ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME
1

UNIVERSITY OF TARTU

ACTA KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

VOLUME 1

TARTU
1996

Editor

Toivo Jürimäe
University of Tartu
18 Ülikooli street
EE 2400 Tartu
Estonia

Printed by Tartu University Press
Tiigi 78, EE2400 Tartu, Estonia
Order No. 340.

CONTENTS

NUTRITIONAL HABITS IN BODY COMPOSITION, SOMATOTYPE, PHYSICAL ACTIVITY, AND CARDIO-RESPIRATORY FITNESS IN MALE AND FEMALE PHYSICAL EDUCATION STUDENTS

R. M. Philippaerts, A. L. Claessens, J. M. ten Brinke,
D. G. van der Scheer, G. P. Beunen and J. A. V. Lefevre
Faculty of Physical Education and Physiotherapy,
Katholieke Universiteit Leuven, Belgium

ABSTRACT

The aims of this study were: (1) to describe nutritional habits, physical activity, cardio-respiratory fitness, body composition and somatotype in physical education students; (2) to examine differences between male and female students; (3) to explore the relationship between nutritional habits, and physical activity, cardio-respiratory fitness, body composition and somatotype. The subjects were 34 male and 30 female, second year Physical Education Students at the Katholieke Universiteit Leuven, Belgium, with chronological ages of 20.9 ± 0.9 years and 20.2 ± 1.0 years respectively. Anthropometric variables (body mass, stature, and 5 skinfolds) were measured. Body composition (percent body fat and fat free mass) was estimated by means of a prediction formula. Somatotype, physical activity and cardio-respiratory fitness dimensions were assessed. The dietary history method was used to assess nutritional habits. The students had slightly lower body fat percent, and they were more mesomorphic and less endomorphic than average young adults. Males have significantly ($p < 0.01$) higher body mass, stature, and fat free mass and lower percent body fat, and sum of skinfolds than females. Males and females differed significantly ($p < 0.001$) in somatotype, males were more mesomorphic and less endomorphic. In males, the average total daily energy intake was rather high (4332 ± 1172 kcal), but in females the intake was average

(2321 ± 596 kcal). The intake of protein was for both male (13.1 ± 2.3 E%) and female (14.4 ± 2.0 E%) according to the recommended amounts, but significantly higher ($p < 0.05$) in female students. The intake of fat (in males 35.5 ± 7.6 E% and in females 35.2 ± 6.5 E%) was quite high and intake of carbohydrates (in males 51.4 ± 7.5 E% and in females 50.4 ± 6.0 E%) was low. The low carbohydrate intake is remarkable, especially because they are even lower than the recommendations for sedentary people. Comparing energy intake and total energy expenditure, it seems that male students had a positive energy balance and female students a negative energy balance. It was also shown that males had a higher rate of physical activity level than females, due to a higher degree of physical activity during leisure time. Only in males a significant correlation was found between proportions of fat and carbohydrate intake (resp. positive and negative) and percentage body fat, fat mass, and endomorphy.

KEY WORDS: Nutritional habits, Body composition, Somatotype, Physical activity, Cardio-respiratory fitness

INTRODUCTION

Among sports participants there is a growing interest in the relationships between nutrition and sports performance. It is clear that a balanced diet is a basic condition for optimal athletic performance, fast recovery after physical strain, and avoidance of health-related risks. Both nutrition and physical activity have an impact on body composition. An adequate diet, in terms of quantity and quality, and maintenance of energy balance will maximize performance [33].

The influence of physical activity on percent body fat is clearly notable when looking at the differences between athletes and sedentary people. Regular physical activity is an important factor in the regulation of body weight. Regular training generally results in a decrease in fatness and an increase in fat free mass. Although there is considerable variability in body composition among the different types of athletes, generally athletes have lower body fat percentages than non-athletes. The magnitude of changes in body composition with regular training varies with the type, intensity, and duration of the program [12, 14, 20, 35].

Physical performance and success in sport are positively related to a specific somatotype. To some extent it is possible to change somatotype by diet and training into a somatotype that is more optimal for a specific sport. Most sports top level athletes are more mesomorphic and less endomorphic than non-athlete reference groups. Also important differences in somatotype can be found between males and females. In general females are more endomorphic and less mesomorphic than males, and relatively close in ectomorphy. These differences are due to genetic factors, dietary pattern, physical activity, and other socio-cultural or environmental factors [6].

A large variety of studies have yielded much useful information about the relationship between physical activity and body composition and about the influence of nutrition on body composition. Also specific information about the best composition of the athletes diet has become available in the last two decades [13, 17, 25, 34, 36]. In physical education, students anthropometric, body composition, and somatotype characteristics have been studied [6, 8, 16]. However, the available literature about nutrition and the relationship with both physical activity and body composition is limited and studies about nutritional habits in physical education students are totally lacking. These students participate in all kind of sports and they have a high energy expenditure and because of the growing interest in the links between nutrition and sports performance, it is important for these sports students to pay more attention to nutritional habits.

Therefore, the aims of this study are: (1) to describe nutritional habits, physical activity, cardio-respiratory fitness, body composition and somatotype in physical education students; (2) to examine if there are differences between male and female students; (3) to explore the relationship between nutritional habits, and physical activity, cardio-respiratory fitness, body composition and somatotype in this specific population and to examine if the observed trends are the same in males and females.

MATERIALS AND METHODS

Subjects

The subjects were 34 male and 30 female, second year Physical Education Students from the Katholieke Universiteit Leuven, Belgium. Chronological age of the students varied for the males between 19.2 and 24.0 years, with a mean of 20.9 ± 0.9 years and for the females between 19.2 and 23.0 years, with a mean of 20.2 ± 1.0 years.

Anthropometry, Body Composition, and Somatotype

To determine body size, body mass was measured with a beam balance accurate to 0.1 kg and stature was measured with the Harpenden wall stadiometer (Holtain Ltd., Crosswell, Crymmych, Dyfed, Wales). Body Mass Index (BMI) was calculated from body mass and stature. The triceps (TRSK), suprailiac (SISK), subscapular (SSSK), thigh (THSK) and medial calf (CASK) skinfolds were measured. Measurements were taken on the left side of the body. Skinfolds were taken twice with a Harpenden skinfold caliper. When a difference between the two trials was more than 10%, a third measurement was taken. The mean of all trials was taken as the final value for the particular skinfold. Sum of five skinfolds (SUM5) was calculated from TRSK, SISK, SSSK, THSK, and CASK. Biceps and calf girths were measured with a steel tape (Harpenden) accurate to 1 mm, and humerus and femur breadths were measured with a spreading caliper (manufactured by Siber Hegner, Zürich) accurate to 1 mm. All measurements were taken by experienced observers (JTB, DVDS and ALC). Detailed descriptions of all anthropometric procedures are given in Claessens *et al.* [7] .

Somatotype was estimated by the anthropometric method of Heath-Carter [6] to obtain an overall description of body shape.

Percent body fat (FAT%) was calculated from density using Siri's formula [28], where body density was estimated with the sex and age specific prediction equations according to Durnin and Womersley [10]. Fat mass (FM) was calculated from percent body fat (FAT%) and body mass, and fat free mass (FFM) was calculated as body mass minus fat mass (FM).

Physical Activity

Habitual physical activity over the proceeding year was assessed by an adopted version of the structured questionnaire and coding table of Reiff and co-workers [23]. This implied a translation and an adjustment of the original protocol. The adjustment of the questionnaire was made in the leisure time supplement. Participation in sports activities during leisure time was estimated using a standardized questionnaire with the same retrospective approach [24]. It covered three aspects of sport participation: type of sport activities, diversity of sport activities, and the amount of time spent on each activity (calculation of hours per week over a 1-year period). A fourth aspect, i.e. the organizational context of sport involvement (in a club, at school, in the family, alone), was also asked. Total habitual physical activity of the proceeding year was reduced to an average week and to an average day of the week. Instructions were given to the students how to fill up the questionnaire, and the questionnaires were checked and corrected if necessary. The group studied was quite homogeneous concerning physical activity because during the day at the Faculty of Physical Education and Physiotherapy the activity level was the same for every subject. Thus the variation in total activity depended on the activity in their leisure-time. Total activity was calculated as follows. Because basal metabolic rate (BMR) is fairly close to 1 $kcal.kg^{-1} \cdot h^{-1}$, each activity is expressed as multiples of BMR. Each activity index reflects the ratio of work metabolic rate (WMR) to BMR. Total energy expenditure (TEE in kcal per day) was calculated as:

$$WMR/BMR * \text{body mass (kg)} * 24\ (h)$$

Cardio-respiratory Fitness

Cardio-respiratory fitness was assessed by means of the Leger endurance shuttle run test as described in the Eurofit Manual [9]. This endurance test has been validated and approved to be a good field test to predict maximal oxygen uptake ($\dot{V}O_2max$) [18]. However, cardio-respiratory fitness was expressed in minutes (ESHR) the subjects sustained running the programmed pace.

Nutritional Intake

Dietary intake was assessed by interviewing the subjects about their usual food intake by means of a structured dietary history questionnaire. This method is often used in epidemiological studies because it is possible to obtain an estimate of usual diet in one interview, although quantitative estimation of intake of all nutrients is not possible [4]. Subjects were asked to estimate their food intake during an average day (24 h-recall) at 7 different moments (before breakfast, breakfast, morning snacks, lunch, afternoon snacks, dinner, and evening snacks) of the day and to mention brand names and cooking recipes. No difference was made between weekdays and weekend days. Food consumption was converted into macro nutrients using a computer program based on a nutrient file from the Dutch food table [30] and total energy intake (TEI) and proportions of energy intake (E%) as protein, fat and carbohydrates were calculated. Proportion of fat intake was further divided into saturated, mono-unsaturated and poly-unsaturated fat and carbohydrates intake was divided into mono/di-saccharides and polysaccharides. The macro nutrients expressed in proportions of energy intake were compared to the amounts recommended for an average population by the Dutch Nutrition Council [31]. The recommendations were taken from the Dutch Nutrition Council instead of the Belgian because of two reasons. First, the Dutch food table is more comprehensive than the Belgian food table. Second, dietary habits in the Dutch and Flemish population are quite similar.

Statistical Analysis

Descriptive statistics (means and standard deviations) were calculated for each variable within both sexes. Student's t-test was used to verify differences between male and female physical education students. Pearson's correlation coefficients were determined to explore relations. All calculations were carried out using SAS procedures [26].

RESULTS

Anthropometry, Body Composition, and Somatotype

Descriptive characteristics of the subjects are shown in Table 1.

Table 1. Means, standard deviations (Mean and SD), t-test for anthropometric, body composition, and somatotype characteristics in Physical Education Students (N = 64)

	MALES (n = 34)		FEMALES (n = 30)		
	Mean	SD	Mean	SD	t-value
Age (years)	20.9	0.9	20.2	1.0	2.6*
Body mass (kg)	74.7	8.6	59.8	7.1	7.5**
Stature (cm)	180.2	6.1	164.7	4.7	11.2**
BMI(kg/m^2)	23.0	1.9	22.0	2.1	1.9
Calf girth(cm)	37.5	2.1	35.8	2.0	3.4**
Biceps girth(cm)	31.8	1.8	27.9	2.4	7.4**
Hum.breadth(cm)	7.1	0.4	6.2	0.2	10.6**
Fem.breadth(cm)	9.7	0.4	8.6	0.4	12.7**
TRSK(mm)	8.1	3.1	13.7	4.1	–6.3**
SSSK(mm)	10.1	2.7	10.9	3.0	–1.2
SISK(mm)	7.8	3.3	13.3	4.5	–5.6**
THSK(mm)	12.2	4.5	23.8	6.3	–8.5**
CASK(mm)	7.7	3.2	15.3	5.9	–6.3**
SUM5(mm)	45.9	14.4	77.1	19.2	–7.4**
FAT%(%)	12.1	3.2	24.4	4.1	–13.3**
FM(kg)	9.3	3.3	14.8	4.0	–6.0**
FFM(kg)	65.5	6.4	45.0	3.8	15.6**
Endomorphy	2.4	0.8	4.0	1.0	–6.5**
Mesomorphy	4.5	0.8	3.9	0.9	3.0**
Ectomorphy	2.8	0.9	2.3	1.0	1.9
TEE(kcal/day)	3735	498	2717	422	8.6**
WMR/BMR	2.1	0.3	1.9	0.2	3.3**
ESHR(min)	11.0	1.4	7.6	1.4	9.1**

* $p < 0.05$
** $p < 0.01$

Males and females were approximately of the same age and had a similar body mass index. Body mass and stature were significantly ($p < 0.01$) higher in males, they were 14.9 kg heavier and 15.5 cm taller than females. Body Mass Index was 23.0 ± 1.9 for the males and 22.0 ± 2.1 kg/m^2 for the females. This difference was not significant. Calf and biceps girths, and humerus and femur breadths were significantly ($p < 0.01$) higher in males. All skinfolds, except subscapular, were significantly ($p < 0.01$) thicker in females. The significant difference ($p < 0.01$) between males (45.9 mm) and females (77.1 mm) in SUM5 was 31.2 mm. Percent body fat (FAT%) and fat mass (FM) were significantly ($p < 0.01$) lower in males (12.3% and 5.5 kg respectively), whereas fat free mass (FFM) was significantly ($p < 0.01$) higher (20.5 kg).

Descriptive statistics for somatotype components are also given in Table 1. The mean somatotype of the male students was 2.4 / 4.5 / 2.8 and of the female students 4.0 / 3.9 / 2.3. The females differed significantly ($p < 0.01$) in endomorphic and mesomorphic values compared to males. No significant difference was found in ectomorphy. Figure 1 provides a visual representation of the somatotype distribution of the male and female physical education students on the somatochart.

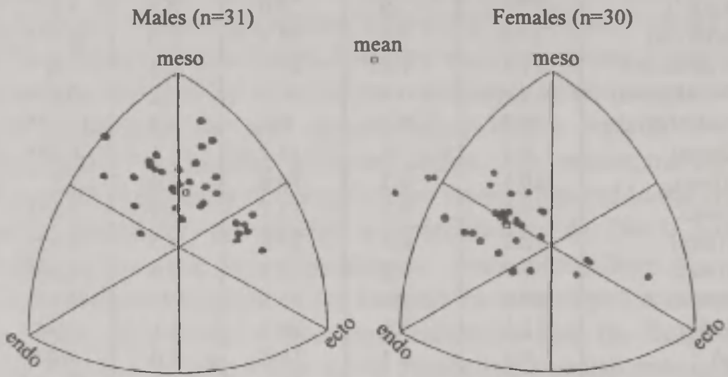

Figure 1. Individual somatoplots of male (left) and female (right) physical education students.

The somatotype distributions of the males showed fairly consistent patterns of dominant and moderately high mesomorphy. The majority of the female somatotypes were meso-endomorphs, with distributions clustered around the ectomorphic axis northwest of the somatochart centre.

Physical Activity and Cardio-respiratory Fitness

The results of the assessment of physical activity and cardio-respiratory fitness are also summarized in Table 1.

The total energy expenditure was significantly ($p < 0.01$) higher in males (3735 ± 498 kcal/day) than in females (2717 ± 432 kcal/day). The work-to-basal metabolic ratio (WMR/BMR) varied between 1.7 and 2.8 with a mean of 2.1 for the males and between 1.6 and 2.3 with a mean of 1.9 for the females. This difference in physical activity between males and females was significant ($p < 0.01$).

Cardio-respiratory fitness, assessed by means of an endurance shuttle run test (ESHR), was significantly ($p < 0.01$) higher in the male students. These students could sustain the test 11 minutes (range 8–13 min) with a maximal speed of 13.5 ± 0.7 km/h. For the females these variables were respectively 7.6 minutes (range 4–10 min), and 11.8 ± 0.7 km/h (maximal speed is not shown in the table).

Nutritional Habits

The results of the dietary history are shown in Table 2.

Table 2. Means, standard deviations (Mean and SD), t-test for average total daily energy intake (TEI) and the macro-nutrients expressed in proportions of energy intake (E%) in Physical Education Students

	MALES (n = 34)		FEMALES (n = 30)		
	Mean	SD	Mean	SD	t-value
TEI(kcal)	4332	1172	2321	596	8.8*
PROTEIN (E%)	13.1	2.3	14.4	2.0	–2.3*
FAT(E%)	35.5	7.6	35.2	6.5	0.2
– saturated	15.2	3.4	15.6	2.6	–0.5
– mono-unsaturated	13.4	3.4	13.7	2.9	–0.3
– poly-unsaturated	6.0	2.2	5.2	1.3	1.7
CARBOHYDRATES (E%)	51.4	7.5	50.4	6.0	0.6
–mono/di saccharides	24.8	7.2	24.0	5.9	0.5
–polysaccharides	26.2	5.9	26.6	4.9	–0.3

* $p < 0.05$
** $p < 0.01$

The average total daily energy intake for males was 4332 ± 1172 kcal and for females 2321 ± 596 kcal. This difference was highly significant ($p < 0.01$). The intake of macronutrients in proportions of energy intake were quite similar between males and females. Only the proportion of protein intake in females was slightly higher ($p < 0.05$).

Relationship Between Nutrition and Body Composition, Somatotype, Physical Activity and Cardio-respiratory Fitness

Table 3. Correlations between nutritional habits (average Total Daily Energy Intake (TEI), and the macro-nutrients expressed in proportions of energy intake (E%), and anthropometric, body composition, somatotype, physical activity and cardio-respiratory fitness characteristics in male (n = 34) and female (n = 30) Physical Education Students.

	TEI		PROTEIN		FAT		CARBOHY-DRATE	
	Males	Females	Males	Females	Males	Females	Males	Females
Body mass	–0.02	0.14	0.12	–0.15	–0.01	0.08	–0.02	–0.03
Stature	0.14	0.23	0.07	–0.07	–0.14	–0.04	0.12	0.06
BMI	–0.13	0.04	0.08	–0.15	0.07	0.13	–0.09	–0.09
Calf girth	–0.09	0.14	0.17	–0.17	–0.12	0.3	0.07	–0.3
Biceps girth	–0.04	0.09	0.09	–0.17	–0.11	0.08	0.09	–0.02
Hum.breadth	0.10	–0.10	0.06	–0.15	–0.12	0.04	0.08	0.00
Fem.breadth	0.26	0.04	–0.07	–0.01	–0.06	–0.02	0.10	0.02
SUM5	–0.05	0.08	–0.05	–0.14	0.3	–0.04	–0.29	0.09
FAT%	–0.09	0.01	–0.03	–0.13	0.4*	0.01	–0.4*	0.03
FM	–0.11	0.05	0.02	–0.11	0.3	0.01	–0.33*	0.02
FFM	0.03	0.22	0.14	–0.16	–0.18	0.13	0.14	–0.09
Endomorphy	–0.12	–0.01	–0.04	–0.08	0.4*	–0.03	–0.4*	0.06
Mesomorthy	–0.03	–0.09	0.09	–0.13	–0.04	0.18	0.01	–0.15
Ectomorphy	0.18	0.01	–0.05	0.16	–0.12	–0.16	0.14	0.11
TEE	0.11	0.33	0.04	–0.27	–0.05	0.13	0.04	–0.05
WMR/BMR	0.18	0.36	–0.09	–0.26	0.03	0.11	–0.00	–0.03
ESHR	0.07	0.06	0.28	–.09	–0.25	–0.07	0.18	0.10

* $p < 0.05$
** $p < 0.01$

Table 3 gives the correlations between the variables related to nutrition and anthropometry, body composition, somatotype, physical activity, and cardio-respiratory fitness for male and female students separately. In male students most of the correlations were not significant. Only fat intake (in E%) was significantly positively related to FAT% and endomorphy. Also correlations between carbohydrate intake (in E%) and FAT%, FM and endomorphy were significant, but negative. Correlations between fat and carbohydrate intake (in E%) and FFM were not significant. In female students no correlation was significant. However, in females all correlations with protein intake (in E%) were negative. Only the correlation between protein intake (in E%) and ectomorphy was positive.

DISCUSSION AND CONCLUSIONS

The group studied had normal values for body mass, stature and BMI compared with average young adults (20–25 years) [14]. Average percent body fat in young males is 18% and in young females is 28% [14], so this is slightly higher than found in the physical education students in this study (12.1% and 24.4% respectively).

The male and female students differed significantly concerning body mass, stature and percent body fat. Gualdi Russo *et al.* [16]. also found that skinfolds were thicker in female sports students than in their male counterparts.This correspondences, of course, to what is found in the general population. For both males and females BMI fell into the category (20.0–24.9 kg/m^2) of normal weight according to Garrow [15].

In their overview Carter and Heath [6] reported somatotype data for various populations. Somatotype components for both males and females in the present study were similar to the mean values that were found in physical education students in other countries. In comparison with an average population and other students, it was also found that physical education students were more mesomorphic and less endomorphic. Although this swing towards the north easterly direction is obvious, it is even more pronounced in athletes.

In general, in a given population, females are more endomorphic and less mesomorphic than males, and relatively close in ectomorphy [6]. This was also found in this study, where the most pronounced differences between males and females were found in endomorphy ($p < 0.01$) and mesomorphy ($p < 0.05$).

The average total daily energy intake of 4332 ± 1172 kcal in males seems to be very high compared to a population of the same age and sex, who are moderately active. Generally, a daily energy intake between 2600 and 3300 kcal is recommended for moderately active to active men. The average total daily energy intake of 2321 ± 596 kcal in females was closer to the recommended of 2050 ± 2750 kcal for moderately active to active women [32].

