literature where a similar pattern of low cycle power and power endurance are also documented for children with cerebral palsy (Emons & Baak, 1993) and children with chronic diseases (Inbar *et al*, 1996). An emergent body of information has shown that the steady state exercise performance of young people with moderate ID is substantially lower to that of young people without ID (Wondra *et al*, 2000). The present results suggested that in adolescent boys with moderate ID, the PP and MP are also poor in comparison to their peers without ID. The reasons of that are a combination of decreased physical activity and a lack of opportunities for exercise for people with various forms of disabilities. More opportunities for exercise and physical activity should therefore be organised for young people with moderate ID to help them develop fully their exercise potential. In conclusion, our results showed that while the reliability coefficients and levels of agreement between repeated WAnTs are high and comparable to that of young people without ID, there were greater variations in WAnT power in the adolescent boys with moderate ID compared to boys without ID.

References

Armstrong, N., Welsman, J. & Chia, M. (2001). Brit. J. Sp. Med., 35, 118-124.
Atkinson, G. & Nevill, A. (1998). Sp. Med., 26, 222-238.
Bland, J. & Altman, D. (1995).. Int. J. Epidemiol., 24, S7-S14.
Blimkie, C.J., Roche, P. & Bar-Or, O. (1986). Children and Exercise XII, Rutenfranz, J. (Ed.).
Chia, M.(1998). Ph.D Thesis. University of Exeter. UK.
Chia, M. (2000). Eur. J. Phys. Educ., 5, 231-258.
Chia, M., Armstrong, N. Childs, D. (1997). Pediatr. Exer. Sci., 9, 80-89.
Clasey, J., Kanaley, J., Wideman, L., Heymsfield, S., Teates, C., Gutgesell, M., Thorner, M., Hartman, M. & Weltman, A. (1999). J. Appl. Physiol., 86, 1728-1738.
Cormack, K.F., Brown, A.C., Hastings, R.P. (2000). J. Intel. Dis. Res., 44, 125-129.
Draheim, C.C., Laurie, N., McCubbin, J.A. Perlins, J.L. (1999). Med. Sci. Sp. Exerc., 31, 1849-1854.
Emons, H.J.G. Baak, M.A. (1993). Pediatr. Exer. Sci., 5: 412.
Fernhall, B., Pitetti, K.H., Vukovich, M., Stubbs, N.S., Hensen, T., Winnik, J. Short, F. (1998). Am. J. Ment. Retard., 102, 602-612.
Horvat, M., Croce, M., Pitetti, K.H. Fernhall, B. (2000). Med. Sci. Sp. Exer., 31, 1190-1195.
Inbar, O., Bar-Or, O. Skinner, J. (1996). The Wingate Anaerobic Test.
Luckasson, R., Coulter, D., Polloway, E., Deiss, S., Schalock, R., Snell, M, Spitalnick, D. Stark, J. (1992). Mental retardation: definition, classification, and systems of supports (9th ed.).
Naughton, G., Carlson, J. Fairweather, I. (1992). Int. J. Sp. Med., 13, 512-51
Sherill, C. O'Conner, J. (1999). APAQ, 16, 1-8.
Stadler, L. Pitetti, K. (1996). Med. Sci. Sp .Exer., 28, S49.
Tanner, J (1962) Growth at Adolescence.
Unnithan, V., Clifford, C. Bar-Or, O. (1998). Sp. Med., 26, 239-251.
Weiner, J.S., Lourie, J.A. (1981). Practical Human Biology.
Wondra, V.C, Pitetti, K.H., Yarmer, D.A. (2000). Med. Sci. Sp .Exer, 32, 1273.