The macro-nutrients in proportions of energy intake (E%) were compared to the amounts recommended for an average population by the Dutch Nutrition Council [31]. The intake of protein was for both males (13.1 ± 2.3E%) and females (14.4 ± 2.0E%) according to the recommended amounts (10–15E%), but the intake of fat (35.5 ± 7.6E% in males 35.2 ± 6.5E% in females) was quite high, because the intake is recommended to be between 30–35 E%. The intake of carbohydrates (51.4 ± 7.5E% in males and 50.4 ± 6.0E% in females) was low considered to the recommended intake of more than 55E% for sedentary people. The recommendations for sports participants are even higher (> 60% of the diet should be carbohydrates) [25], so the low carbohydrate intake of the physical education students is remarkable, because it should be expected that on the average their carbohydrate intake lie between 55 and 60E%. The natural fats in a diet can be either saturated, mono-unsaturated or poly-unsaturated. It is recommended that the diet should contain these separate types of fat in a proportion of 1:1:1. For the students this proportion turned out to be 3:2:1, so their diet contained too many saturated and too few poly-unsaturated fats. There are also two types of carbohydrates, mono/di-saccharides and polysaccharides, of which poly-saccharides are preferable. The amount of mono/di-saccharides should be between 15–25E%. The diet of the male students contained 24.8 ± 7.2E% sugars and that of the females 24.0 ± 5.9E%. In this situation, there is an extra need for carbohydrates as polysaccharides. However the solution of the problem is not an extra need for polysaccharides but an alteration in eating behaviour: less saturated fats and a better proportion of the different saccharides.

Total energy expenditure (TEE) was lower than total energy intake (TEI) for the males. For the females total energy expenditure was higher than the intake. These findings suggest the existence of a positive energy balance for the male students and a negative energy balance for the females. Baecke *et al.* [3] studied food consumption, habitual physical activity, and body fatness in young Dutch adults, and they found similar patterns in food consumption as in the present study. They also found a positive energy balance in males. The reason for discrepancy between energy intake and energy expenditure could have many causes. First,the methods used to estimate physical activity and dietary intake have both their limitations. Assessment of physical activity by means of a questionnaire and appropriate coding tables provides only a rough estimation of the real physical activity. A common problem faced by researchers is the coding of physical activities by type and by intensity. It is important to have an all-inclusive coding system, and even then, there are several factors that may limit the use a questionnaire for determining the precise energy cost of physical activity. But a questionnaire can be very useful to indicate relations between physical activity and measures of caloric intake, physiological fitness and health status [2, 21]. The dietary history method includes errors in the amount of food eaten, reporting error, coding errors and errors in food tables [4, 11]. Secondly, it is suspected that some individuals tend to generally under-or overestimate their food intake. Especially in females and obese persons the phenomenon of underestimation of energy intake is often seen [19, 22, 27].

Work-to-basal metabolic ratio (WMR/BMR) was significantly higher in males compared to females, so the males were more active in their leisure-time, because week program (practical and theoretical lessons) at the Faculty of Physical Education and Physiotherapy was the same for every subject. Also performance in endurance shuttle run (ESHR in min.) was significantly better in males, but this was expected due to the sex difference. However a slightly significant correlation ($r = 0.34$ with $p < 0.1$) was found between ESHR and WMR/BMR in males and not in females. It seems that the male students benefit more by the higher activity level during leisure time. This is in agreement with the general accepted thesis that training, with sufficient frequency, intensity, and duration, benefits fitness [1, 20, 30].

Poor relationship was found between nutritional habits (energy intake and proportions of intake) and anthropometric, body composition, somatotype, physical activity, and cardio-respiratory fitness variables. Higher correlations, but not significant, were found between TEI, TEE, and WMR/BMR in both sexes. Thus it might be postulated that average total daily energy intake is positively related to physical activity. However, correlations between average total daily energy intake and cardio-respiratory fitness in male and female students were low. Probably this is due to the homogenity of the two groups. Also outcome of dietary intake by history method needs to be regarded with caution [4, 11, 22, 27]. Nevertheless, protein intake (inE%) was slightly higher in females than in males but still according to the recommended amounts. Protein requirements may be slightly elevated due to exercise, be it endurance or resistance exercise. The magnitude of the elevation depends on the intensity of the program and the energy balance attained [5]. Maybe there is a slight change in eating behaviour in female students because of the study curriculum. Since the male students had already a higher degree of physical activity during leisure time, it seems normal higher protein intake only occurred in the female students. Only in male students fat and carbohydrate intake (in E%) was significantly related ($p < 0.05$) to FAT%, FM, and endomorphy, resp. positive and negative. This was not found in female students. It seems that male physical education students are more liable to fat and carbohydrate intake than their female colleagues.

In conclusion, this study yielded information about nutritional habits, physical fitness, body composition and somatotype in physical education students. The students had slightly lower body fat percent, and they were more mesomorphic and less endomorphic than average young adults. Male students had a high daily energy intake, and both males and females had a high proportion of fat intake and a low proportion of carbohydrate intake. Compared to the general Dutch population, the energy intake of physical education students is closer to the recommendations of the Dutch Nutrition Council, but there is good evidence that the proportion of fat intake is still too high, especially for this moderately active or active young adults. Proportion of protein intake was according to the recommended amounts, but female students had a slightly higher protein intake than the male students. Comparing energy intake and energy expenditure, it seems that male students had a positive energy balance and female students a negative energy balance. It was also shown that males had a higher rate of physical activity level than females because of higher activity during leisure time. Average total daily energy intake was positively related to physical activity in both sexes. Only in male students, the 'fat' component was positively related to fat intake and negatively related to carbohydrate intake.

ACKNOWLEDGEMENTS: We are very grateful to Dr. Greet Vansant (Academic Hospital "Gasthuisberg", Katholieke Universiteit Leuven) for her fruitful suggestions and assistance in preparing the dietary history. We also like to thank the second year students at the Faculty of Physical Education and Physiotherapy of the Katholieke Universitet

Leuven for participating in this study. This manuscript was prepared during a three months term of probation (March-May 1993) of J. M. ten Brinke and D. G. van der Scheer (University of Agricultur Wageningen, The Netherlands) with the Research Unit 'Differentional and Developmental Kinanthropology' at the Faculty of Physical Education and Physiotherapy, K. U. Leuven (within the scope of an Erasmus-project).

REFERENCES

1. **ACSM** (1995) ACSM's guidelines for exercise testing and prescription. Baltimore: Williams and Wilkins.
2. **Ainsworth B. E., Haskell W. L., Leon A. S., Jacobs D. R., Montoye H. J., Sallis J. F., Paffenbarger R. S.** (1993) Compendium of physical activities: classifications of energy costs of human physical activities. Med. Sci. Sports Exerc. 1: 71–80.
3. **Baecke J. A. H., van Staveren W. A., Burema J.** (1983) Food consumption, habitual physical activity, and body fatness in young Dutch adults. Am. J. Clin.Nutr. 37: 278–286.
4. **Bingham S. A.** (1991) Limitations of the various methods for collecting dietary intake data. Ann. Nutr.Metab. 35: 117–127.
5. **Butterfield G. E., Tremblay A.** (1994) Physical activity and nutrition in the context of fitness and health. In Bouchard C, Shephard R J, Stephens T (eds.): Physical activity, fitness, and health: international proceedings and consensus statemant (Second international consensus symposium on physical activity, fitness, and health; Toronto; 1992). Champaign: Human Kinetics Publishers, pp. 257–269.
6. **Carter J. E. L., Heath B. H.** (1990) Somatotyping-Development and Applications. Cambridge: Cambridge University Press.
7. **Claessens A. L. M., Vanden Eynde B., Renson R., Van Gerven D.** (1990) The description of tests and measurements. In J Simons, GP Beunen, R Renson, ALM Claessens, B Vanreusel, and JAV Lefevre (eds.): Growth and Fitness of Flemish Girls. The Leuven Growth Study. Champaign, IL: Human Kinetics Publishers, pp. 21–39.
8. **Claessens A. L., Lefevre J.** (1992) Secular trends in somatic and motor characteristics of physical education students. Am. J. Hum. Biol. 4: 301–311.
9. Council of Europe (1988) Eurofit. Handbook for the Eurofit Tests of Physical Fitness. Rome: Council of Europe.

10. **Durnin J. G. V. A., Womersley J.** (1974) Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 man and women aged 16–72 years. Br. J. Nutr. 32: 77–92.
11. **Dwyer J. T.** (1991) Concept of nutritional status and its measurement. In JH Himes (ed.) Anthropometric assessment of nutritional status. New York, etc.: Wiley-Liss, Inc., pp. 5–28.
12. **Eisenman P.** (1986) Physical activity and body composition. In V Seefeldt (ed.): Physical activity and well-being. Reston, VA: AAHPERD, pp. 163–182.
13. **Van Erp-Baart A. M. J., Saris W. H. M., Binkhorst R. A., Vos J. A., Elvers J. W. H.** (1989) Nationwide survey on nutritional habits in elite athletes (Part I and II). Int. J. Sports Med. 10: S3–S16.
14. **Forbes G. B.** (1987) Human body composition. New York: Springer Verlag.
15. **Garrow J. S.** (1981) Treat Obesity Seriously. Edinburgh: Churchill Livingstone.
16. **Gualdi Russo E., Gruppioni G., Gueresi P., Belcastro M. G., Marchesini** V. (1992) Skinfolds and body composition of sport participants. J. Sports Med. Phys. Fit. 3: 303–313.
17. **Katch F. I.** (1986) Sport, Health and Nutrition. Champaign, IL: Human Kinetics Publishers.
18. **Leger L., Gadoury** C. (1989) Validity of the 20m shuttle run test with 1 min stages to predict $\dot{V}O_2$ max in adults. Can. J. Sports Sci. 14: 21–26.
19. **Lichtman S. W., Pisarska K., Raynes Berman E., Pestone M., Dowling H., Offenbacher E., Weisel H., Heshka S., Matthews D. E., Heymsfield S. B.** (1992) Discrepancy between self reported and actual caloric intake and exercise in obese subjects. N. Eng. J. Med. 27: 1893–1898.
20. **Malina R. M., Bouchard C.** (1991) Growth, maturation, and physical activity. Champaign, IL: Human Kinetics Books.
21. **Paffenbarger R. S., Blair S. N., Lee I., Hyde R. T.** (1993) Measurement of physical activity to assess health effects in free-living populations. Med. Sci. Sports Exers. 1: 60–70.
22. **Quandt S. A.** (1987) Methods for determining dietary intake. In FE Johnston (ed.): Nutritional Anthropology. New York: Alan R. Liss, Inc., pp. 67–84.
23. **Reiff G. G., Monotoye H. J., Remington R. D., Napier J. A., Metzner H. L., Epstein F. H.** (1967) Assessment of physical activity by questionnaire and interview. J. Sports Med. Phys. Fit. 7: 135–142.
24. **Renson R.** (1973) Sociokulturele determinanten van de somatische ontwikkeling, de motorische vaardigheid en het sportgedrag van 13-jarige jongens (Socioculture determinants of the somatic development,

motor fitness and sport behaviour of 13-year-old Belgian boys). Unpublished doctoral dissertation, Leuven: KU Leuven.

25. **Saris W. H. M., van Erp-Baart M. A., Brouns F., Westerterp K. R., Hoor F. ten.** (1989) Study on food intake and energy expenditure during extreme sustained exercise: The Tour de France. Int. J. Sports Med. 10: S26–S31.
26. SAS-Institute, Inc. (1988) Statistical System Procedures Guide. Released 6.03 Edition Cary. NC: SAS Institute, Inc.
27. **Schoeller D. A.** (1990) How accurate is self-reported dietary energy intake? Nutr. Rev. 48: 373–379.
28. **Siri W. E.** (1961) Body volume measurement by gas dilution. In J Brozek, and A Heuschil (eds.): Techniques for measuring body composition. Washington, DC: National Academy Press, pp. 108–117.
29. Stichting NEVO (Dutch foundation) (1987) NEVO-tabel: Nederlands voedingsstoffenbestand 1986–1987 (NEVO-table: Dutch survey of nutritious matter 1986–1987). s'-Gravenhage: Voorlichtinsbureau voor de Voeding.
30. **Van Gerven D., Vanden Eynde B., Gerard H.** (1982) Extra- curricular sports participation and cardiac performance of a group of boys aged 13 to 18 years. In H Lavalle'e, and RJ Shephard (eds.): Child growth and development: proceedings (International symposium on child growth and development; Trois-Rivie'res; 1980). Trois-Rivie'res: Universite' de Que'bec, pp. 291–295.
31. Voedingsraad (Dutch Nutrition Council) (1986) Advies richtlijnen goede voeding (Advice guidelines prudent diet). Voeding 47:159.
32. Voorlichtingsbureau voor de voeding (Dutch information service on nutrition) (1987) De Nederlandse voedingsmiddelentabel (Dutch food table). The Hague: Vo Vo, p. 38.
33. **Williams C., Devlin J. T.** (1992) Foods, nutrition and sports performance: An International Scientific Consensus held 4–6 February 1991 and organized by Mars, Incorporated with International Olympic Committee patronage. London, etc. E & FN Spon, pp. xv–xvi.
34. **Williams M. H.** (1983) Ergogenic Aids in Sport. Champaign, IL: Human Kinetics Publishers.
35. **Wilmore J. H.** (1983) Body composition in sport and exercise: directions for future research. Med. Sci. Sports Exerc. 1: 21–31.
36. **Wilmore J. H., Freund B. F.** (1984) Nutritional enhancement of athletic performance. Nutr. Abstr. Rev. 54: 1–16.

Correspondence to:
Prof. Dr. A.L.Claessens
Faculty of Physical Education and Physiotherapy
Katholieke Universiteit Leuven
Tervuursevest, 101
B-3001 Heverlee, Leuven
Belgium

SIGNIFICANCE OF HORMONAL METABOLIC CONTROL IN SPORTS PERFORMANCE

A. Viru, T. Smirnova and M. Viru
Institute of Exercise Biology, University of Tartu, Tartu, Estonia

ABSTRACT

Results regarding the contribution of hormonal metabolic control in exercise performance are reviewed. The essential role of hormonal metabolic control in sports performance is most convincingly evidenced in (1) contribution of adrenalin in muscle glycogenolysis, (2) correlated influences of several hormones in control of lipolysis, and (3) action of glucocorticoids ensuring performance in prolonged exercises. In addition, rather suggestive is the dose-depending influence of triiodothyronine on the capacity for prolonged exercise performance.

KEY WORDS: Hormones, Sport performance

INTRODUCTION

A great body of results are obtained on hormonal responses to various exercises and training effects on these responses [15, 16, 57, 60]. The significance of exercise-induced hormonal responses in metabolic control during exercise are explored with the aid of special experiments [15, 16, 58, 60]. Nevertheless, it is not a simple task to establish links between endocrine functions and exercise performance capacities. The present brief review is aimed to discuss this problem and indicate further tasks to establish the endocrine foundations of exercise performance.

ACTION OF DEFICIENCY AND EXCESS OF HORMONES

Almost all endocrine disturbances induce impaired physical working capacity, independently of whether they are caused by pathological processes or called forth experimentally. The aggravating effects of hormone deficiencies are, at least partially, abolished by adequate substitute treatment (see for reference [58]). Nevertheless, this is not a sufficient foundation to claim the dependence of physical working capacity on the endocrine function in a normal organism.

During exercise a widespread activation of the endocrine function occurs. Hence, one may ask whether the amplitude of activation of the endocrine function is a limiting factor in regard to maximum physical working capacity. If this is so, hormone administration should increase the maximum. There are a number of studies which describe such results in regard to the administration of adrenalin, adrenocortical extract, glucocorticoids, aldosterone, corticotropin and triiodothyronine (for review see [58]). In these studies the validity of the tests used for the evaluation of physical working capacity was different and in some cases doubtful. The most striking facts are the dose-depending increase in the working capacity (Figure 1) due to triiodothyronine [52] and adrenalin [4, 18, 21]. Physiological stimulation of the thyroid function by thyrotropin administration resulted in a less pronounced increase of working capacity in rats [10].

SIGNIFICANCE OF ADRENALIN IN MUSCLE GLYCOGENOLYSIS

The effect of exogenous adrenalin in working capacity is comparable with three facts: (1) there is an increased capacity for secreting adrenaline in the trained organism [29, 30, 69], (2) there is a good accordance between the highest levels of supramaximal exercise intensities and of catecholamines in the blood [55], (3) in normal men the β-adrenergic blockade impaires endurance [5, 7, 36, 54). Thus is seems quite plausible to assume that the capacity for secreting adrenaline belongs to the group of factors limiting the physical working capacity.

The capacity for adrenalin secretion may be decisive in the mobilization of muscle glycogen stores [1, 38, 42, 44] and is therefore important both for anaerobic working capacity and for the capacity to perform aerobic-anaerobic exercises. One of the recent studies on adrenaldemedullated rats showed that the markedly reduced endurance (running at 21 m·min^{-1} up a 10% grade until exhaustion; approximately 1 and 2 hours respectively in adrenaldemedullated and sham-operated rats) was associated in adrenaldemedullated rats with hypoglycemia, elevated plasma insulin, reduced blood lactate response, and decreased muscle glycogenolysis during exercise as compared with the sham-operated animals. Adrenalin infusion corrected the endurance time, the insulin response and muscle glycogen depletion. Hypoglycemia during running until exhaustion diminished likewise. Glucose infusion restored endurance run times and blood glucose to the normal without correcting the deficiencies in the blood lactate response and muscle glycogenolysis [46]. Hence, the reduced endurance might be related to the impaired carbohydrate supply of the contracting muscles due to abnormal muscle glycogenolysis in adrenalin deficiency.

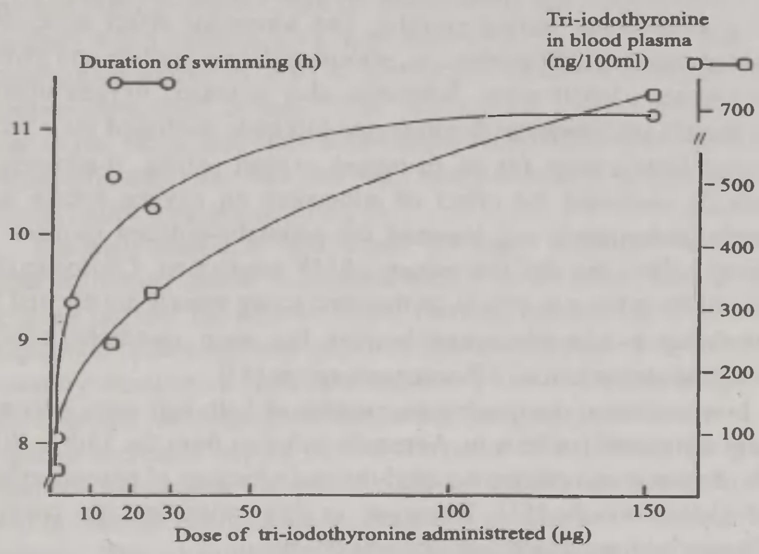

Figure 1. Effect of triiodothyronine administration on maximal duration of swimming and blood plasma level of triiodothyronine. Constructed by results of Tomson and Kallikorm [52].

Adrenalin action on anaerobic glycogenolysis consists in the activation of glycogen phosphorylase. This effect is mediated by β-adrenergic receptor, blocade of there which diminished the use of muscle glycogen, as well as the release of lactate [20, 27]. In humans propranolol infusion eliminated the increase in muscle cAMP content during dynamic exercise and reduced phosphorylase activation [5].

Striking evidence of the essential role of adrenalin in muscle glycogenolysis has been obtained in experiments on isolated muscle preparation. Contractions induced a prompt rise in the intensity of glycogenolysis in the isolated rat muscle. However, this rise was only transient. A more prolonged increase in the rate of glycogenolysis, together with increased mechanical work was obtained following the administration of either adrenalin or noradrenalin. These effects were prevented by β-adrenergic but not α-adrenergic blockade [40].

Conversion of phosphorylase b to a, as well as glycogenolysis, is also transient in muscles during their contractions [8]. Both of these processes are reactivated by adrenalin [14]. E. A. Richter and coauthors [44] confirmed with experiments on isolated perfused rat hindquarters that contractions, per se, stimulate glycogenolysis only for a brief period. The influence of adrenalin is necessary for continued glycogenolysis during exercise. The adrenaline effect associated with increased cAMP production, phosphorylase activation and glycogen synthesis inactivation. Adrenalin also increased oxygen uptake and muscle performance. β-adrenergic blockade abolished the effects of adrenaline except for an increased oxygen uptake. α-adrenergic blockade abolished the effect of adrenaline on oxygen uptake and muscle performance and lessened the adrenalin-induced increase in glycogenolysis but did not reduce cAMP production. Consequently, some of the adrenalin effects on the contracting muscle are elicited by stimulating α-adrenoreceptors besides the main metabolic effects through the stimulation of β-adrenoreceptors [43].

In normal men the quadriceps muscles of both legs were intermittantly stimulated for 30 min. Adrenalin infusion from the 15th to 30th min of muscle stimulation doubled the mole fraction of phosphorylase and glycogenolysis [51]. However, in this experiment no positive influence on muscle performance was observed.

STIMULATION OF LIPOLYSIS

During prolonged aerobic exercises the contribution of adrenalin to working capacity seems to be related to sparing the muscle glycogen use by stimulation of lipolysis. In dogs the impairment of working capacity and intensive depletion of muscle glycogen content after β-blockade could be prevented by an infusion of triglyceride together with heparin, which elevates the plasma free fatty acid level [39]. Following chemical sympathectomy the maximal running time was approximately a third of that in the normal animals. An increase in the rate of glycogen utilization and a fall in the free fatty acid concentration was observed in sympathectomized rats instead of a rise in normals [41]. In men after β-blockade the maximal duration of exercise at 60% $\dot{V}O_2$ max was only 50% of the maximal (83 ± 9 and 166 ± 10 min, respectively) in association with elevated oxidation of carbohydrates and reduced the blood levels of free fatty acids and glycerol. After blockade of lipolysis by the administration of nicotinic acid, the endurance time constituted 73% of the normal [17].

The mobilization of lipid resources and the transition from carbohydrate to lipid oxidation is closely connected with the reduction of insulin level in the blood. The role of somatotropin, glucagon, thyroxine and other hormones may be additional in lipid mobilization, particularly when exercise lasts more than an hour. However, intramuscular administration of 2 IU of human growth hormone increased the somatotropin level during 2-hour exercise but did not stimulate the rise in the blood free fatty acid concentration [53]. This result is in agreement with the fact that the lipolytic action of somatotropin appears after a lag period of 2 h [13].

The significance of well-timed transition from carbohydrate to lipid utilization seems to be associated with the reservation of blood glucose for fuel for nervous cells. Through maintaining the working capacity of active nervous cells it influences the performance level. A contrary situation, a high level of insulin in the blood, hastens the development of hypoglycemia during prolonged exercise and that mean a decreased supply of fuel for nerve cells. During electrically elicited contractions for a prolonged period the work output of severely diabetic rats was not decreased in comparison with the normal animals. The administration of insulin enhanced the decrease in the blood glucose concentration and aggrevated the work output [26].

The old evidence on improved working capacity after glycocorticoid administration [57] was not confirmed in experiments where the working capacity was precisely assessed [25]. Stimulation of adrenocortical activity by administration of corticotropin gave an improved working capacity in some studies [9, 10]. However, this result was not confirmed by determination of $\dot{V}O_2$ max and PWC_{170} in trained and untrained persons [64] or by estimation of maximal duration of swimming with an additional load in rats [49]. The blockade of adrenocortical response to short-term exercise with a previous dexamethasone treatment did not change the levels of maximal oxygen uptake and PWC_{170} either [64]. An impressive affect of a single subcutaneous injection of cortisol on the endurance time in rats was demonstrated by Gorostiaga *et al.* [19]. However, in this case cortisol was administered 21h before treadmill running and the improved endurance was directly related to the enhanced glycogen stores. Thus, the improved endurance was achieved by the stimulation of glycogen synthesis before exercise.

Results were obtained which showed that the capacity of the adrenal cortex to secrete glucocorticoids is in relation to working capacity in prolonged exercises. When the volume of zona fasciculata of the adrenal cortex, producing glucocorticoids, was dramatically decreased by previous prolonged treatment with dexamethasone, the maximal duration of swimming was only 37% of that in intact animals [49].

The significance of glucocorticoid response to prolonged exercise was tested in rats by Sellers *et al.* 1988 [46]. Adrenalectomized rats were given a subcutaneously implanted corticosterone pellet at the time of adrenalectomy. This manipulation avoided actual adrenocortical insufficiency, but eliminated the glucocorticoid response to exercise. In order to simulate the exercise-induced response, a group of adrenalectomized and corticosterone implanted rats were treated with corticosterone injection immediately before the exercise bout. Other adrenalectomized-implanted rats were treated with corn oil before the exercise. In resting conditions the blood corticosterone level was similar in sham-operated and adrenalectomized-implanted rats. After the exercise the blood corticosterone level remained at the level of sedentary control rats in adrenalectomized-implanted rats, but proved to be increased 6 to 7 times in sham-operated and adrenalectomized rats injected with corticosterone before exercise. The duration of treadmill running (21 $m \cdot min^{-1}$, 15% grade) until exhaustion was in sham-operated rats 138 ± 6 min compared to 114 ± 9 min in adrenalectomized-implanted rats injected with corticosterone and 89 ± 8 min for adrenalectomized-implanted rats. Consequently, the rise in glucocorticoids during exercise does play a role in the ability of the rat to run to exhaustion. The difference in endurance between sham-operated and adrenalectomized-implanted and injected with corticosterone rats might be related to the significantly reduced adrenaline response. Some significance might also be attributed to a possible mineralocorticoid deficiency.

Inhibition of the rise in glucocorticoids during exercise had no effect on liver glycogen, liver adenosine — 3.5-cyclic monophosphate, plasma insulin, blood glucose, lactate, glycerol or 3-hydroxybutyrate. Only the plasma free fatty acids level was depressed in adrenalectomized oil treated rats compared to sham-operated animals at exhaustion [46].

Studies of urinary excretion of metabolites of glucocorticoids during longlasting competitions in sportsmen showed an association of good performance with a stable level of elevated adrenocortical activity [56, 57]. Accordingly the conception on functional stability as a necessary quality for endurance performance was established [63]

The mechanism that related adrenocortical activity to working capacity in the normal organism has still not been established. Studies on adrenalectomized rats showed the importance of glucocorticoids in maintaining the vascular tone in gluconeogenesis and especially in the regulation of transmembrane shifts of sodium and water [56, 58]. The restoration of working capacity of adrenalectomized rats (measured by the duration of swimming with an additional load of 3% of body weight) did not take place after 5 days treatment with cortisol if actinomycin D was simultaneously administered [65]. Following the treatment with actinomycin D, the RNA synthesis and thereby protein synthesis are blocked. Hence the glycocorticoid effect on working capacity, at least in adrenalectomized rats, depends on the additional synthesis of some responsible proteins. Cortisol administration did not restore the working capacity either when a high dose of progesterone was injected together with cortisol [66]. Progesterone competites with glucocorticoids for specific glucocorticoid receptor in the cellular cytoplasm and thus interferes with the action of glucocorticoids on the genetic apparatus of cells. In the liver tissue this competitive effect of progesterone is supposedly avoided by a cytoplasmic factor [12]. If this is the case, then the interference of progesterone in the glucocorticoid effect on the physical working capacity indicates the mediation of this effect through protein synthesis in tissues other than the hepatic tissue.

There are, of course, a number of various proteins (e.g. enzymes of amino acid metabolism and of gluconeogenesis) whose enhanced synthesis, because of the action of glucocorticoids, has a cumulative effect on physical working capacity. Among such enzymes an essential role belongs to Na^+, K^+-ATPase of the myocardial and skeletal muscle cells.

A period of swimming for 90 min was required to detect a significant increase of Na^+, K^+-ATPase activity in the microsomal fraction of the myocardial cells of untrained rats. Further continuation of exercise up to 6–10 h was accompanied by the return of the enzyme activity to the initial level. After an extreme duration of exercise (more than 16h) the Na^+, K^+-ATPase activity decreased significantly. The dynamics of plasma corticosterone concentration and of the activity of myocardial Na^+, K^+-ATPase were approximately parallel during these exercises [34]. In the skeletal muscle with predominantly white fibers the Na^+, K^+ -ATPase activity was increased immediately after swimming for 90 min and dropped to the initial level after swimming until exhaustion. In the muscle with predominantly red fibers, no significant changes were found. In trained rats swimming for 1.5 h did not increase either the plasma level of corticosterone or the myocardial Na^+, K^+-ATPase activity. After swimming for 18–20 h the blood corticosterone remained at an elevated level and the Na^+, K^+-ATPase activity did not differ from the initial level [32]. Rats exhausted by a 1-week hard training regimen exhibited a decreased level of corticosterone in the blood and a diminished Na^+, K^+-ATPase activity in the skeletal muscle [35].

Swimming with an additional load of 3% body weight until exhaustion (mean duration 201 min) caused increased Na^+, K^+-ATPase activity in the myocardial cells of normal rats. In adrenalectomized rats the lowered enzyme activity persisted after the exercise [33]. The physical working capacity of adrenalectomized rats, treated separately with gluco- or mineralcorticoids, correlated also with the activity of the enzyme [31].

These studies led to the suggestion that during prolonged exercise an additional synthesis of Na^+, K^+-ATPase is necessary for maintaining the adequate function of the Na^+, K^+-pump. The induction of this synthesis obviously required a sufficient supply of glucocorticoids.

In prolonged exercises, the essential role of glucocorticoids may concern the metabolic control of protein degradation, glucose-alanine cycle, gluconeogenesis, glycogenolysis and the permissive function in regard to adrenergic responses, including stimulation of lipolysis. Experiments on adrenalectomized rats confirmed the role of glucocorticoids in the exercise-induced accumulation of alanine in the red portion of the quadriceps muscle, blood plasma and liver in association with the increased activity of alanine-aminotransferase in the red quadriceps in urea formation and maintaining arginase activity [62]. in glucogenolysis both in the liver and skeletal muscles, peripheral glucose utilization and starving hepatic glycogen reserve [67].

THE POSSIBILITY OF ALDOSTERONE EFFECT

Data about the aldosterone effect on aerobic capacity as well as on results of some anaerobic tests [45, 47. 48] need further confirmation and a detailed study. Further studies are required to establish the relation of performance levels with the aldosterone and vasopressin responses to exercise.

GENERAL DISCUSSION

The effect of increased hormone production as well as that of an exogenous hormone can enhance the physiological responses in target cells if: (1) there are sufficient reserves in binding sites of cellular hormone receptors or (2) the elevated hormone level in the extracellular and intracellular compartment helps to achieve a rapid turnover of the receptorhormone complex. The first condition is necessary for simultaneous initiation of the activity in an increased number of locuses. connected with the actualization of the hormone effect. Of course. in this case the presumption is that there are available free sites through which the enhanced response will be achieved. The latter condition gives us a possibility for maintaining a high rate of initiation that results in a rapid emergence of responses, initiated quickly one after another, and in the persistence of a high level of functioning in target cells. Both these conditions emphasize the importance of alterations at the level of modulating regulation of hormone reception [55]. Special studies are required to establish the role of these alterations in improved physical working capacity.

There are no data about the hormone effect directly on the contractile mechanism in muscles. Therefore, if there is any connection between the hormone response and physical working capacity, it must be an expression of metabolic responses induced by hormones. However, it is a complicated task to prove the significance of each hormone in controlling metabolic processes during exercise, because various multifactoral systems controlling metabolism exist. The situation expresses Barcroft's rule of duplicated mechanisms [2]. Within a control system the lack of the effect of a hormone may be effectively compensated for by other factors. The stimulation of a hormone effect may likewise induce the activation of opposite responses which will inhibit or mask the stimulated effect. Nevertheless, with the increase of mobilization of the body's capacities the opportunities for such variation and compensations decrease. In conclusion, it is difficult to believe that top performance is possible without the optimal participation of the endocrine functions.

FURTHER PERSPECTIVES

Summing up, the above presented discussion allows us to consider the most evidenced in regard to the esential roll of hormonal metabolic control in sports performance (Figure 2).

(1) contribution of adrenalin in muscle glucogenolysis,
(2) correlated influences of several hormones in the control of lipolysis,
(3) action of glucocorticoids ensuring performance of prolonged exercises.

Rather suggestive is also the dose-depending influence of triiodothyronine on the capacity for prolonged exercise performance. However, this fact needs further evaluation, while (a) the exercise-induced responses of the pituitary-thyroid system are usually modest if any [15, 57], (b) the mechanism of thyroid hormone action of working capacity is not established. Results have been published on the significance of vasopressin in the working capacity [23, 24]. However, the effect of vasopressin was demonstrated in hypophysectomized rats: administration of vasopressin together with adrenocortical extract was necessary to restore the working capacity completely after hypophysectomy [23]. The essential role of vasopressin was confirmed by the fact that ablation of the posterior pituitary was enough to decrease working capacity significantly. The substitute treatment with adrenocortical extract did not influence the working capacity in those rats [24]. No information has been obtained regarding the vasopressin effect on working capacity in the normal organism.

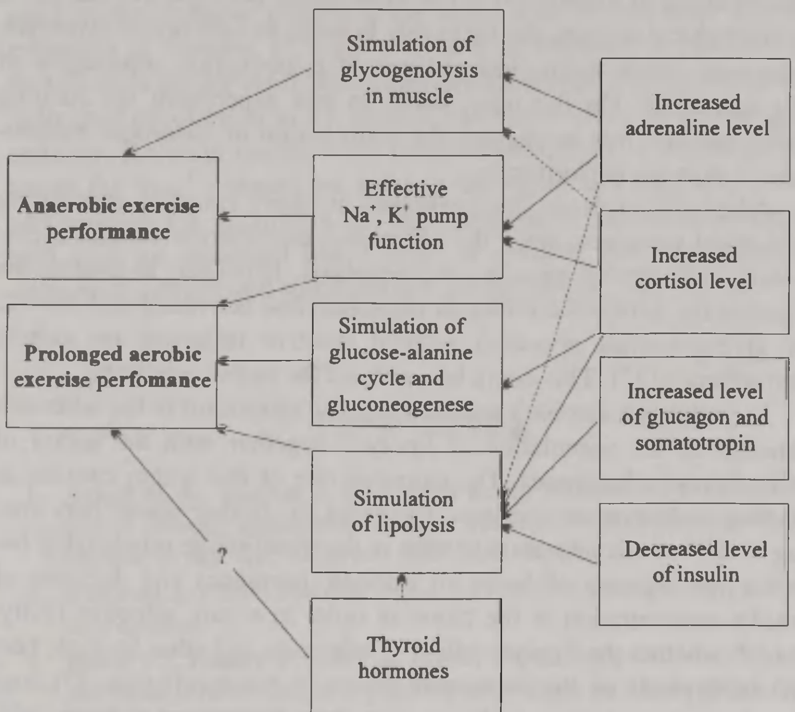

Figure 2. Suggested pathways of hormonal influences on performance level in athletes.

The necessity for adrenalin in the pronounced increase of the rate of muscle glycogenolysis suggests a mechanism by which adrenalin is essential for the anaerobic working capacity. It seems rather perspective to study the relationship between the individual magnitude of adrenalin response to supramaximal exercises and the actual anaerobic working capacity. However, the necessity for evaluation of this relationship is emphazised also two sets of results. First, the adrenalin effect on muscle glycogenolysis is mediated by α-adrenoreceptor [43]. Consequently the performance capacity for supramaximal exercises and glycogenolysis may not be directly related. Further, β-adrenergic blockade excludes the decrease in glycogen in fast-twitch oxidative-glycolytic and slow-twitch oxidative muscles in the course of running and swimming. In the fast-twitch glycolytic fibers glycogenolysis was blocked after running for 30 min at low speed, but was almost normal after running to exhaustion at the same speed [20]. On the one hand. in anaerobic exercises the main role belongs to fast-twitch glycolytic exercises, which seems independent of β-adrenergic stimulation of glycogenolysis. On the other hand, in this experiment the running speed was too low to suggest the contribution of anaerobic metabolism in exercise performance.

Adrenalin's role on glycogenolysis is likely essential also during prolonged exercises, since the adrenaline contribution ensures a persisting high rate of muscle glycogenolysis. However, in continuous exercise the adrenaline effect on phosphorylase activation and the rate of glycogenolysis appeared without positive influence on muscle performance [37]. This could be a subject for further research.

In prolonged aerobic exercise the most significant is the adrenalin function in the stimulation of lipolysis together with the action of other lipolytic hormones. The essential role of this action consists in starting carbohydrate reserves. The tasks for further researchers arising in this connection are: (1) what is the quantitative relationship between the increase of levels of lipolytic hormones and decrease of insulin concentration in the blood in order to ensure effective lipolysis, (2) whether the lipolytic effect of adrenalin and other lipolytic hormones depends on the permissive action of glucocorticoids, (3) does the elevated lipolysis actually support glucose transport to brain cells, (4) how the situation is influenced after glucose intake during prolonged exercise.

Further studies are necessary also for evaluation of the effectiveness of glucostatic mechanism and oxidation control in regard to performance capacity during prolonged exercises. Is the positive action of exogeneous triiodothyronine related to stimulation of the oxidation rate? At the same time a question arises whether hormonal mechanism exist for the stimulation/inhibition of free radical oxidation.

What is the mechanism of positive influence of the glucocorticoid response for performance capacity in prolonged exercises? Above several possibilities were indicated. Rather perspective should be studies on the significance of the permissive action of glucocorticoids as well as on the glucocorticoid control of the function of the Na^+, K^+-pump. Besides glucocorticoids one must take into consideration that prolonged action on Na^+, K^+-pump are exerted by adrenalin, thyroxine and insulin [6].

Several other more specific questions are waiting for further research. Among them one may list: (1) the influence of fatique on hormonal metabolic control, (2) influence on performance capacity exerted by the rhythmic pattern of the blood level of estrogens and progesterone in females, (3) role of insulin in transport of glucose into muscle cells during short-term anaerobic exercises, (4) significance of individual pecularities in the general endocrine status for performance capacity. Recently results were obtained indicating a correlation between the basal testosterone level in the blood and explosive power performance [3]. In rowers the improvement of performance associated with an increased blood level of cortisol and augmented responses of cortisol and somatotropin during rowing [50].

REFERENCES

1. **Arnall D. A., Marker J. C., Conlee R. K., Winder W. W.** (1986) Effect of infusing epinephrine on liver and muscle glycogenolysis during exercise in rats. Am. J. Physiol. 250: E641–E649.
2. **Barcroft J.** (1934) Features in the Architecture of Physiological Function, London.
3. **Bosco C., Tihany J., Viru A.** (1996) Relationship between field test and basal serum testosterone and cortisol levels in soccer player. Clin. Physiol. 16: 317–322.
4. **Cannon W. B., Nice L. B.** (1913) The effect of adrenal secretion on muscular fatigue. Am.J.Physiol. 32:44–60.
5. **Chasiotis D., Brandt R., Harris R.C., Hultmann E.** (1983) Effects of β-blockade on glucogen metabolism in human subjects during exercise. Am. J. Physiol. 245: E166–E170.
6. **Clavsen T.** (1986) Regulation of active Na^+, K^+-transport in skeletal muscle. Physiol. Rev. 66: 542–580.

7. **Cleroux J., Van Nguyen P., Taylor A. W., Leenen H. H.** (1989) Effects of β_1-vs β_{1+2}-blockade on exercise endurance and muscle metabolism in humans. J. Appl. Physiol. 66: 548–554.
8. **Conlee R. K., McLane J. A., Rennie M. J., Winder W. W., Holloszy J. O.** (1979) Reversal of phosphorylase activation in muscle despite continued contractile activity. Am. J. Physiol. 237:R291–R296.
9. **Derevenco P.** (1972) Relationship between hormonal control and physical activity. I Effect of corticotropin and dexamethasone on physical activity of rats. Endocrinol. Exp. 6: 171–178.
10. **Derevenco P., Ivanof L., Axente V., Derevenco V.** (1975) Action of some pituitary hormones on the work capacity in rats. Rev. Roum. Morphol. Embryol. Ser. Physiol. 12: 91–95.
11. **Dietz M. R., Chilasson J.-L., Soderling T. R., Exton J. H.** (1980) Epinephrine regulation of skeletal muscle glycogen metabolism. J. Biol. Chem. 255: 2301–2312.
12. **Disorbo D. M., Milholland R. J., McPartland R. P., Rosen F.** (1977) Evidence for a factor in liver cytosol which controls the competition between progesterone and triamcinolone acetonide for the glucocorticoid receptor. Life Sci. 20, 1593–1598.
13. **Fain J. N., Kovacev V. P., Scow R. V.** (1965) Effect of growth hormone and dexamethasone on lipolysis and metabolism of isolated fat cells of the rat. J. Biol. Chem. 240: 3522–3529.
14. **Fell R. D., Holloszy J. O., Ivy J. L., Rennie M. J.** (1981) Adrenaline reactivates muscle phosphorylase after reversal of activity with repeated contraction. J. Physiol. 317: 21P–22P.
15. **Galbo H.** (1983) Hormonal and Metabolic Adaptation to Exercise. Stuttgart, New York, G.Thieme Verlag.
16. **Galbo H.** (1992) Exercise physiology: humoral function. Sports Sci. Rev. 1: 65–93.
17. **Galbo H., Holst J. J., Cristensen N.J., Hilsted J.** (1976) Glucagon and plasma catecholamines during beta-receptor blockade in exercising man. J. Appl. Physiol. 40:855–863.
18. **Goffart M., Ritchie J. M.** (1952) The effect of adrenaline on the contraction of mammalian skeletal muscle. J.Physiol. 116: 357–371.
19. **Gorostiaga E. M., Czerwincki S. M., Hickson R. C.** (1988) Acute glucocorticoid effects on glycogen utilization, O_2 uptake, and endurance. J. Appl. Physiol. 64, 1098–1106.
20. **Gorski J., Pietrzyk K.** (1982) The effect of beta-adrenergic receptor blockade on intramuscular glycogen mobilization during exercise. Eur. J. Appl. Physiol. 48: 201–205.
21. **Gruber C. M.** (1914) The fatigue threshold as affected by adrenalin and by increased arterial pressure. Am. J. Physiol. 33: 335–355.