WINGATE ANAEROBIC TEST POWER OF BOYS AND GIRLS EXPRESSED IN RELATION TO LOWER LIMB MUSCLE MASS AS DETERMINED USING DUAL ENERGY X-RAY ABSORPTIOMETRY

Chia Michael YH

Physical Education & Sports Science Group, National Institute of Education, Nanyang Technological University. Singapore

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 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 (Gotfredsen *et al*, 1997). 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 (Armstrong & Welsman, 1997; Nevill *et al*, 1992). 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 (Nevill *et al*, 1992) 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) (Armstrong & Welsman, 1997). 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

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 (1962). 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. 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. LLMM was derived from the Hologic computer software (Version 9.80).

Conduct of the WAnT

After a standardized warm-up, participants completed a 30s WAnT on a cycle ergometer (Monark 834E), from a rolling start of 60 rev·min^{-1}, with the applied force set at 0.74 N·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 (Chia, 2000; Chia *et al*, 1997). 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 (Chia, 2000). MP was the average power over 30s and is often regarded as a measure of muscle endurance (Chia, 2000).

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 participants-namely, means and standard deviations for stature, body mass, and LLMM were generated. Sex differences in descriptive characteristics and WAnT performances (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 (Armstrong & Welsman, 1997). Power function ratios (i.e. PP/LLMM^b and MP/LLMM^b) that are size-independent were subsequently computed (Armstrong & Welsman, 1997; Nevill *et al*, 1992). 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.

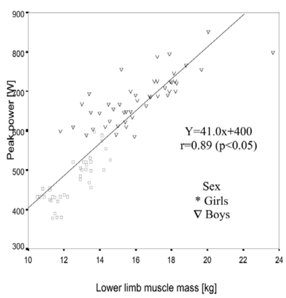


Figure 1: PP & LLMM relationship

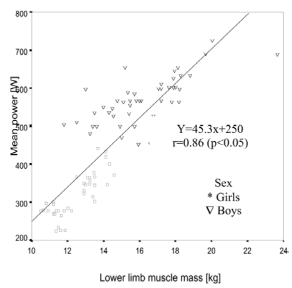


Figure 2: MP & LLMM relationship

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.

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.*

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 (Van Praagh *et al*, 1990). 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 (Armstrong & Welsman, 1997; Docherty & Gaul, 1991). 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. Armstrong & Welsman, 1997; Carlson & Naughton, 1994). 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 & Welsman, and Carlson & Naughton, 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 (Schmidt-Nielsen, 1984) its use in sports science is less widespread (Armstrong & Welsman, 1997; Chia, 1998). 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 (Armstrong & Welsman, 1997). 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 to 14-year-old boys and girls (Armstrong & Welsman, 1997). However, the finding that boys were more powerful than girls in maximal exercise tests is supported by other studies (Docherty & Gaul, 1991). 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 (Docherty & Gaul, 1991; Van Praagh *et al*, 1990). 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. Armstrong and Welsman, 1997; Nevill *et al*, 1992) 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 (Schmidt-Nielsen, 1984). 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 dataset 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.

References

Armstrong, N., Welsman, J. (1997). Young People and Physical Activity.
Carlson, J. Naughton, G. (1994). J Sp Med Phy Fit, 34: 362-369
Chia, M. (1998). Ph.D thesis. University of Exeter. UK
Chia, M. (2000). Eur J Phy Educ, 5 (2): 231-258
Chia, M., Armstrong, N., Childs, D. (1997). Pediatr Exerc Sci, 9: 80-89
Docherty, D., Gaul, C.A. (1991). Int J Sp Med, 12: 525-532
Gotfredsen, A., Baeksgaard, L., Hilsted, J. (1997).. J Appl Physiol, 82: 1200-1209
Nevill, A., Ramsbottom, R., Williams, C. (1992). Eur J App Physiol, 65: 110-117
Schmidt-Nielsen, K. (1984). Scaling: Why is animal size so important?
Tanner, J.M. (1962). Growth at Adolescence.
Van Praagh, E., Fellman, N., Bedu, M., Falgairette, G., Coudert, J. (1990). Pediatric Exercise Science, 2: 336-348