22. **Häggendal L., Hartley L. H., Saltin B.** (1979) Arterial noradrenaline concentration during exercise in relation to the relative work levels. Scand. J. Clin. Lab. Invest. 26: 337–342.
23. **Ingle D. J.** (1955) Effect of endocrine glands on normal muscle work. Am. J. Med. 19: 724–728.
24. **Ingle D. J.** (1957) Work performance of rats following partial hypophysectomy. Endocrinology 61: 173–176.
25. **Ingle D. J., Nezamis J. E., Jeffries J. W.** (1949) Work performance of normal rats given continuous injection of adrenal cortex extract. Am. J. Physiol. 157: 99–102.
26. **Ingle D. J., Nezamis J. E., Morley E. H.** (1951) Work output and blood glucose values in severely diabetic rats with and without insulin. Am. J. Physiol. 165: 469–472.
27. **Issekutz B.** (1978) Role of beta-adrenergic receptors in mobilization of energy sources in exercising dogs. J. Appl. Physiol. 44:869–878.
28. **Kaiser P.** (1984) Physical performance and muscle metabolism during β-adrenergic blockade in man. Acta Physiol. Scand. 536: 1–53.
29. **Kjaer M.** (1989) Epinephrine and some other hormonal responses to exercise in man: with special reference to physical training. Int. J. Sports Med. 10: 1–15.
30. **Kjaer M.** (1992) Regulation of hormonal and metabolic responses during exercise in humans. Exerc. Sport Sci. Rev. 20: 161–184.
31. **Kõrge P.** (1976) Myocardial sodium-potassium pump and its adrenocortical regulation as factors limiting cardiac adaptation to severe physical exertion, Kardiologia 16: 15–21 (in Russian).
32. **Kõrge P., Masso R., Roosson S.** (1974) The effect of physical conditioning on cardial response to acute exercise. Can. J. Physiol. Pharmacol. 52: 745–752.
33. **Kõrge P., Roosson S.** (1975) The importance of adrenal glands in the improved adaptation of trained animals to physical exertion. Endokrinologie 64: 232–238.
34. **Kõrge P., Roosson S., Oks M.** (1974) Heart adaptation to physical excretion in relation to work duration. Acta Cardiol. 29: 303–320.
35. **Kõrge P., Viru A., Roosson S.** (1974) The effect of chronic physical overload on skeletal muscle metabolism and adrenocortical activity. Acta Physiol. Acad. Sci. Hung. 45: 41–45.
36. **Malan D. D. J., Frits J. T., Dreyer A. C., Strydom G. L.** (1983) The influence of β-adrenoceptor blockade on the hemodynamic response and physical performance of middle and long distance runners. In: Knuttgen H. G., Vogel J. A., Poortmans J. (Eds) Biochemistry of Exercise. Human Kinetics Publ. Champaign, 755–761.

37. **Malig H., Stern D., Altland P., Highman B., Brode B.** (1966) The physiological role of the sympathetic nervous system in exercise. J. Pharmacol. Exper. Ther. 154: 35–45.

38. **Marker J. C., Arnall D. A., Conlee R. K., Winder W. W.** (1986) Effect of adrenaldemedullation on metabolic responses to high intensity exercise. Am. J. Physiol. 251: R552–R559.

39. **Nazar K., Brzezinska Z., Kozlowski S.** (1975) Sympathetic activity during prolonged physical exercise in dogs: control of energy substrate utilization. In: Howald H., Poortmans JR (eds) Metabolic Adaptation to Prolonged Physical Exercise. Basel, Birkhäuser Verlag, 204–210.

40. **Nesher R., Karl I. E., Kipnis D. M.** (1980) Epitrochlearis muscle. II Metabolic effects of contraction and catecholamines. Am.J.Physiol. 239: E461–E467.

41. **Peronnet F., Imbach A.** (1983) Endurance and metabolic adjustments to exercise in sympathectomized (6-OHDA) rats. In: Knuttgen HG, Vogel JA, Poortmans J (eds). Biochemistry of Exercise. Champaign, Human Kinetics Publ. 762–765.

42. **Richter E. A., Galbo H., Cristensen N. J.** (1981) Control of exercise-induced muscular glucogenolysis by adrenal medullary hormones in rats. J.Appl.Physiol. 50: 21–26.

43. **Richter E. A., Ruderman N. B., Galbo H.** (1982) Alpha- and beta-adrenergic effects on muscle metabolism in contracting, perfused muscle. In: Knuttgen HG, Vogel JA, Poortmans J (eds). Biochemistry of Exercise, Champaign, Human Kinetics Publ. 766–773.

44. **Richter E. A., Ruderman N. B., Gavras H., Belur E. R., Galbo H.** (1982) Muscle glycogenolysis during exercise: dual control by epinephrine and contractions. Am. J. Physiol. 242: E25–E32.

45. **Schramm U., Skipka N.** (1981) The effects of aldosterone on aerobic and anaerobic metabolic rate during 5 min exercise. Pflügers Arch. 391, R54.

46. **Sellers T. L., Jaussi A. W., Yang H. T., Heninger R. W., Winder W. W.** (1988) Effect of the exercise-induced increase in glucocorticoids on endurance in the rat. J. Appl. Physiol. 65: 173–178.

47. **Skipka W., Schöning L., Stegemann J., Vetter H.** (1978) Increased of $\dot{V}O_2$ max induced by aldosterone. Pflügers Arch. 377, R34.

48. **Skipka W., Schramm U.** (1983) Delay of fatigue effects during exhaustive exercise by aldosterone. In: Knuttgen H. G., Vogel J. H., Poortmans J. (Eds.) Biochemistry of Exercise, Human Kinetics Publ. Champaign, 886–891.

49. **Smirnova T. A., Viru A. A.** (1977) Dependence of physical working capacity on the state of cortisol function and character of tissue distribution of corticosterone. Acta Comment. Univ. Tartuensis, 419: 130–133.

50. **Snegovskaya V., Viru A.** (1993) Elevation of cortisol and growth hormone levels in the course of further improvement of performance capacity in trained rowers. Int. J. Sports Med. 14: 202–206.
51. **Spriet L. L., Ren J. M., Hultman E.** (1988) Epinephrine infusion enhances muscle glycogenolysis during prolonged electrical stimulation. J. Appl. Physiol. 64: 1439–1944.
52. **Tomson K., Kallikorm A.** (1977) Effect of a single administration of 3,3'-triiodine thyronine on the physical working capacity of white rats. Acta Comment. Univ. Tartuensis 499: 183–186. (In Russian.)
53. **Toode K., Smirnova T., Tendzegolskis Z., Viru A.** (1993) Growth hormone action on blood glucose, lipids and insulin during exercise. Biol. Sport 10: 99–105.
54. **Uusitupa M., Siitonen O., Härkönen M., Aru A., Hermaa R., Gordin A.** (1980) The metabolic and hormonal effects of selective and nonselective beta-blockade during physical exercise. Acta Endocrin. 94 (237): 84.
55. **Vendsalu A.** (1966) Studies on adrenaline and noradrenaline in human plasma. Acta Physiol. Scand. 49 (173), 1–123.
56. **Viru A.** (1977) Function of Adrenal Cortex in Muscular Activity. Moscow, Medicine. (In Russian.)
57. **Viru A.** (1985) Hormones in Muscular Activity. Vol. 1. Hormonal Ensemble is Exercise. Boca Raton FL, CRC Press.
58. **Viru A.** (1985) Hormones in muscular Activity. Vol. 2. Adaptive Effect of Hormones in Exercise. Boca Raton FL, CRC Press.
59. **Viru A.** (1991) Adaptive regulation of hormone interaction with receptor. Exp. Clin.Endocrinol. 97: 13–28.
60. **Viru A.** (1992) Plasma hormones and physical exercise. Int. J. Sports Med. 13: 201–209.
61. **Viru A.** (1995) Adaptation in Sports Training. Boca Raton FL, CRC Press.
62. **Viru A., Litvinova L., Viru M., Smirnova T.** (1994) Glucocorticoids in metabolic control during exercise: alanine metabolism. J. Appl. Physiol. 76: 801–805.
63. **Viru A., Matsin T.** (1988) Functional stability of adrenocortical activity during bicycle ergometer and running exercise. Biol. Sport 5: 305–313.
64. **Viru A., Smirnova T.** (1982) Independence of physical working capacity from increased glucocorticoid level during short-term exercises. Int. J. Sports Med. 3: 80–83.
65. **Viru A., Smirnova T.** (1985) Involvement of protein synthesis in action of glucocorticoids in working capacity of adrenalectomized rats. Int. J. Sports Med. 6: 225–228.

66. **Viru A., Smirnova T., Seene T., Tomson K., Eller A.** (1979) Participation of glucocorticoids in development of physical working capacity. Sechenov Physiol. J. USSR 65, 1790–1795. (In Russian.)
67. **Viru M., Litvinova L., Smirnova T., Viru A.** (1994) Glucocorticoids in metabolic control during exercise: glycogen metabolism. J. Sports Med. Phys. Fit. 34: 377–382.
68. **Winder W. W., Young H. T., Jaussi A. W., Hopkins C. R.** (1987) Epinephrine, glucose and lactate infusion in exercising adrenomedullated rats. J. Appl. Physiol. 62: 1442–1447.
69. **Yakovlev N. N., Viru A.** (1985) Adrenergic regulation of adaptation to muscular activity. Int. J. Sports Med. 6: 255–264.

Correspondence to:
Prof. Atko Viru
Institute of Exercise Biology
University of Tartu, 18 Ülikooli street, Tartu, EE2400, Estonia

GENDER DIFFERENCES IN THE EXTENT OF MOTOR IMPAIRMENT AMONG STUDENTS WITH LEARNING DISABILITIES

R.- J. Shephard and M. Bluechardt
School of Physical & Health Education, University of Toronto, Health Studies Programme, Brock University, St.Catharines, & University of Regina, Regina, Canada

ABSTRACT

Possible reasons for gender differences in the prevalence of learning disabilities were explored. The Bruininks-Oseretsky Test battery was applied to a sample of prepubertal students, 33 boys and 10 girls with learning disabilities. The average age was 9.4 ± 1.1 years. The female students were taller ($p < 0.001$) and heavier ($p < 0.05$) than a representative sample of Canadian children, but the boys were of normal size. Relative to the North American norms of Sattler (1988), the motor performance of boys and girls was reduced for balance ($p < 0.001$), bilateral coordination ($p < 0.001$), strength ($p < 0.025$), upper limb coordination ($p < 0.001$), visual motor control ($p < 0.001$), upper limb speed and dexterity ($p < 0.001$) and response speed ($p < 0.001$), with corresponding deficits in gross motor ($p < 0.005$), fine motor ($p < 0.001$) and battery ($p < 0.001$) composite scores. Substantial gender differences favoured males for strength ($p < 0.005$), gross motor composite ($p < 0.025$), response speed($p < 0.005$), fine motor composite ($p < 0.05$) and battery composite ($p < 0.05$) scores. The observed gender differences in motor skills cannot be explained by any association with body build. Possible explanations are (1) that the leisure pursuits of girls demand more coordination than those of boys, so that girls with learning disabilities are excluded from physical activities, with a progressive worsening of their motor performance, or (2) that, for culturally-related reasons, there is a gender inequity in the threshold for a diagnosis of learning disability between girls and boys.

KEY WORDS: Bruininks-Oseretsky test, Clumsy children, Gender inequities, Motor skills

INTRODUCTION

Learning disabilities are a major problem for those teaching "integrated" school classes. The prevalence of the conditionis as high as 20% [8]. Some of the students concerned have become gifted athletes, but the majority are "clumsy", with 75% showing motor problems. It is less clear whether an unusual body build contributes to the clumsiness, or whether disability is similar in boys and girls.

We thus tested three hypotheses:

1. Clumsiness is substantial relative to other children of similar age.
2. Clumsiness is similar in boys and girls diagnosed as learning disabled.
3. Body size does not influence the extent of motor impairment.

METHODS

Subjects. The sample comprised 43 students (33 boys, 10 girls) of average age 9.4 ± 1.1 years. All were unselected volunteers, diagnosed as communication learning disabled, and recruited in accordance with an experimental protocol approved by the University Committee on Human Experimentation.

In five students there was a problem in understanding language, and the remander were classed as specific learning disabled. Twenty six of the students were periodically withdrawn from normal classes for special instruction, and 11 were receiving instruction at a special school for those with learning disabilities.

Chemotherapy included Ritalin (methyl phenidate, 4 students), Dilantin (phentoin, 1 student) and Tegretol (carbamazepine, 1 student).

The Bruininks-Oseretsky test is a field performance test specifically designed to test gross and fine motor proficiency in young children [3].

Gross motor skills are evaluated by tests of running speed and agility (shuttle-run), balance (8 items), bilateral coordination (8 tapping, jumping and drawing tests) and strength (standing broad jump, sit-ups, and two types of push-ups).

Fine motor skills are examined by tests of visual motor control (8 drawing, cutting and copying tasks), upper limb speed and dexterity (8 items, manipulating pegs, pennies, a pencil and beads) and response speed (catching a stick that is dropped).

A final test of upper limb coordination examines a combination of gross and fine motor skills (9 items, mainly bouncing, catching and throwing).

Data analysis

Scores for subtests were related to age-specific scores obtained on 765 U.S. and Canadian children [3, 6]. The norms for sub-tests had a standardized score of 15 ± 5 units, with no difference in requirements between boys and girls. The composite scores for gross motor and fine motor performance were converted to age and gender-specific scores, with standardized norms of 50 ± 10 units.

Departures from published norms were examined by unpaired t-tests, on the assumption that the published means were invariate. The level of alpha was adjusted by the Bonferonni technique to allow for multiple comparisons.

Relationships between body build and motor performance were tested by fitting linear regressions, using the method of least squares.

RESULTS

Physical characteristics. The physical characteristics of the subjects are summarized in Table 1. The boys did not differ from their published norms of the Canada Fitness Survey [4], but the girls were significantly taller ($p < 0.05$) and heavier ($p < 0.001$) than their peers in the general population.

Table 1. Physical characteristics of subjects, mean ± SD and values expressed as a percentage of the corresponding norms for the Canadian population [4].

Stature:	Boys	1.35 ± 0.14 m	(98.3 ± 9.8% of CFS)
	Girls	1.43 ± 0.09 m	(104.5 ± 6.4% of CFS)
Body mass:	Boys	34.4 ± 9.1 kg	(105.6 ± 30.4% of CFS)
	Girls	38.7 ± 4.6kg	(120.8 ± 17.2% of CFS)

Motor Performance. All scores with the exception of running speed were low relative to the population norms of Bruininks [3] (Table 2). Statistically significant deficits of motor performance were demonstrated for balance, bilateral coordination, strength, visual motor control, upper limb speed and dexterity, response speed, and composite scores for gross motor, fine motor and overall battery scores.

Table 2. Motor proficiency, as assessed by the Bruininks-Oseretsky test. Mean ± SD of scores for students with a learning disability, standardized to an age-specific normative value of 15 ± 5 units for sub-scales and 50 ± 10 units for composite score (see text).

Variable	Standardized score		
	Males (n = 33)	Females (n = 10)	All subjects (n = 43)
Gross motor sub-tests			
Running speed and aqility	17.0 ± 7.7	16.4 ± 4.2	16.8 ± 7.0
Balance	9.5 ± 6.5	7.6 ± 6.5	9.1 ± 6.5****
Bilateral coordination	11.9 ± 4.5	10.4 ± 2.9	11.5 ± 4.2****
Strength	14.1 ± 4.8	8.3 ± 3.3****	12.8 ± 5.1**
Fine motor sub-tests			
·Visual motor control	10.3 ± 5.2	8.9 ± 6.9	10.0 ± 5.6****
Upper limb speed /dexterity	10.7 ± 4.3	8.9 ± 5.3	10.3 ± 4.5***
Response speed	9.2 ± 3.8	5.4 ± 3.8****	8.8 ± 4.1****
Upper Limb Coordination	10.6 ± 5.4	9.2 ± 6.4	10.3 ± 5.6
Composite scores			
Gross motor	43.9 ± 17.2	37.9 ± 7.7**	42.5 ± 15.6***
Fine motor	35.3 ± 13.2	28.2 ± 19.4*	31.6 ± 18.7****
Battery	35.1 ± 20.1	31.1 ± 20.8*	31.7 ± 23.5****

Test involves both gross and fine motor coordination.
Significance of difference between genders, and between all subjects and norms:
**** $p < 0.001$ *** $p < 0.005$ ** $p < 0.025$ * $p < 0.05$.
Note: since 10 ten test comparisons have been made, alpha has been set at $p < 0.005$ (see text).

Scores were uniformly pooper in the girls than in the boys, and these differences were larger than could be explained by gender differences in the composite scores for the normal population (Table 3).

Table 3. The conversion of a given crude score into age-specific (pooled) and age and gender-specific normalized value for the Bruininks-Oseretsky test of motor proficiency.

Test item	Crude score	Corresponding pooled	Normalized score	
			Male	Female
Gross motor composite	59	50	50	51
	45	40	39	41
	34	30	30	36
Fine motor composite	44	50	51	49
	34	40	40	40
	24	30	30	30
Battery composite	118	50	49	51
	96	40	40	41
	74	30	30	31

Relationship of motor performance to body build. Linear regressions tested the association of the individual motor performance items with height and body mass. Of the eighteen regressions that were calculated, only one showed a marginal trend (Figure 1): height vs gross motor score in girls, with a positive slope of 1.76 + 0.73 ($p < 0.038$).

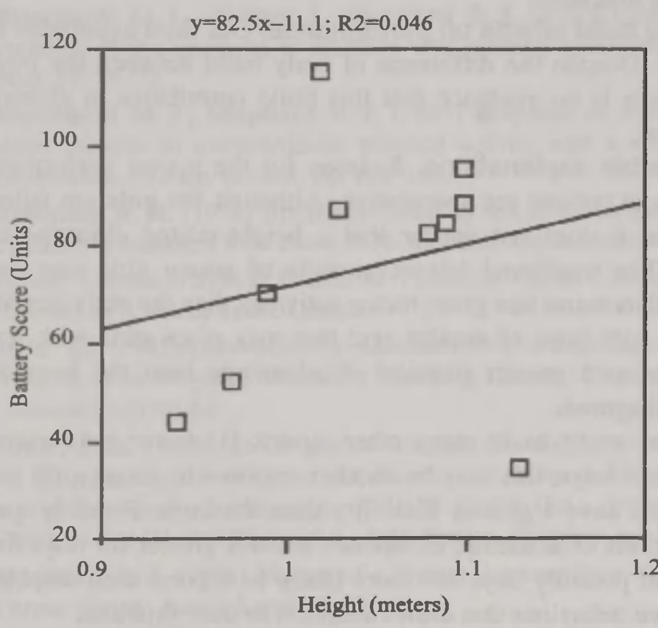

Figure 1. Relationship between standing height and battery score for female subjects.

DISCUSSION

Body size. The girls were a little taller and substantially heavier than the national average. This cannot be attributed to regional differences, since Ontario data usually match national norms [5]. Nor has there been any substantial secular trend in the height of children since the 1981 Canada Fitness Servey [7]. Socio-economic status was average or below average, so this is also unlikely as an explanation of the excess height of the girls.

Performance. Our first hypothesis can be accepted: As previously noted by other authors (see Bluechardt *et al.* [1] for review), the children with learning disabilities have a substantial deficit in most facets of motor performance.

We might anticipate an impact upon socialization and self-esteem. Classroom teachers reported deficits in social behaviour for some of the students, but the students themselves rated their competence as "medium" in both academic and non-academic domains.

Gender difference. Our second hypothesis is rejected: the performance of the girls is substantially inferior to that of the boys with the same diagnosis.

Body build effects on performance. Our third hypothesis is also rejected: Despite the difference of body build between the boys and girls, there is no evidence that this build contributes to clumsy performance.

Possible explanations. Reasons for the poorer performance of the girls at present are speculative. Although the girls are taller than the boys, it does not appear that a height-related clumsiness is to blame. The traditional leisure pursuits of young girls may demand more balance and less gross motor activities than the activities that are popular with boys of similar age; this may place girls with learning disability at a greater physical disadvantage than the boys with a similar diagnosis.

In our study, as in many other reports [1] fewer girls were diagnosed than boys; this may be another reason why those girls who are diagnosed have a greater disability than the boys. Possibly, parental expectations of academic excellence are still greater for boys than for girls, and possibly boys are more likely to express their disability by disruptive behaviour that draws attention to their problem.

Therapeutic implications. Given a substantial deficit of motor skills, we might anticipate that a programme of perceptual motor training would enhance physical performance, thereby improving self-esteem and remedying the learning problem. In fact, our own studies [2] and others [1] have found little improvement in either academic or sport performance from such training programmes, even when they incorporate a social skills component.

There seem several explanations of this paradox.:

1. If a child has a reputation for limited athletic competence, it is difficult to dissipate this, even if actual performance is enhanced.
2. The student with a learning disability is likely to have an accumulated deficit of social skills which takes a long time to reverse.
3. There may, finally, be little generalization of instruction from the gymnasium to the academic classroom.

ACKNOWLEDGMENTS: Dr. Shephard is currently Canadian Tire Acceptance Limited Resident Scholar in Health Studies at Brock University. The support of CTAL is gratefully acknowledged.

REFERENCES

1. **Bluechardt M. L., Wiener J., Shephard R. J.** (1995) Exercise programmes in the treatment of children with learning disabilities. Sports Med. 19: 55–72.
2. **Bluechardt M. J., Shephard R. J.** (1995) Response of learning disabled students to extracurricular physical activity with a social skills component. J. Learn. Disabil. 28: 160–169.
3. **Bruininks R. H.** (1978) Bruininks-Oseretsky test of motor proficiency: examiner's manual. Circle Pines, MN: American Guidance Service.
4. Fitness Canada. Physical Fitness of Canadian Youth. (1985) Ottawa: Fitness and Amateur Sport, Canada.
5. **Jette' M.** (1982)Anthropometric Characteristics of Canadian Children from Birth to 19 years. Report to Nutrition Canada, Ottawa. Ottawa: University of Ottawa.
6. **Sattler J. M.** (1988) Assessment of learning disabilities, attention deficit hyperactivity disorder, conduct disorder, pervasive development disorders and sensory impairments. In: J. M. Sattler (Ed.), Assessment of Children, 3rd Ed. San Diego, CA.: J. M. Sattler, Publisher, pp. 597–645.
7. **Shephard R. J.** (1986) Fitness of a Nation. Lessons from the Canada Fitness Survey. Basel: Karger Publications.
8. **Sherrill C.** (1986) Adapted Physical Education and Recreation. Dubuque, Iowa: W. C. Brown.

Correspondence to:
Professor Roy J. Shephard,
School of Physical & Health Education,
320, Huron St., Toronto, ON.M5S, 1A1, Canada

PHYSIQUE AND PHYSICAL FITNESS IN PREPUBERTAL CHILDREN

L. Raudsepp and T. Jürimäe
Institute of Sport Pedagogy, University of Tartu, Tartu, Estonia

ABSTRACT

The purpose of this study was to examine the relationships between physique's measurements and physical fitness in prepubertal children. Gender differences in body measures and physical fitness were also studied. Ninety-two 7–9-year-old children were divided into two groups: 44 boys (mean age 8.1 ± 1.5 yrs) and 48 girls (mean age 7.9 ± 1.4 yrs). Twenty-two physique's measurements were taken according to the O-Scale physique assessment system. Somatotype components were anthropometrically determined according to the Heath-Carter somatotyping method. EUROFIT test battery was used to evaluate the physical fitness of the children. The findings of the study indicated that relationships between physique's measurements and physical fitness were mostly non-significant ($p > 0.05$) and there were no clear differences in associations in respect of boys and girls. Furthermore, although the boys surpassed girls in circumferential measurements and girls surpassed boys in skinfold thicknesses, these differences were generally non-significant ($p > 0.05$). Gender differences in physical fitness indicated that boys were superior in running speed, strength and endurance tests and girls resulted higher in flexibility and balance.

KEY WORDS: Physique, Physical fitness, Children

INTRODUCTION

Many factors influence physical fitness at a particular time period or age. The researchers of motor development have acknowledged the fact that little information exists about the extent to which various factors such as physical growth actually influence the motor development of young children [21].

Several studies [10, 11, 18, 28, 29, 30, 31] have reported the age and sex peculiarities in somatotype in ages 6–10 years. In general it is evident that boys are more mesomorphic and less endomorphic than girls [5, 10, 17]. It appears that the somatotype reflects the general biological differences in body morphology of boys and girls [16].

There are relatively few experimental studies relating to the physical growth characteristics and physical fitness in children [5]. It has been observed that in general physical fitness has a low positive correlation with mesomorphy and body size and a low negative correlation with fatness and endomorphy [8, 12, 20, 28, 29]. Negative relationships between both endomorphy and body fatness with physical fitness is especially obvious in tasks requiring movement of the body mass [28, 29]. On the other hand, Hensley *et al.* [17] reported that among preadolescent children body fatness may have relatively different effects on the performance of boys and girls.

This study examined the relationships between physique's measurements and physical fitness in prepubertal children. In addition, gender differences in physique and physical fitness were examined.

MATERIALS AND METHODS

Ninety-two elementary school children from Tartu, Estonia, aged 7–9 years, served as subjects in the study. They were divided into two groups: 44 boys (mean age 8.1 ± 1.5 yrs) and 48 girls (mean age 7.9 ± 1.4 yrs). The parents of every child were informed about testing procedures, and they consented to their child's participation in this study.

Twenty-two physique's measurements were taken according to the O-SCALE physique assessment system [32]. The girth of the arm (relaxed and tensed), forearm, wrist, chest, waist, gluteal, thigh, calf and ankle were measured using a steel tape measure. Humerus and femur width were measured with sliding caliper following standard measurement technique [19]. Body height was measured using Martin's metal anthropometer to the nearest 0.1 cm and body mass was measured to the nearest 0.1 kg. Body mass index (BMI) was calculated (mass, kg/height^2, m). The measurements of skinfold thickness were obtained with Holtain caliper by one investigator at the following sites: triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, and medial calf. Three complete sets of measurements were carried out on each subject and the mean of three measurements at each site was used. Scores for five skinfolds (triceps, subscapular, supraspinale, abdomen, thigh) were summed to provide a single index of adiposity, following standard protocols [19]. Endomorphy, mesomorphy and ectomorphy were anthropometrically determined according to the Heath-Carter somatotyping method [5].

EUROFIT test battery [14] was administrated to evaluate the physical fitness of the children.

Standard statistical procedures were used to analyze the data. Descriptive statistical procedures included means, standard deviations and zero-order correlations. A one-way ANOVA was used to test the significance of the mean difference between the sexes on the physique and physical fitness measures. Statistical significance was set at $p < 0.05$.

RESULTS

The means and standard deviations of anthropometric characteristics of the subjects are presented in Table 1. The results of the one-way ANOVA indicated that there was a significant ($p < 0.05$) difference between boys and girls on forearm, wrist, chest and ankle girth. The mean scores of boys on these characteristics were significantly higher than those of the girls.

Table 1. Means ($\bar{X}$) and standard deviations (SD) of anthropometric characteristics.

Variable	Boys (n = 44)		Girls (n = 48)		p
	X	SD	X	SD	
1. Height (cm)	130.8	8.1	127.0	6.2	NS
2. Body weight (kg)	27.2	5.5	24.9	4.2	NS
3. BMI (kg/m^2)	15.6	1.5	15.2	1.3	NS
4. Arm girth relaxed (cm)	18.1	1.9	17.9	1.5	NS

5. Arm girth flexed and tensed (cm)	19.8	2.2	19.3	1.9	NS
6. Forearm girth (max. relaxed) (cm)	19.1	1.8	18.3	1.4	*
7. Wrist girth (distal styloid) (cm)	13.2	1.1	12.5	0.9	*
8. Chest girth (mesosternale) (cm)	63.4	4.8	60.4	3.6	*
9. Waist girth (cm)	56.5	5.4	55.7	5.1	NS
10. Gluteal girth (max) (cm)	38.5	4.8	39.1	3.6	NS
11. Thigh girth (cm)	35.8	4.3	35.4	3.8	NS
12. Calf girth (max) (cm)	26.5	2.7	25.7	2.3	NS
13. Ankle girth (cm)	19.3	1.8	18.2	1.7	*
14. Humerus width (cm)	5.5	1.1	5.2	0.9	NS
15. Femur width (cm)	6.9	0.9	6.4	1.3	NS

* $p < 0.05$ NS — Not Significant

The means and standard deviations of body fatness measurements and somatotype components are presented in Table 2. The boys surpassed the girls significantly ($p < 0.05$) only in biceps skinfold. There were no significant ($p > 0.05$) sex differences regarding the somatotype components.

Table 2. Means ($\bar{X}$) and standard deviations (SD) of body fatness measurements and somatotype components.

Variable	Boys (n = 44)		Girls (n = 48)		p
	$\bar{X}$	SD	$\bar{X}$	SD	
1. Triceps skinfold (mm)	7.7	3.4	7.3	3.1	NS
2. Subscapular skinfold (mm)	6.3	1.8	6.9	1.7	NS
3. Biceps skinfold (mm)	7.3	2.4	8.7	2.8	*
4. Iliac crest skinfold (mm)	5.7	2.9	6.0	2.4	NS
5. Supraspinale skinfold (mm)	6.3	2.8	6.4	2.6	NS
6. Abdominal skinfold (mm)	7.5	3.8	7.9	3.4	NS
7. Front thigh skinfold (mm)	12.1	4.1	11.6	2.2	NS
8. Medial calf (mm)	11.9	3.8	11.2	2.5	NS
9. Sum of five skinfolds (mm)	39.9	8.4	40.1	8.7	NS
10. Endomorphy	1.9	0.9	2.2	0.8	NS
11. Mesomorphy	3.6	1.5	3.3	1.6	NS
12. Ectomorphy	3.5	1.2	3.5	1.3	NS

* $p < 0.05$ NS — Not Significant

The means and standard deviations of physical fitness characteristics are presented in Table 3. The boys surpassed the girls significantly ($p < 0.05$–0.01) in sit-ups, 10×5 m shuttle run, standing broad jump, handgrip strength, and endurance shuttle run. The mean result of the sit- and-reach test was significantly ($p < 0.05$) higher in girls.

Table 3. Means ($\bar{X}$)and standard deviations (SD) of physical fitness characteristics.

Variable	Boys (n = 44)		Girls (n = 48)		p
	$\bar{X}$	SD	$\bar{X}$	SD	
1. Balance (x)	5.9	3.8	6.2	4.2	NS
2. Sit-and-reach (cm)	30.1	8.1	35.3	8.6	*
3. 10×5 m shuttle run (s)	23.5	2.2	25.9	3.7	**
4. Standing broad jump (cm)	130.1	17.9	121.2	23.3	*
5. Bent arm hang (s)	9.2	6.5	8.8	8.1	NS
6. Plate tapping (s)	20.5	5.1	21.4	6.1	NS
7. Handgrip strength (kg)	15.7	3.9	11.9	4.2	**
8. Sit-ups (x)	16.4	4.2	11.8	5.8	**
9. Endurance shuttle run (min)	4.9	2.4	3.8	3.1	*

* $p < 0.05$ ** $p < 0.01$ NS — Not Significant

The correlation coefficients for selected anthropometric measurements, somatotype components and physical fitness characteristics are presented in Tables 4 and 5. In general, only low or moderate ($r = 0.2$–0.5) correlations were found between the physique's measurements and physical fitness test scores for both sex groups. BMI, sum of skinfolds and endomorphy had either low negative or positive relationships with physical fitness tests. In boys, statistically significant ($p < 0.05$) correlations were found only between sum of skinfolds and endurance shuttle run and endomorphy and endurance shuttle run ($r = -0.57$ and $r = -0.52$, respectively). In girls, sum of skinfolds was significantly ($p < 0.05$) correlated with standing broad jump ($r = -0.55$), sit-ups ($r = -0.62$) and endurance shuttle run ($r = -0.45$). Endomorphy had a significant ($p < 0.05$) negative correlation only with bent arm hang ($r = -0.52$). Mesomorphy had significant ($p < 0.05$) correlation only with sit-ups in girls ($r = 0.55$). Ectomorphy was significantly ($p < 0.05$) related with 10×5 m shuttle run ($r = -0.54$) in boys and with sit-ups ($r = 0.53$) in girls.

Table 4. Correlations between selected physique's measurements and physical fitness in boys (n = 44).

Variable	Height	Weight	BMI	SumSF	ENM	MM	EKM
1. Balance	–.15	.22	–.21	.17	.13	.14	.22
2. Sit-and-reach	–.06	–.17	–.22	–.33	–.42	–.29	.14
3. 10×5m shuttle-run	–.21	.29	.23	.21	–.05	.02	–.54*
4. Standing broad jump	.24	–.16	–.29	–.22	–.19	.37	.07
5. Bent arm hang	.14	–.13	–.27	–.16	–.13	–.02	.33
6. Plate tapping	–.23	–.15	.37	.33	.36	–.28	–.20
7. Sit-ups	–.17	–.04	.15	.22	.25	.18	.20
8. Handgrip strength	.05	–.14	–.22	.15	–.11	.27	–.18
9. Endurance shuttle run	.18	–.33	–.39	–.57*	–.52*	.32	.14

* $p < 0.05$ BMI — body mass index; SumSF — sum of skinfolds; ENM — endomorphy; MM — mesomorphy; EKM — ectomorphy

Table 5. Correlations between selected physique's measurements and physical fitness in girls (n = 48).

Variable	Height	Weight	BMI	SumSF	ENM	MM	EKM
1. Balance	.07	–.16	.13	.37	.27	–.33	–.40
2. Sit-and-reach	–.18	.06	.24	–.14	.14	.14	–.24
3. 10×5m shuttle run	.26	.11	.04	–.36	–.23	.15	–.21
4. Standing broad jump	.19	–.25	–.27	–.55*	–.28	.33	.30
5. Bent arm hang	–.17	–.27	–.44*	–.26	–.52*	–.29	.31
6. Plate tapping	.05	–.16	–.07	.31	–.01	.16	–.16
7. Sit-ups	.22	–.16	–.31	–.62*	–.47*	.55*	.53*
8. Handgrip strength	.15	.22	.12	–.07	.21	–.05	–.18
9. Endurance shuttle run	.28	–.18	–.12	–.45*	–.29	.33	.29

* $p < 0.05$ BMI — body mass index; SumSF — sum of skinfolds; ENM — endomorphy; MM — mesomorphy; EKM — ectomorphy

DISCUSSION

Generally speaking, the results of this study concerning relationships between physique and physical fitness confirm the previous findings [2, 8, 17, 20, 26, 27, 28, 29]. It was observed that the correlations between body fatness and somatotype with physical fitness tests are relatively low in absolute magnitude. As expected, the sum of skinfolds was found to be negatively associated with most of the physical fitness tests in both boys and girls. The relatively higher negative relationships between sum of skinfolds and physical fitness tests were found where movement of the body mass is required (shuttle runs, standing broad jump). This fact is confirmed by previous studies [3, 7, 17, 27, 28, 29]. Theoretically, this relationship is due to the fact that body fat adds to the mass of the body without contributing to the force producing capability, thus becoming excess weight to be moved during the weight-bearing tasks [1]. However, Hensley *et al.* [17] reported that the effect of body fatness on performance may be both sex-specific and task-specific.

There are relatively few studies relating somatotype with physical fitness in young children [5]. This study indicates that endomorphy, like body fatness, has low negative correlations with most physical fitness tests in both sexes. In this respect, our findings are consistent with those of earlier studies [28, 29, 30, 31].

Numerous studies [2, 3, 5, 30] have reported that high mesomorphy is positively associated with most physical performance tests, especially in adolescent and adult age groups. In this respect, our results do not indicate so clear relationships between mesomorphy and physical fitness tests in either boys or girls. Only few physical fitness items (standing broad jump, 10 × 5 m shuttle run) have low positive correlations with mesomorphy in both sexes. One explanation for this discrepancy with previous studies could be the fact that the influence of muscular mass to physical fitness is not so well expressed in ages 7–9 comparing with adolescent and adult ages.

Our results indicate that ectomorphy was significantly related only with 10 × 5 m shuttle run in boys and with sit-ups in girls. Most of the physical fitness tests have either low positive or negative correlations with ectomorphy and there is no concurrence in relationships in respect of boys and girls. This is in agreement with early reported findings [2, 3, 5] that physical fitness test scores correlate variably with ectomorphy. This may be due to fact that the 3 somatotype components are not independent, and that in predicting motor performance the information given by the ectomorphy component is already included in the information given by mesomorphy and/or endomorphy [3, 6]. However, Slaughter *et al.* [29] and Hensley *et al.* [17] have reported that linearity was an important determinant of performance in elementary school children.

Examining sex differences in physique of children revealed that although the boys tended to surpass the girls in most of the anthropometric measurements and girls exceed boys in skinfold thicknesses and sum of skinfolds, these differences are not statistically significant. It should be noted that this finding is in agreement with other reports [15, 22, 25] that have found little if any sex differences in body composition among preadolescent children. Hensley *et al.* [17] have reported that other underlying biological and cultural factors than body fatness are more important in the explanation of gender differences in physical performance in prepubertal children.

The observed sexual dismorphism in somatotype distributions is in agreement with previous studies [10, 18, 30]. General findings from our and earlier reported studies indicate that boys are more mesomorphic and less endomorphic than girls. Although gender differences in somatotype are apparent already in preschool and elementary school years, the marked sexual dismorphism appears after adolescence [5].

Sex differences in favour of boys in the physical fitness tests requiring running speed, explosive and functional strength and cardiorespiratory endurance are confirmed with motor development studies [9, 13, 24]. It is not surprising either that girls surpassed boys in balance and sit-and-reach tests results. Nevertheless, sex differences in physical fitness tests are relatively small during prepubertal years and there is no full understanding of what kind of factors and to which extent influence the differences in motor performances [23].

In summary, the findings of this investigation indicated that the relationships between physique's measurements and physical fitness were mostly non-significant and there were no clear differences in associations in respect of boys and girls. Furthermore, although the boys surpassed the girls in anthropometric measurements and girls surpassed boys in skinfold thicknesses, these differences were generally non significant. Finally, the gender differences in physical fitness indicated that boys were superior in running speed, strength and endurance and girls resulted higher in flexibility and balance.

REFERENCES

1. **Astrand O., Rodahl K.** (1977)Textbook of work physiology. (2nd Ed.). McGraw-Hill, New York.
2. **Beunen G., Ostyn M., Renson R., Simons J., Swalus P., Van Gerven D.** (1977) Somatotype and physical fitness of 14 year old boys. In H. Lavalle & R. J. Shephard (eds.). Frontiers of activity and child health. Editions du Pelician, Quebec, 36–55.
3. **Beunen G., Claessens A., Ostyn M., Renson R., Simons J., Van Gerven D.** (1985) Motor performance as related to somatotype in adolescent boys. R. A. Binkhorst, H. C. G. Kemper, W. H. M. Saris (eds.). Children and Exercise XI. Champaign, IL.: Human Kinetics, 279–284.

4. **Carter J. E. L.** (1980) The Heath-Carter somatotype method. San Diego State University Syllabus Service.

5. **Carter J. E. L., Heath B. H.** (1990) Somatotyping — development and applications. Cambridge, Cambridge University Press.

6. **Claessens A., Beunen G., Simons J., Swalus P., Ostyn M., Renson R., Van Gerven D.** (1980) A modification of Sheldon's anthroposcopic somatotype technique. Anthrop. Közl. 24: 45–54.

7. **Cureton K. J., Boileau R. A., Lohman T. G.** (1975) Relationship between body composition measures and AAHPER test performances in young boys. Res. Quar. 46: 219–229.

8. **Cureton K. J., Boileau R. A., Lohman T. G., Misner J. E.** (1977) Determinants of distance running performance in running performance in children: analysis of a path model. Res. Quar. 48: 270–279.

9. **DeOreo K., Keogh J.** (1980) Performance of fundamental motor tasks. In:. C. B. Corbin (ed.). A textbook of motor development (2nd ed), Dubuque, IA: Brown, 76–91.

10. **Duquet W.** (1980) Studie van de toepasbaarheid van de Heath Carter somatotype-methode op kinderen van 6 tot 13 jaar. (Applicability of the Heath-Carter somatotype method to 6 to 13 year old children), PhD Dissertation, Vrije Universiteit Brussel, Belgium.

11. **Eiben O. G.** (1985) The Körmend Growth Study: Somatotypes. In: Physique and body composition, O. G. Eiben (ed.). Budapest: Humanbiologia Budapestinensis 16: 37–52.

12. **Erbaugh S. J.** (1984) The relationship of stability performance and the physical growth characteristics of preschool children. Res. Quar. Exerc. Sport 55: 8–16.

13. **Espenschade A. S., Eckert H. M.** (1980) Motor development (2nd ed.), Columbus, OH: Merrill.

14. EUROFIT. (1988) Handbook for the EUROFIT tests of physical fitness. Rome.

15. **Forbes G. B., Amirhakimi G. H.** (1970) Skinfold thickness and body fat in children. Hum. Biol. 42: 401–418.

16. **Hall R.** (1982) Sexual dismorphism in homo sapiens. New York, Praeger.

17. **Hensley L. D., East W. B., Stillwell J. L.** (1982) Body fatness and motor performance during preadolescence. Res. Quar. Exerc. Sport 53: 133–140.

18. **Holopainen S., Lumiaho–Häkkinen P., Telama R.** (1984) Level and rate of development of motor fitness, motor abilities and skills by somatotype. Scand. J. Sports Sci. 6, 67–75.

19. **Lohman T., Roche A., Martorell R.** (eds.) (1988) Anthropometric Standardization Reference Manual. Champaign, IL: Human Kinetics Books.

20. **Malina R. M.** (1975) Anthropometric correlates of strength and motor performance. J. H. Wilmore, J. F. Keogh (eds.) In: Exercise and Sport Sciences Reviews (Vol. 3). New York: Academic Press, 249–274.

21. **Malina R. M.** (1980) Biologically related correlates to motor development and performance during infancy and childhood. C.B. Corbin (ed.). In: A textbook of motor development (2nd ed.), Dubuque, IA: Brown, 200–211.

22. **Malina R. M., Rarick G. L.** (1977) Growth, physique, and motor performance. In: G. L. Rarick (ed.). Physical Activities: Human Growth and Development. New York: Academic Press, 46–68.

23. **Malina R. M., Bouchard C.** (1991) Growth,. maturation and physical activity. Champaign, IL: Human Kinetics.

24. **Morris A. M., Williams J. M., Atwater A. E., Wilmore J. H.** (1982) Age and sex differences in motor performance of 3 through 6 year old children. Res. Quar. Exerc. Sport 53: 214–221.

25. **Parizkova J.** (1961) Total body fat and skinfold thickness in children. Metabolism 10: 794–807.

26. **Parizkova J.** (1977) Body fat and physical fitness. Martinus Nijhoff, The Hague.

27. **Pate R. R., Slentz C. A., Katz D. P.** (1989) Relationship between skinfold thickness and performance of health related fitness test items. Res. Quar. Exerc. Sport 60: 183–189.

28. **Slaughter M. H., Lohman T. G., Misner J. E.** (1977) Relationship of somatotype and body composition to physical performance in 7–12 year old boys. Res. Quar. 48, 159–168.

29. **Slaughter M. H., Lohman T. G., Misner J. E.** (1980) Association of somatotype and body composition to physical performance in 7–12 year old girls. J. Sports Med. Phys. Fit. 20: 189–198.

30. **Štepnicka J.** (1976) Somatotypes of Bohemian and Moravian youth. Acta Facultatis Medicae Universitatis Brunensis. 57, 233–242.

31. **Štepnicka J.** (1977) Somatotypes of Czechoslovak athletes. O. Eiben (ed.), In: Growth and Development: Physique, Budapest: Akademiai Kiado (Hungarian Academy of Sciences), 357–364.

32. **Ward R., Ross W. D., Leyland A. J., Selbie S.** (1989) The advanced O-Scale physique assessment system. Instructional Manual. Kinemetric Inc.

Correspondence to:

Lennart Raudsepp Institute of Sport Pedagogy
University of Tartu 18.Ülikooli Street Tartu, EE 2400 Estonia

CONTRIBUTION OF VERTEBRAL COLUMN, HIP FLEXION AND KNEE EXTENSION TO TRUNK FORWARD FLEXION IN YOUNG GYMNASTS

V. Hein
Institute of Sport Pedagogy, University of Tartu, Tartu, Estonia

ABSTRACT

The aim of present study was to investigate the body segment configuration influence on the range of the motion in each joint contributable to the trunk forward flexion in standing and sitting positions in 30 young modern gymnasts at age of 7–9 years. The measuring of the range of the motion in the hip joint and in total vertebral column was produced by gravity goniometer in different positions and the knee extension by constructed linear instrument. The flexibility of vertebral column was calculated by the difference between the trunk forward flexion and hip flexion. The obtained results indicated higher values of hip joint in sitting position compared with values recorded in standing position. Vertebral column flexion decreased from 56.7° ± 17.5 in standing position to 29.70° ± 9.07 in sitting position. The contribution of the range of the motion of the hip joint flexion and total vertebral flexion to trunk forward flexion were evaluated by multiple regression analysis. The relationship between test scores of trunk forward flexion and vertebral column flexion in sitting position was $r = 0.50$ ($p < 0.01$). Regression equation $y = 12.7 + 0.18x$ was conducted with the sit-and-reach test being predicted by knee extension range of motion.The tests scores obtained by used methods permit to receive more information about the range of motion at different joints what may be useful to take account in enhance procedure of trunk forward flexion.

KEY WORDS: Flexion, Hip joint, Vertebral column, Range of motion

INTRODUCTION

Flexibility is of considerable importance in numerous athletic events. The most frequently used method for evaluating trunk forward flexion is the sit-and-reach test. It provides a simple measure of flexibility in the hip, spine and hamstring muscles [5]. The sit-and-reach or finger-to-floor tests show a high relationship to hip joint values a negligible effect to low back mobility [4, 6, 8]. However, there are few reports relating total back flexibility to it [3].

For enhance performance the trunk forward flexion is important at first to point out the mobility of each joint in it. Awareness of the range of motion (ROM) in each joint associated with total trunk forward flexion allows the selection of which the structures most restrict the motion.

A good review of the methods and guidelines for measurements the ROM of joint is given by Hubley-Kozey [2]. A few authors [5, 13] report measurement methods for knee extension, whereas a extension movement is quite complicated and problematic because a number of the muscles and tendons in the lower extremities cross the knee joint. Most of the methods for spinal flexibility record the ROM in the lumbar spine [7, 9, 14]. In trunk forward flexion it is also important to consider the flexibility in the upper segments of the vertebral column. Analogously to the method of Macrae and Wright [7], Jackson and Baker [3] determined total back flexibility by measuring the erect distance between the point below the lumbasacral joint and the seventh cervical vertebrae and subracting this from the flexed distance between those points.

Little information exists on how the body segment configurations influence measurements of hamstring muscles tightness as determined by the test of trunk forward flexibility. Sharpe *et al.* [10] report that the sit-and-reach test scores performed with ankle dorsiflexion and plantar flexion are less than with ankle dorsiflexion alone by approximately 0.04 m.

Extensive cross — sectional data on trunk forward flexion at various ages have now been obtained by through the Canada Fitness Survey [11, 12] but it is still unclear how the ROM at the vertebral column, the hip and knee joints influence total trunk forward flexion.

The aim of this investigation was to evaluate the consistency of trunk forward flexion by different measurement methods and the contribution of different joints ROM in it. Test scores of the ROM of different joints in total trunk forward flexion allow to determine their deficiences for individuals which will be useful in establishing a flexibility procedure and help to perform right selection for certain athletic events based, in part, on flexibility test scores.

MATERIAL AND METHODS

Subjects

Thirty modern gymnasts aged 7–9 participated in the study. They trained three times a week for an average of 90 min. for each session. Informed consent was obtained from each subject beforehand. No subject had any limitation of joint movement due to injury.

Measurements

Sit-and-reach. The subject placed the soles of both feet against the testing box which had a height of 0.3 m. The zero point of the measurement was taken from the edge of the box. The linear measurement to the nearest half centimetre was obtained by having the subject reach and hold his maximum distance for two seconds.The feet were together and the knees fully extended.

Stand-and-reach. The subject stood on the testing box rotated vertically. The measurement procedure was the same as in the sit-and-reach test.

Back forward flexibility. The subject was asked to hold his arms behind his head. The gravity goniometer was fastened to one side of the chest (midaxillary line) at nipple height. The subject was informed at first to bend forward with a straight vertebral column (the first point). This allowed a determination of the ROM of flexion in the hip joint and then to perform a maximum trunk forward flexion (the second point). The test scores were recorded in both points. The difference between the results for the two points was calculated and recorded as the estimation of vertebral column flexibility. The same procedure was performed in the sitting position. The subject was then instructed to sit with the legs extended forward forming an angle of 90° with the straight back.

Knee extension. The special instrument was constructed to measure the knee extension (Figure 1). The knee extension range of motion

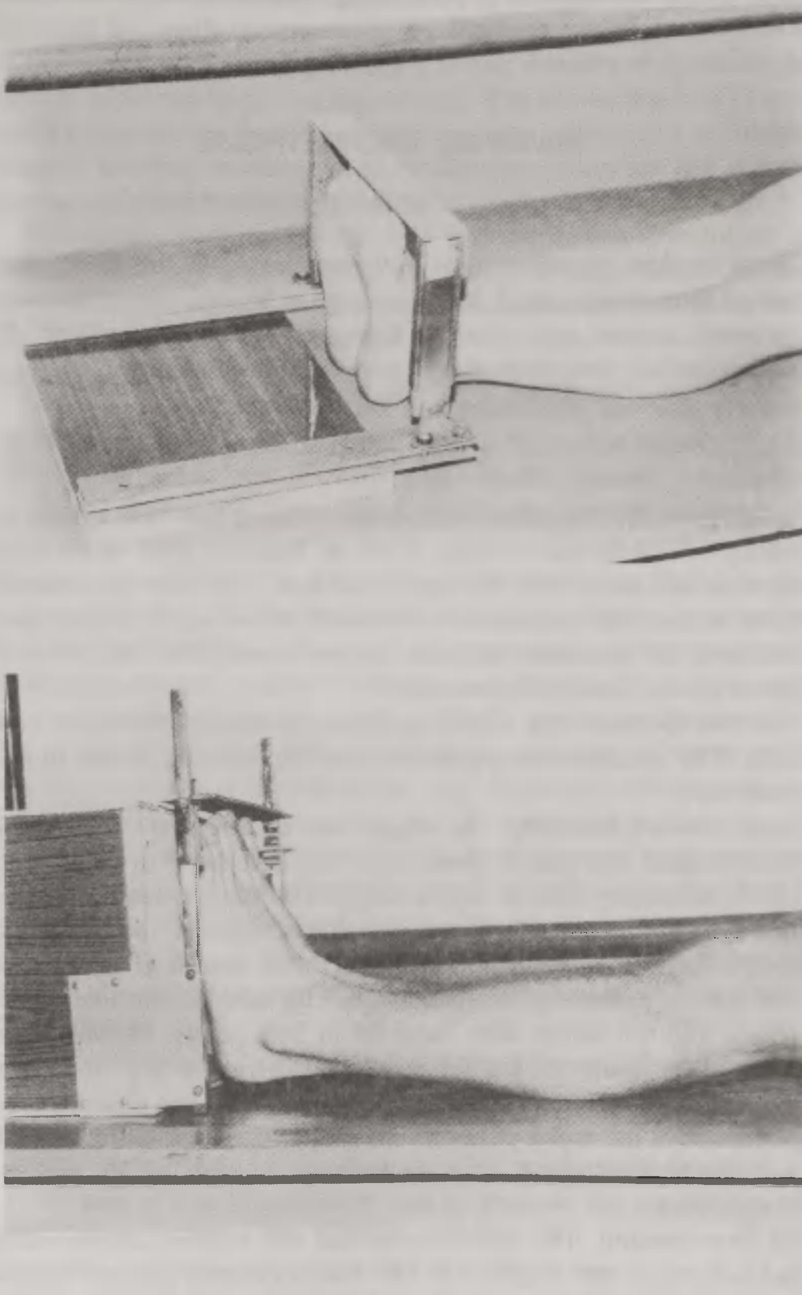

Figure 1. Instrument for measurement the knee extension.

was recorded by linear measurements with specification 1 mm. A special scale was engraved on an istrument slate. The knee extension was measured with the subject sitting on an examination table. The ankle was maintained at 90°. The toes were extended and fitted under the measurement plate. The height of measurement plate was recorded. The subject was then asked to lift his heels up as much as possible keeping the thighs on the table. The second height of the plate was taken and interval accounted. The interval was observed as the knee extension ROM.

Reliability of measurement. The reliability of the knee extension measurement was determined on 15 of the subjects. The intertester coefficient correlation was $r = 0.97$ ($p < 0.000...$) and intratester $r = 0.95$ ($p < 0.000...$). The reliability and accuracy of the goniometer measurement are accepted by most of investigators [1, 2].

Procedure. All measurements were produced under the same conditions: temperature, time, warm up exercises and by one tester. In all measurements no external forces were used. Height and weight were recorded prior to testing flexibility.

Statistics. A standard Statgraphics package was used to estimate means and standard deviations. Pearson Product moment correlation coefficients between test scores were established and regression models were constructed for trunk forward flexion.

RESULTS

Anthropometric characteristics of the subjects are presented in Table 1, the results of ROM in Table 2.

Table 1. Age, height and mass of modern gymnasts (n = 30)

Parameter	Average	Standard deviation
Age (yr)	8.37	0.72
Height (m)	1.31	0.05
Mass (kg)	24.92	2.77

Table 2. Means ± standard deviations of flexibility of several joints in the modern gymnasts(n = 30)

Standing position		Sitting position	
Hip flexion	91.86 ± 17.68	Hip flexion	44.10 ± 10.88
Trunk flexion	148.40 ± 11.94	Trunk flexion	73.47 ± 12.64
Vertebral flexion	56.70 ± 17.15	Vertebral flexion	29.70 ± 9.07
Stand and reach	14.1 ± 3.7cm	Sit and reach	15.2 ± 3.6cm
	Knee extension 1.35 ± 0.94 cm		

Note. Results are given in degrees unless stated otherwise.

Vertebral flexion in the sitting position was more than 50 percent lower than in the standing position. ROM of the hip flexion and in the total trunk forward flexion was smaller in the standing position than in sitting position. To compare the hip flexion and trunk flexion results in the standing position with the corresponding results in the sitting position, the configuration of body segments — trunk and lower extremities under the angle 90° in sitting position must be taken into account.

Hip flexion ROM formed from the total trunk forward flexion in standing position 62% and sitting position 68%, vertebral flexion respectively 38% and 32%. Proceeded from correlation matrix (Table 3), multiple regression model was constructed by stepwise variable selection procedure to determine the variation in trunk forward flexion values in the sitting position:

$$c = -4.31 + 1.04d + 1.07f$$

where: c — total trunk forward flexion, d — hip flexion (t — 33.08 $p < 0.000...$), f — vertebral column flexion (t — 28.25 $p < 0.000...$). The variables were in degrees. The multiple correlation coefficient was 0.98. The influence of independent variables d and f are presented as component effects plot (Figure 2, 3).

Table 3. The Pearson Product Moment correlations coefficients between different tests.

	1	2	3	4	5	6	7	8	9
Standing position									
1. Hip flexion	1.00								
2. Trunk flexion	0.40*	1.00							
3. Vertebral flexion	–0.76**	0.29	1.00						
Sitting position									
4. Hip flexion	0.57**	0.23	–0.43*	1.00					
5. Trunk flexion	0.51**	0.49**	–0.19	0.67**	1.00				
6. Vertebral flexion	–0.01	0.41*	0.29	–0.30	0.50**	1.00			
7. Sit and reach	0.40*	0.64**	0.03	0.53**	0.52**	0.06	1.00		
8. Stand and reach	0.42**	0.69**	0.05	0.60**	0.61**	0.10	0.91**	1.00	
9. Knee extension	0.40*	0.29	–0.21	0.57**	0.50**	–0.03	0.47**	0.47**	1.00

* $p < 0.05$ ** $p < 0.01$

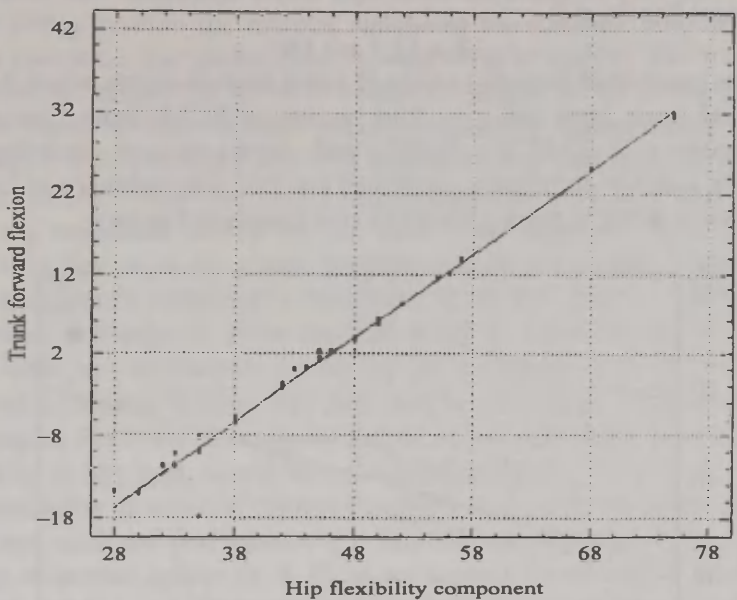

Figure 2. The influence of hip flexion component on trunk forward flexion.

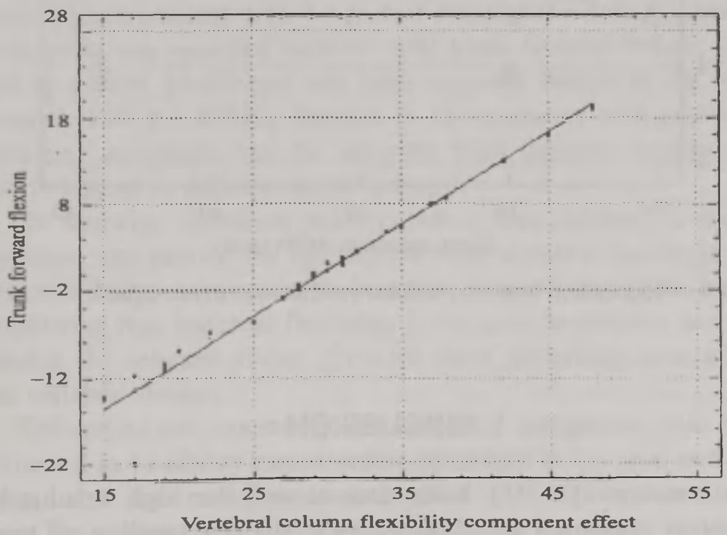

Figure 3. The influence of vertebral column flexion component on trunk forward flexion.

The simple linear regression equation to predict the total trunk forward flexion was

$$k = 12.7 + 0.18r$$

It was established from test scores of linear measurements, where k — sit and reach (cm) and r — knee extension ROM (mm). Intercept parameter t — 12.07 $p < 0.000...$ and slope parameter accordingly 2.82 $p < 0.008$, correlation coefficient $r = 0.47$. The influence of knee extension ROM in trunk forward flexion illustrates Figure 4.

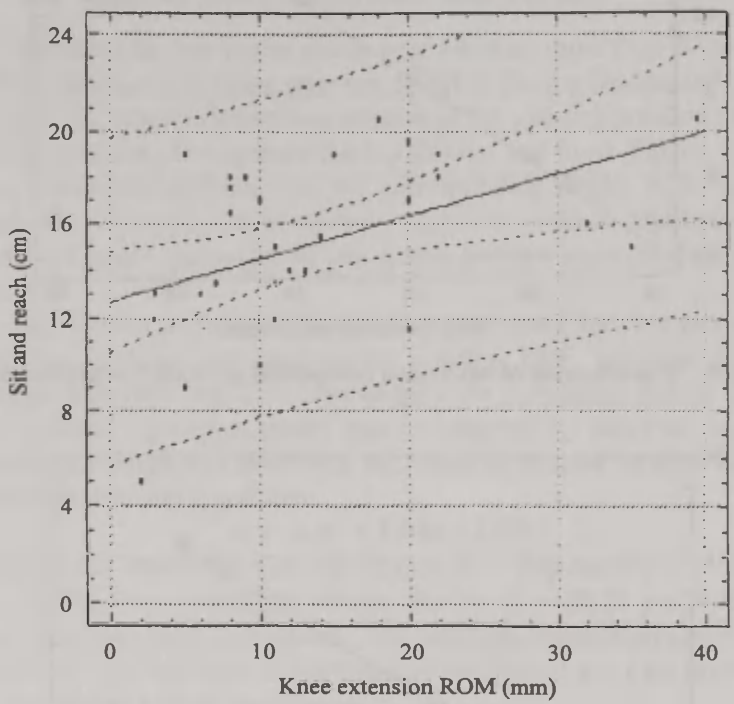

Figure 4. Regression line for trunk forward flexion in knee joint.

DISCUSSION

Several authors [2, 15] have documented the high relationship between sit-and-reach and fingertip — to floor or standing toe touch tests. The present results confirmed this and have also showed that the hip joint flexibility in the sitting position is greater than in the standing position (Table 2). It may be explained by the different lengths of the muscles and hamstrings which depend on the positioning of limbs. In the sitting position the muscles stabilizing the standing position are less contracted and permit more forward range of motion. The reverse conditions existed for ROM in vertebral column. In the sitting position, ROM of the vertebral column decreased approximately two times. It allows to assume that hip flexion hinders motion in the vertebral column. These phenomena may explain the balance of two tests scores mentioned above. In the same time increased total trunk forward flexion in the sitting position must be considered. These results suggest a complicated movement at several joints in the trunk forward performance. From the total ROM in trunk forward flexion 62–68% was attributable to the hip joint mobility and 32–38% to vertebral column flexion. This fact must be considered enhance when trying to flexibility. It suggests that to improve forward flexion primarily in hip joint would be considered primarily. To evaluate the contribution of vertebral column flexibility to trunk forward flexion on sit-and-reach test performance it is important to note that recent findings of several authors [4, 6, 8] do not support the validity of sit-and-reach test as a suitable measure of low back flexibility that previously was supposed [11, 15]. Low correlation coefficient 0.07 between sit-and-reach test and total back flexibility as reported by Jackson and Baker [3] is consistent with the present findings (0.03–0.06). Another relationship was recorded between total trunk forward flexion measured by gravity goniometer and total vertebral flexion in the sitting position (0.50 $p < 0.001$). Reason of inconsistency with previously confirmed statements may be occurred from different measurement units or caused by different age of subjects.

The stepwise regression analysis tests scores obtained in degrees confirmed that beyond the hip flexion, total vertebral flexion is most predictive independent variable in trunk forward regression model. Considering that vertebral flexibility is not easy to enhance and even harmful, the selected young gymnasts must preferably have a good total vertebral flexion.

Well spread and commonly recommended straight leg raise test is performed as flexibility measurement procedure in hip joint and hamstring, but it does not allow to determination of their separate influences. To remove these disadvantages a special instrument was developed to measure knee extension ROM what is directly conducted with harmstring location. It was assumed that ROM of knee extension characterizes more exactly harmstring flexibility. This method is free from external assistance as it usually occurs in the straight leg raise test. Additionally the external forces are complicated to determine and are not usually employed in the sit and reach test.

In spite of the fact that knee joint ROM extension was quite restricted, a simple regression was conducted and the sit-and-reach test was predicted by knee extension ROM. According to linear model equation the sit-and-reach test result may be increased by approximately 2 cm by increasing the ROM in knee extension 10 mm. The influence of knee extension ROM to the trunk forward flexion confirmed the significant correlation coefficient between ROM in knee extension and different tests scores of trunk forward measurements.

In conclusion, the tests scores obtained by used methods in this study permit to receive more information about the range of motion at different joints what may be useful to take account in enhance procedure of trunk forward flexion.

REFERENCES

1. **Boone D. C.,Azen S. P., Lin C. M., Spence C., Baron C., Lee L.** (1978) Reliability of goniometric measurement. Phys.Ther. 58: 1355–1360.
2. **Hubley-Kozey C. L.** (1991) Testing flexibility. In:, 2nd — edn. Physiological Testing of the High-Performance Athlete. MacDougall J. D., Wenger H. A. (ed.) Champaign: IL: Human Kinetics Press. 330–351.
3. **Jackson A. W., Baker A. A.** (1986) The relationship of the sit and reach test to criterion measures of harmstring and back flexibility in young females. Res. Q. Exerc. Sport 57: 183–186.
4. **Kippers V., Parker A. W.** (1987) Toe touch test — A measure of its validity. Phys. Ther. 67: 1680–1684.
5. **Kirby R. L., Simms F. C., Symington V. J., Garner J. B.** (1981) Flexibility and musculoskeletal symtomatology in female gymnasts and age-matched controls. Am. J. Sports Med. 9: 160–164.
6. **Liemonh W., Sharpe G. L., Wasseramn J. E.** (1994) Criterion related validity of the sit and reach test. J. Strength and Cond. Res. 8: 91–94.
7. **MacRae J. F., Wright V.** (1969) Measurement of back movement. Ann. Rheumatic Dis. 28: 584–589.
8. **Minkler S., Patterson P.** (1994) The validity of modified sit and reach test in college — age students. Res. Q. Exerc. Sport. 65: 189–192.

9. **Salminen J. J., Oksanen A., Mäki P., Penti J., Kujula U. M.** (1993) Leisure time physical activity in the young. Correlation with low back pain, spinal mobility and trunk muscle strength in 15-year old school children. Int. J. Sport Med. 14: 406–410.
10. **Sharpe G. L.,Liemohn W. P., Martin S. B.** (1994) The effects of ankle joint position on the sit and reach test. Res. Q. Exerc. Sport 65: Suppl A: 41.
11. **Shephard R. J.** (1983) Fitness and Lifestyle Research Institute. Fitness and lifestyle in Canada. Ottawa
12. **Shephard R. J.** (1986) Fitness of a nation: Lessons from the Canada Fitness Survey. Basel Karger Publishing
13. **Suni J.** (1994) Test manual for assessment of health — related fitness. In: UKK Institute of Health Promotional Research, Tampere. 289.
14. **Twomey L., Taylor J.** (1979) A description of two new instruments for measuring the range of sagittal and horizontal plane motion in the lumber region. Austr. J. Physiother. 25: 201–203.
15. **Wells K. F., Dillon E. K.** (1952) The sit and reach test: A test of back and leg flexibility. Res. Q. Exerc. Sport. 23: 115–118.

Correspondence to:
Vello Hein
Institute of Sports Pedagogy
University of Tartu 18 Ülikooli Street
EE 2400 Tartu Estonia

THE USE OF PHOTOGRAPHS IN LONGITUDINAL KINANTHROPOMETRIC ANALYSIS

D. A. Brodie and M. Grant
Department of Movement Science and Physical Education,
University of Liverpool, United Kingdom

ABSTRACT

Photographs of 18 boys taken annually for five years were analyzed and measurements of stature, tibial length and bi-acromial breadth were recorded. These results were compared with data obtained from the Coquitlam Growth Study (COGRO) and subjectively the test results appeared to follow a similar pattern. Sources of error in obtaining photographic measurements are described. The test results were converted to z-scores to see if any differences in proportionality occurred over the five years. The results were subjected to a related one-way analysis of variance. Significant differences ($p < 0.01$) were obtained for both sets of data and the variance located by Newman-Keuls post hoc tests. To examine if there were any correlations between the proportionality of tibial length and bi-acromial breadth, the z-scores were analyzed by a Pearson Correlation test. A non-significant correlation was found suggesting that there are no uniform increase in dimensions during growth. The mean z-score results were compared with those calculated from the COGRO data and some similarities observed. Application of proportionality measures are suggested in clinical and sporting contexts.

KEY WORDS: Photographic measurement, Anthropometry, Boys

INTRODUCTION

Anthropometrical measurements have been taken from photographs for several years. From a study by Tanner and Weiner [5] it was concluded that photogrammetric measurements in general were as reliable as measurements taken from the living model.

From one occasion to another, posing differences accounted for two-thirds of the measurement error. In an attempt to standardize the posture of the subject Dupertuis and Tanner [2] described a pose which they suggested should be adopted by fellow investigators.

The major advantages of using photographs in the measurement of body parts are that the researcher has a permanent record of the subjects appearance to refer back to at any time. Any measurement may be repeated with the confidence that the subject has not moved.

The purpose of this study was to investigate the use of photographs in longitudinal kinanthropometric analysis.

There are three distinct parts to this study:

1. a comparison of photographic measurements with the Coquitlam Growth Study Age-Sex Prototypes (COGRO);
2. an examination of the proportionality differences of the test subjects;
3. a comparison of the mean proportionality differences between the test subjects and subjects in the Coquitlam Growth Study.

METHODS

Black and white transparencies of eighteen boys were analyzed. Anterior, lateral and posterior views of each subject had been photographed annually from the ages of 11 to 15. Measurements were obtained from the anterior views of each subject.

In the anterior views the subjects, wearing only shorts, assumed an upright stance with upper limbs in the position of rest [6] or the standard front view as described by Dupertuis and Tanner [2].

The transparencies were projected (Kodak Carousel S-AV 2010 Projector) on to a flat white wall. In an attempt to reduce distortion of the images the projector was placed on a stand 120 cm high, 10 m from the wall. In this position it was unnecessary to elevate the front or back of the projector.

Two lines 1 metre vertically apart were marked on the wall. On each transparency a metre reference stick was positioned to the side of the model. When the slides were projected the reference metre rule was lined up with the markers on the wall by adjusting the projector focal distance.

In each photographic session the subjects were positioned in front of a grid. This made it easier to measure the horizontal and vertical dimensions.

Each image was focused and the following measurements obtained with a standard three metre metal measuring tape (Rabone Chesterman), for height and a sliding anthropometer (Holtain) for breadth.

a. height — vertical distance from the vertex to floor
b. tibial length — most proximal point of the medial tibial condyle to the distal end of the medial malleolus
c. bi-acromial breadth — horizontal distance between the lateral borders of the acromion processes.

All landmarks were those indentified by Ross *et al.* [4] and measurements described by Ross and Wilson [3].

These measurements were selected for the study as the bony landmarks were all exposed in the anterior view photographs. One major restriction of using photographs is that it is impossible to measure girths, thicknesses and volumes.

RESULTS AND DISCUSSION

Comparisons with other data

The scores were recorded and the means and standard deviations for each age group calculated as shown in Table 1.

It can be seen that the COGRO values (in bold) are consistently larger than the present study, but the trend is very similar. For height and bi-acromial breadth the mean values of the British study lie between the 50th and third centiles of the Canadian subjects. For tibial length, the difference is quite marked, with the British mean results lying below the third centile of the COGRO boys. The details of the subjects participating in the Coquitlam study and the methods of measurement were not recorded. Thus more detailed comparisons between the two groups may be inappropriate, especially as the Coquitlam group appear to be cross-sectional in nature, whereas the present study is longitudinal.

Table 1: Means (standard deviations) for height, tibial length and biacromial breadth for each age group

Age	N	Height	Tibial Length	Biacromial breadth
11	18	138.7 (5.8)	32.2 (2.4)	30.2 (1.3)
11	**26**	**143.1 (6.9)**	**38.3 (2.7)**	**31.0 (1.9)**
12	18	143.5 (6.9)	33.7 (2.6)	31.0 (1.4)
12	**33**	**149.2 (6.4)**	**39.0 (2.5)**	**31.8 (3.2)**
13	18	150.7 (8.0)	35.8 (2.9)	32.0 (1.6)
13	**35**	**159.2 (6.9)**	**43.0 (2.6)**	**34.3 (1.9)**
14	18	158.2 (8.6)	37.8 (2.9)	33.7 (1.8)
14	**76**	**165.5 (8.6)**	**44.4 (2.9)**	**35.5 (2.4)**
15	18	165.7 (9.2)	39.3 (2.9)	35.3 (2.1)
15	**77**	**170.5 (8.7)**	**45.5 (2.9)**	**36.9 (2.4)**

The above compares data between two studies that provide the necessary information. A more general comparison between the height values of the present study and UK normative centiles [1] is shown in Figure 1. It can be seen that this sample lies close to the 10th centile of the UK population (circles) and that the COGRO values (triangles) lie at about the 25th centile. It is clear that in relative terms these boys are on average small and this could be explained by their socio-economic origins. The children from the present study came from a relatively poor neighbourhood in the North of England and would not have had the nutritional benefits at a young age of boys from a better socio-economic background. There may also be some secular change as the comparison between the present study and the data provided by Buckler is some 10 years apart. However, this is not likely to account for much of the difference.

The photographic subjects had not been measured by any other method, therefore, the accuracy of the figures obtained remain untested. However, Tanner and Weiner [5] found in their study that these dimensions may be 'relatively reliable' obtained from photographs.

The benefits of taking photographs for growth purposes is that certain analyses may be undertaken retrospectively from the permanent record. It must, however, be recognized that sources of error from photographs occur and these include:

- identification of bony landmarks due to hair, muscle and adipose tissue overlay
- the quality of the exposure of the photograph

- the quality of the projection facilities which must be designed to avoid 'shadowing'
- the accuracy of the measurements from the photographs, although the use of a sliding anthropometer assisted this process
- ensuring consistency of posture for every photographic occasion.

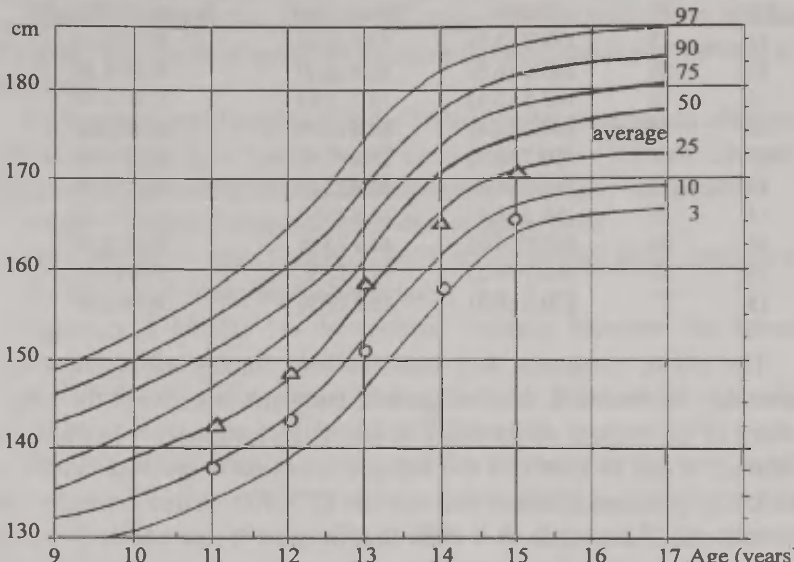

Figure 1: Centiles of height.

Proportionality difference between the test subjects

Ross and Wilson [3] developed a stratagem for proportional growth assessment. Central to the stratagem is a phantom which is a conceptual unisex, bilaterally symmetrical model derived from reference male and female data.

In comparing measurements to the phantom, raw data has to be converted to a z-score.

These z-scores are calculated from the equation:

$$z = \frac{l}{s}\left[v\left(\frac{170.18^{d}}{h}\right) - p \right]$$

where:

z = a proportionality value of z-score

v = any variable
s = the phantom standard deviation for the given variable
h = the subjects height
d = dimension exponent (1 for both values in this study)
p = phantom value for the variable
N.B. 170.18 is the phantom height constant.

In interpreting the results, a score of 0 suggests that the particular measurement is in proportion to that of the phantom. Positive scores indicate the dimension is greater than the phantom and a negative value proportionally smaller.

Z-scores may therefore be used in analysing proportional differences within a subject, between subjects, between the same subjects on different occasions and between a subject and a prototype.

The tibial and bi-acromial measurements from the 18 test subjects were converted to z-scores (Table 2). For comparison the COGRO data is also shown in the table.

Table 2. Mean scores for tibial and bi-acromial z-scores for present study and COGRO data

Age	Present study		COGRO data	
	Tibial	Biacromial	Tibial	Biacromial
11	0.28	–0.50	2.95	–0.61
12	0.48	–0.69	2.48	–0.93
13	0.69	–0.95	3.18	–0.72
14	0.71	–0.89	3.02	–0.77
15	0.59	–0.92	2.90	–0.64

The mean tibial z-score results show that in both data sets (UK and COGRO) and at all ages, the length of the tibia is proportionately greater than that of the phantom. This implies that the COGRO boys especially had longer tibia than the unisex phantom which is rather surprising when one considers that a comparison is being made with adults and in some cases pre-adolescent boys. The other feature of the tibial results is the pattern of proportionality change. A peak is reached in both the UK and COGRO data at age 13–14 which would be consistent with the height growth spurt in boys. The bi-acromial values in the COGRO subjects appears to be proportionately lower than the phantom and only at age 15 is the trend starting to change back towards proportional growth. In the present study it is staying relatively small to at least age 15 when the measurements stopped and could easily not reach proportionality until the children were older. As stated earlier it is unwise to make detailed comparisons because of the nature of the data sets. It is worth noting, however, the consistency of the bi-acromial scores which in both sets of data are all negative indicating a proportionately small breadth than the unisex phantom and yet very similar in absolute values.

If all parts of the body were growing proportionately larger over time, there should be a positive and significant correlation between the z-scores for bi-acromial and tibial values. A Pearson Product Moment Correlation at each age revealed non-significant correlations. This confirms the observation that growth patterning lacks uniformity with the distal parts usually elongating before the proximal parts.

To assess if any differences in the proportionality of tibial length and bi-acromial length between the test subjects and within the same subjects over the 5 year period, the data were submitted to a related one-way analysis of variance. The results are summarised in Tables 3 and 4.

Table 3. Source of variance table — tibial length

Source of variance	Sum of squares (SS)	Degrees of freedom (DF)	Mean squares (MS)	F ratios
between conditions	2.26	4	0.56	F 4.68 = 3.91 C.V. = 2.51 3.62 $p < 0.01$
subjects	38.71	17	2.28	F 17.68 = 15.83 C.V. = 1.72 2.15 $p < 0.01$
error	9.82	68	0.14	
total	50.78	89		

From the tables it can be seen that there are significant differences between the different ages and between the subjects in both sets of data.

To locate where the differences occurred between the ages, the data were further analyzed in a Newman-Keuls test. These results are summarised in Tables 5 and 6.

Table 4. Source of variance table — bi-acromial breadth

Sourse of variance	Sum of squares (SS)	Degrees of freedom (DF)	Mean squares (MS)	F ratios
between conditions	2.76	4	0.69	$F_{4.68} = 6.90$ C.V. = 2.51 3.62 $p < 0.01$
subjects	22.27	17	1.31	$F_{17.68} = 13.10$ C.V. = 1.72 2.15 $p < 0.01$
error	6.81	68	0.10	
total	31.84	89		

Table 5. Tibial length z-scores: Summary of Newman-Keuls test

Age 11→ 13	significant at 0.01 level
Age 11→ 14	significant at 0.01 level
Age 11→ 15	significant at 0.05 level

Table 6. Bi-acromial breadth z-scores: Summary of Newman-Keuls test

Age 11 → 13	significant at 0.01 level
Age 11 → 14	significant at 0.01 level
Age 11 → 15	significant at 0.01 level
Age 12 → 13	significant at 0.01 level
Age 12 → 14	significant at 0.05 level
Age 12 → 15	significant at 0.05 level

Table 5 shows that for tibial length, the low z-value at age 11 (Table 2) is contributing most to the differences observed. With the bi-acromial z-scores it is only the differences between ages 11 and 12 which are non significant.

The merit of this study is that once serial photographs have been obtained, it is possible to determine growth patterns of individuals, of individuals relative to groups and of different components of the body relative to each other. This enables relative development to be tracked and to show any abnormality or growth differential at an early age. Not only is there a great variation in the final size and shape after growth ceases, but the time of maximum adolescent growth and the speed of growth at this time shows great individuality. In by far the majority of cases such variations are within the realms of normality although they may be different from what is considered normal. This study has shown, for examples, that although the average child's height is below average for the UK norms, the growth patterning of height is perfectly normal. There is a clear sequencing of the different bodily components with the more distal parts preceding the proximal bones. Thus the initial acceleration of the hands and feet is followed by the calves and forearms, followed by the thighs and upper arms and finally the hips, chest and shoulders. This demonstrates why the patterning of the tibial measurements, representing the lower leg, precedes the biacromial measurements.

The technique described in this study was first described over 20 years ago and has since been utilized by relatively few kinanthropometrists with the exception of those trained by Ross and colleagues. The other reason for a dearth of literature in this area is that relatively few longitudinal studies have kept appropriate photographs. It is recognized that the same anthropometric records made at the time and recorded longitudinally could yield the same data set. Most longitudinal studies merely report the changes as a univariate function over time and fail to attempt a relative growth index as provided by the z-score procedure. Also, as has been demonstrated here, it is possible retrospectively to take a series of photographs and examine proportionality. These photographs were especially posed to obtain the maximum clarity of anthropometric landmarks. However, provided one independent linear measurement were known (e.g.height) it would be possible to undertake a similar assessment from more informal photographs (e.g. children in swimming trunks at the beach) recognizing that some scientific rigour would be lost.

In summary, this paper introduces a kinanthropometric procedure for proportional assessment during growth. It can demonstrate developmental patterning based upon an inexpensive procedure, namely serial photographs. The procedure could be replicated simply to obtain international and multi-ethnic comparisons.

CONCLUSION

Photographs have the clear advantage over other measurement techniques in that they provide a permanent record for the researcher. The major disadvantages are that the researcher is limited in the measurements that can be performed on a two dimensional record and that with the delay for the development of the photograph, any positional alterations would be impossible. This could be overcome by using video recordings.

In the clinical setting growth disorders may be identified by comparing a patient's proportionality scores with those of normal subjects. Some disorders (e.g., patients with Marfan's syndrome) may be identified with non-invasive techniques such as this.

In the sporting context body type is influential in the quality performer. If the potential elite athletes could be identified early then resources and training may be directed towards the future champions.

REFERENCES

1. **Buckler J.** (1987) The adolescent years: the ups and downs of growing up. Castlemead Publications, 152 pp.
2. **Dupertuis C. W., Tanner J. M.** (1950) The pose of the subject for photogrammetric anthropometry, with special reference to somatotyping. Am. J. Phys.Anthropol. 8: 27–48.
3. **Ross W. D., Wilson N. C.** (1974) Growth and development. A stratagem for proportional growth assessment. Acta Paediat. Belg., 28 suppl., 169–182.
4. **Ross W. D., Brown S. R., Hebbelinck M., Faulkner R. A.** (1978) Kinanthropometry terminology and landmarks. In: Shephard R. J. and Lavale H. Physical fitness assessment, Thomas Springfield, Illinois, p 44–50.
5. **Tanner J. M., Weiner J. S.** (1949) The reliability of the photogrammetric method of anthropometry, with a description of a miniature camera technique. Am. J. Phys. Anthropol. 7: 145–181.
6. **Warwick R., Wilson P. L.** (1973) Gray's anatomy (35th edition), Longman, Norwich.

Correspondence to:
Prof. David Brodie
Department of Movement Science and Physical Education,
University of Liverpool, P.O. Box 147, Liverpool L69 3BX,
United Kingdom

HEALTH PROFILES IN MIDDLE-AGED FORMER ATHLETES

E. Pihl[1], T. Jürimäe[2], T. Kaasik[1], and D. Brodie[3]

[1] Institute of Public Health, [2]Institute of Sport Pedagogy, University of Tartu, Tartu, Estonia

and [3]Department of Movement Science and Physical Education, University of Liverpool, Liverpool, U.K.

ABSTRACT

The purpose of this study was to compare specific health parameters in middle-aged former top athletes of two different physical activity levels with both recreational sportsmen and nonsportsmen of the same age. In total, 123 males (aged between 40–50 years) were studied and divided into four groups, namely physically active former sportsmen (n = 34), physically passive former sportsmen (n = 25), recreational sportsmen (n = 27), and controls (n = 37).

The subjects completed the Sharkey's questionnaire which provided information about their physical activity and health risk parameters. The chest, abdomen and thigh skinfold thicknesses were measured and body fat percentage was estimated using the bioelectrical impedance method. The waist/hip circumference ratio was also calculated. The concentrations of serum cholesterol, HDL-C, LDL-C, TG and GL were measured. The physical working capacity at a heart rate of 170 beats$\cdot$min^{-1} was measured using a cycle ergometer test. The results of the study showed that the CHD risk factors were lowest in the physically active former sportsmen. This group also had the highest mean physical working capacity but any differences in blood lipid and lipoprotein concentration tended to be caused by poor values in the physically passive group. A relatively good health, high PWC_{170} and low CHD risk in presently active former middle-aged athletes and in recreational sportsmen could be explained as a result of their lifelong regular physical activity, their optimal body mass and their relatively healthy lifestyle.

KEY WORDS: Former athletes, Health risk factors, Physical working capacity, Body composition, Blood lipids.

INTRODUCTION

In recent years evidence for the independent role of high physical activity in the primary prevention of coronary heart disease (CHD) has grown [3, 22, 27, 41]. It has been shown that physically inactive individuals are 1.9 times more likely to develop CHD than the physically active. This finding was independent of other major risk factors [34]. The impact of prior athleticism on health behaviour, CHD risk factors and physical fitness is a poorly understood issue. This is because the lifestyle of top level athletes differ greatly from the general population. It was shown that health in middle age appears to be more strongly related to present physical activity than to prior college sport participation [28, 29]. Previous athleticism has little apparent impact on current health, suggesting that present exercise has more effect on specific clinical variables [6]. It was also shown that former athletes tended to maintain their physical fitness advantage over non-athletes in their middle age [9, 35, 36, 38, 43]. However one of these authors [9] reported no differences in physical activity during leisure or occupational time between former athletes and nonathletes. The greater work capacities of the former athletes were indicated by their higher levels of exercise tolerance.

Cooper *et al.* [7] in a civilian male population and Patton *et al.* [30] in 40 year old and older military males, demonstrated an inverse relationship between aerobic power and CHD risk factors. There is also evidence that physical training postpones the decline of aerobic capacity until at least the age of 65 years [18]. One author has shown that aerobic power has a high genotype dependency [20], but others assert that the role of heredity is moderate [18]. The role of heredity in the fitness of former athletes is inconclusive.

Numerous studies reveal that in sportsmen, especially in endurance sportsmen, the concentration of plasma high-density lipoprotein cholesterol (HDL-C) is high [2, 39]. The concentration of total cholesterol (CHOL), low-density lipoprotein cholesterol (LDL-C) and triacylglycerols (TG) are reduced [10], thus decreasing the CHD risk. A high aerobic capacity is shown to correlate negatively with CHOL and TG [26] and positively with HDL-C [2]. On the contrary, Huttunen *et al.* (16) observed no relationship between LDL-C or HDL-C and the maximal oxygen consumption ($\dot{V}O_2$ max) in middle-aged males.

The purpose of this study was to compare specific health parameters in middle-aged former top athletes of two different physical activity levels with both recreational sportsmen and nonsportsmen of the same age.

MATERIALS AND METHODS

In total, 123 healthy middle-aged (age range 40–50 years) males were studied. Participants gave their informed consent and were requested to abstain from smoking on the day of the examination. Subjects were divided into groups:

1. Former top level sportsmen who were physically active after discontinuation of their sporting career (physically active former sportsmen, PAFS). They exercised regularly at least at the minimal level of the recommendations of the American College of Sports Medicine [1] for recreational purposes (n = 34);

2. Former top level sportsmen who were presently physically inactive (physically passive former sportsmen, PPFS). They had stopped their training and returned to a predominantly sedentary lifestyle after discontinuation of their sporting career 10–15 years ago (n = 25).

The former sportsmen in both groups had participated at national or international level in endurance sports events (e.g. runners, orienteers, skiers etc.) or sports games (e.g. basketball, volleyball etc.) for several years;

3. Recreational sportsmen (RS), moderately active throughout their lives who undertook aerobic exercise 3–4 times a week (n = 27);

4. A control group of men who rarely engaged in sports or physical activities (n = 37). Only subjects reporting no history of chronic diseases were included into the study. The subjects completed an *ad hoc* questionnaire that provided information about the quantity and quality of their physical activity. Their health risk parameters were estimated using the questionnaire and the scale of evaluation recommended by

Sharkey [40]. The values of the following complex of health risk factor were calculated:

1. Risk for coronary heart disease — by summing the indices of smoking, heredity, body mass, stress, physical activity etc.;

2. Risk related to health habits — on the basis of the indices of food intake, sleeping, alcohol consumption etc.;

3. Medical factors, that consisted of general health status and the consumption of medicines;

4. Safety factors, which included car driving, hazardous hobbies etc;

5. Personal factors — by aggregating the indices of education, social factors, occupation and marital status;

6. Psychological factors based on the indices of depression, anxiety and relaxation.

Body height and mass were measured and the body mass index (BMI) using the formula mass (in kg) divided by height (in m squared) was calculated. The subcutaneous skinfold thicknesses were measured at the chest, abdomen and thigh [23] using metal skinfold calipers (Holtain, Crymmych, UK). The body fat percentage was measured using the Bodystat-500 bioelectrical impedance method (Bodystat Limited, Isle of Man, UK). The waist and hip circumferences [23] were measured using a centimetre tape from which the waist/hip ratio was calculated.

The venous blood samples were obtained in the morning after a 12-hour fast. Any vigorous physical activity and intake of medicine were prohibited for at least 24 hours before the examination. In the blood plasma the concentration of CHOL, HDL-C and TG were measured enzymatically using a commercial reagent kits (Labsystems OY, Finland). The concentrations of LDL-C were calculated using Friedewald's equation [12], as was the HDL-C/CHOL ratio. Serum glucose (GL) concentration was measured enzymatically using the Boehringer Mannheim GmbH Diagnostica (Germany) kits.

Physical working capacity of the subjects was estimated by means of a graded submaximal cycle ergometer test, performed in the morning. The initial load was set at 100 W and the second one at 200 W. The duration of both loads was 4 minutes with a rest interval of 1 min between the loads. Exercise heart rate (HR), using the Sport tester PE-3000 (Kemple, Finland) were measured in the last 10 seconds of both loads. Physical working capacity was defined as a work load at HR of 170 beats per min^{-1} (PWC_{170}) and was calculated by extrapola-

HR of 170 beats per min^{-1} (PWC_{170}) and was calculated by extrapolation. The PWC_{170} per kilogram of body mass was also calculated.

Means (x), standard deviations (SD) and linear correlation coefficients r were calculated using conventional statistical methods. Differences between groups were tested for significance using a one way ANOVA. Statistical significance was defined as $p < 0.05$ and when a significant difference was observed a test of simple main effects was employed (unrelated T test).

RESULTS

Differences

The anthropometric and adiposity characteristics of the four groups are presented in Table 1.

Table 1. Mean (standard deviation) demographic and adiposity values of the former sportsmen (physically active, passive and recreational) and controls

	PAFS (n = 34)	PPFS (n = 25)	RS (n = 27)	CON (n = 37)
Age (yr)	44.9 (7.7)	46.6 (7.0)	43.9 (6.5)	43.6(5.9)
Height (cm)	178.5 (6.9)	180.1 (5.9)	178.4 (7.1)	176.4 (5.3)
Mass (kg)	76.3 (9.9)	88.0 (13.2)	81.3 (11.8)	82.4 (13.2)
BMI (kg/m^2)	23.9 (2.4)	27.1 (3.8)	25.5 (2.9)	26.4 (3.7)
Waist/Hips Ratio	0.87 (0.04)	0.92 (0.06)	0.88 (0.05)	0.90 (0.05)
Fat %	16.1 (3.5)	20.4 (4.2)	16.8 (4.9)	18.9 (4.8)
Skinfolds:				
Chest (mm)	9.5 (5.5)	14.8 (6.9)	12.1 (6.5)	13.3 (5.2)
Abdomen (mm)	15.1 (7.7)	25.0 (9.6)	20.3 (11.0)	23.6 (10.1)
Thigh (mm)	10.5 (3.8)	13.1 (4.6)	12.4 (4.5)	12.2 (4.5)
Sum (mm)	36.6 (15.3)	52.5 (18.8)	42.7 (18.5)	49.1 (17.2)

PAFS — physically active former sportsmen
PPFS — physically passive former sportsmen
RS — recreational sportsmen
CON — control group

There were non-significant differences between the parameters of mass, BMI, and all skinfold measures between the groups with the exception of the physically active former sportmen. This group had a significantly lower BMI, and significantly lower skinfold values. The measures of waist/hips ratio and fat % showed differences between more than one pair of the groups. This is shown in detail in Table 2 which indicates the levels of significance between all groups.

Table 1 shows that the all mean skinfold values are lower in the PAFS group. Table 2 shows the detail of the group significant differences and it can be seen that consistently significant differences occur between the PAFS and PPFS groups. Chest, abdomen and sum of skinfolds are also significantly different between the PAFS and control groups but the only other significant difference is between the PAFS and recreational former sportsmen group for the abdomen skinfold.

Table 2. Levels of significance between groups for mass and adiposity measures

	GROUPS					
	1–2	1–3	1–4	2–3	2–4	3–4
Mass	< 0.001	NS	< 0.05	NS	NS	NS
BMI	< 0.001	< 0.05	< 0.01	NS	NS	NS
Waist/Hips ratio	< 0.001	NS	< 0.01	< 0.05	NS	NS
Fat %	< 0.001	NS	< 0.05	< 0.01	NS	NS
Skinfolds:						
Chest	< 0.01	NS	< 0.01	NS	NS	NS
Abdomen	< 0.001	< 0.05	< 0.001	NS	NS	NS
Thigh	< 0.05	NS	NS	NS	NS	NS
Sum	< 0.001	NS	< 0.02	NS	NS	NS

1 — physically active former sportsmen
2 — physically passive former sportsmen
3 — recreational sportsmen
4 — control group

The means and standard deviation for the physical working capacity and venous blood parameters are shown in Table 3.

Table 3. Means (standard deviation) for physical work capacity, cholesterol, triglyceride and glucose values of the former sportsmen (physically active, passive and recreational) and controls

	PAFS (n = 34)	PPFS (n = 25)	RS (n = 27)	CON (n = 37)
PWC_{170} ($kgm \cdot min^{-1}$)	1701(346)	1663(337)	1764(411)	1334(278)
PWC_{170} ($kgm \cdot min^{-1} \cdot kg^{-1}$)	22.2(4.3)	19.0(4.0)	21.8(5.2)	16.1(2.7)
CHOL ($mmol\ l^{-1}$)	5.04(1.18)	5.40(1.17)	5.26(0.83)	5.37(1.27)
HDL-C($mmol\ l^{-1}$)	1.44(0.37)	1.21(0.30)	1.36(0.34)	1.32(0.41)
LDL-C($mmol\ l^{-1}$)	3.42(1.15)	3.84(1.32)	3.57(0.79)	3.80(1.21)
HDL-C/CHOL	29.6(8.1)	23.4(8.8)	26.6(6.8)	25.8(9.6)
TG($mmol\ l^{-1}$)	0.93(0.44)	1.38(0.82)	1.46(0.66)	1.28(0.58)
GL($mmol\ l^{-1}$)	4.52(0.55)	4.45(0.60)	4.52(0.56)	4.28(0.97)

PAFS — physically active former sportsmen RS — recreational sportsmen
PPFS — physically passive former sportsmen CON — control group.

Three of the parameters (CHOL, LDL-C and GL) showed non significant differences between the groups so will not be considered further in the results section. HDL-C, HDL-C/CHOL ratio showed a significant difference ($p < 0.01$) only between the PAFS and PPFS groups. It is interesting to note that in both these cases the significant difference is caused by a lower value in the physically *passive* former sportsmen (Table 3). In the case of the TG measure, the lowest mean is in the physically *active* former sportsmen and this is significantly different from the PPFS group ($p < 0.01$), the RS group ($p < 0.001$) and the controls ($p < 0.01$).

This only leaves from Table 3 the group differences for the physical work capacity values. Table 4 shows these levels of significance between all groups for PWC_{170} expressed in absolute unit and relative to body mass.

Table 4. Levels of significance between groups for physical work capacity measures.

	GROUPS					
	1–2	1–3	1–4	2–3	2–4	3–4
PWC_{170}($kgm \cdot min^{-1}$)	NS	NS	< 0.001	NS	< 0.001	< 0.001
PWC_{170}($kgm \cdot min^{-1} \cdot kg^{-1}$)	< 0.01	NS	< 0.001	< 0.05	< 0.01	< 0.001

1 — physically active former sportsmen 3 — recreational sportsmen
2 — physically passive former sportsmen 4 — control group

Table 4 shows that PWC_{170} in absolute unit was significantly lower ($p < 0.001$) only in the controls compared with other groups. The PWC_{170} in relative units (per kg body mass) was highest in the PAFS group (Table 3). In this measure there were significant differences between all groups except the differences between the PAFS and recreational sportsmen. The results of the analysis of Sharkey's health risk questionnaire are presented in Table 5.

Table 5. Means (standard deviations) of health risk analysis by Sharkey's questionnaire. The higher the number, the lower the risk.

	PAFS (n = 34)	PPFS (n = 25)	RS (n = 27)	CON (n = 37)
CHD Risk Factors	1.4 (3.1)	–4.0(5.1)	–1.2(4.0)	–5.3(4.8)
Health Habits	1.8 (2.3)	1.2(2.7)	1.6(2.1)	0.8(2.4)
Medical Factors	3.1(1.9)	2.6(2.6)	2.7(1.9)	2.5(2.4)
Safety Factors	–0.5(2.1)	–1.3(2.3)	–0.9(2.3)	0.2(3.0)
Personal Factors	3.8(2.3)	2.8(2.7)	3.6(2.1)	2.2(3.0)
Psychological Factors	0.6(1.5)	0.5(1.4)	0.0(1.9)	–0.3(1.7)

PAFS — physically active former sportsmen RS — recreational sportsmen
PPFS — physically passive former sportsmen CON — control group.

There were non-significant differences between the groups for the health habits and medical factors. In the case of the psychological factors there was only one significant group difference and that was between the PAFS group and the controls ($p < 0.05$). The significant group differences for personal, safety and CHD risk factors are shown in Table 6.

Table 6. Levels of significance between groups for personal, safety and CHD risk factors.

	GROUPS					
	1–2	1–3	1–4	2–3	2–4	3–4
CHD Risk Factors	< 0.001	< 0.01	< 0.001	< 0.05	NS	< 0.001
Safety Factors	NS	NS	NS	NS	< 0.01	< 0.05
Personal Factors	NS	NS	< 0.05	NS	NS	< 0.05

1 — physically active former sportsmen
2 — physically passive former sportsmen
3 — recreational sportsmen
4 — control group

The CHD risk factors show the greatest number of significant group differences with only the mean values for the pair of PPFS and controls not achieving significance. The low Safety Factor values for the PPFS and RS groups coupled with the high value for the control group explains the significant differences shown for this measure. A similar explanation is given for the Personal Factors with high values in the PAFS and RS groups coupled with the low value in the control group.

Relationships

The correlation coefficients produced variable results both in terms of the relationships between measures and the results for different groups. Abdominal skinfold thickness correlated significantly with CHOL ($r = 0.457$, $p < 0.02$), with LDL-C ($r = 0.436$, $p < 0.05$), HDL-C/CHOL ratio ($r = 0.469$, $p < 0.02$) and TG ($r = 0.472$, $p < 0.02$) but this was only in the PPFS group. The waist/hips ratio correlated significantly with body fat% in the PAFS group ($r = 0.424$, $p < 0.05$) in the PPFS group ($r = 0.768$, $p < 0.001$) in the RS group ($r = 0.810$, $p < 0.001$) and in the controls ($r = 0.767$, $p < 0.001$). The range of correlation values for all groups between body fat percent and waist circumference was $r = 0.608$ ($p < 0.001$) to $r = 0.885$ ($p < 0.001$). The similar correlation range between body fat percent and hip circumference was lower for all groups, going from $r = 0.461$ ($p < 0.02$) to $r = 0.695$ ($p < 0.001$). It must be remembered that although the above correlations show reasonable levels of significance, those below $r = 0.5$ are still only accounting for less than 25% of the common variance, leaving 75% unexplained.

DISCUSSION

Our results confirm the well-established observation that physical inactivity has a negative influence on body composition measures. In the PPFS group and in the controls, the measured parameters were in general not so favourable as in both physically active groups.

The results of the Sharkey [40] questionnaire indicated that the differences between the groups were especially sensitive for the CHD risk factors. The score of risk was lowest in the PAFS group, being even lower than in the RS group. It is thus concluded that the PAFS group lead the healthiest life in terms of coronary risk. A contributory factor to this cardiac risk factor is the prevalence of smoking. Forty percent of the controls smoked, but this figure dropped dramatically in the active groups with 24 percent of the PPFS group, 18.5 percent of the RS group and only 14.7 percent of the PAFS group.

The mean absolute value of PWC_{170} was significantly lower in the control group compared with the other groups. The mean PWC_{170} relative to kg body mass was significantly lower in the PPFS group than in the PAFS group and in the RS group but higher than in the control (Table 4). These results are in good agreement with the results of an early study by Saltin and Grimby [38] showing that the aerobic capacity in former sportsmen after the end of their sports career remains higher than in average middle-aged men. Fardy *et al.* [11] also revealed that former athletes have a higher $\dot{V}O_2$ max in comparison with their nonathletic peers. The last phenomena may be explained genetically, on the assumption that athletes are persons of inherited superior physical abilities [5]. However, Dishman [9] reported similar aerobic power values in former athletes and nonathletes, even though the groups did not differ in actual levels of physical activity. It was also shown that when training was maintained, the aerobic capacity of master athletes (aged over 40 years) remained unchanged over a follow-up period of 10 years [14, 33]. A recent study by Marti and Howald indicated that a lack of aerobic training and an increase in body fat will strongly and independently influence the rate of age-related decline in aerobic power, irrespective of the history of prior athleticism [25]. Physical working capacity is known to decline with age but the rate of decline is very dependent on other factors including the level of activity maintained over time. A 5–10% decline has been reported per decade for untrained men [8, 15, 36], for older endurance athletes [13] and for masters athletes [32]. When intensity, duration and performances were matched a five percent decline per decade has been suggested [37]. This was also the value proposed in older persons who maintain training [42]. As previous work capacity was unknown and the subjects of the present study were not especially old, extrapolation to earlier performance characteristics are of limited value. What is helpful in all these studies is the clear benefits of maintaining training, especially for those with the genetic composition or motivation to make them highly active in the first place. This study has produced strong evidence that the hierarchy for the aerobic capacity of middle-aged subjects is current regular activity levels followed by previous levels of aerobic performance.

The relatively poor physical work performance of the inactive group, even when previously high performers, will be a combination of physiological factors. Reduction in maximum cardiac output [13] and peripheral oxygen extraction [42] are likely causes.

In the present study the concentration of serum HDL-C was significantly higher in PAFS than in PPFS (Table 3). The number of smokers, the body mass, the body fat percentage, the waist/hips ratio and the abdomen skinfold thikness were all significantly higher in PPFS than in PAFS. All these factors are known to influence negatively serum HDL-C concentration. On the other hand, physical activity is shown to increase serum HDL-C [2, 39]. The high values for HDL-C demonstrates the protective effect of current physical activity because of the lower risk of developing coronary artery disease [17, 24]. The mechanism seems to involve more effective cholesterol removal to the liver where it is excreted after catabolysis.

The HDL-C/CHOL ratio is recognized as an atherogenic index which is influenced by endurance training. The evidence from this study gives support to this with the inactive group having the lower value. The HDL-C concentration was related to PWC_{170} only in the PAFS ($r = 0.356$, $p < 0.05$). This fact coincides with the results of the study of Berg and Keul [2], who revealed that a significant correlation between serum HDL-C and PWC appeared only at high levels of the aerobic capacity, e.g. at higher than 50 $ml \cdot min^{-1} \cdot kg^{-1}$ $\dot{V}O_2max$. Somewhat surprisingly there were non-significant differences between the groups in serum CHOL and LDL-C concentration. Even though mean differences were not shown, there were interesting differences in hypercholesteremia, defined as a concentration of CHOL over 6.2 $mmol \cdot l^{-1}$. Twenty four percent of the controls, 24.0 percent of the PPFS group, 14.8 percent of the RS group and 14.7 percent of the PAFS group had hypercholesteremia. Hyperglycaemia (a concentration of GL higher than 5.5 $mmol \cdot l^{-1}$) had a different pattern with a level of 5.4 percent in the control group, 3.7 percent in the RS group, 2.9 percent in the PAFS group and none among the PPFS group.

Several studies have confirmed a relationship between abdominal obesity and unfavourable lipid metabolism [19, 21]. In the present study the abdominal skinfold thickness correlated significantly with blood lipid concentrations only in the PPFS. CHD risk are ofter associated with abdominal fat distribution measured as a waist/hip ratio [4]. The waist/hip ratio was highest in the PPFS group.

In summary, the reasons for relatively good health, high physical working capacity and a low level of CHD risk factors in middle-aged physically active former sportsmen and in recreational sportsmen appear to be associated with their lifelong regular physical activity, their optimal body mass and relatively healthy lifestyle.

ACKNOWLEDGEMENTS: The authors would like to thank Bodystat Limited (UK) managing director I. J. Meeuwsen for his help with equipment for measuring body composition.

REFERENCES

1. American College of Sports Medicine. (1990) The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. Med. Sci. Sports Exerc. 22: 265–274.
2. **Berg A., Keul J.** (1985) Influence of maximum aerobic capacity and relative body weight on the lipoprotein profile in athletes. Atherosclerosis 55: 225–231.
3. **Berlin J. A., Colditz G. A.** (1990) A meta-analysis of physical activity in the prevention of coronary heart disease. Am. J. Epidemiol. 132: 612–628.
4. **Björntorp P.** (1988) The associations between obesity, adipose tissue distribution and disease. Acta Med. Scand. Suppl 723: 121–126.
5. **Blair S. N., Cooper K. H., Gibbons L. W., Gettman L. R., Lewis S., Goodyear N.** (1983) Changes in coronary heart disease risk factors associated with increased treadmill time in 753 men. Am. J. Epidemiol. 118: 352–359.
6. **Brill P. A., Burkhalter H. E., Kohl H. W., Blair S. N.** (1989) The impact of previous athleticism on exercise habits, physical fitness and coronary heart disease risk factors in middle-aged men. Res. Quart. Exerc. Sport 60: 209–215.
7. **Cooper K. H., Pollock M. L., Martin R. P., White S. R., Linnerud A. C., Jackson A.** (1976) Physical fitness levels vs. selected coronary risk factors. JAMA 236: 166–169.
8. **Dehn M. M, Bruce R. A.** (1972) Longitudinal variants in maximum oxygen intake with age and activity. J. Appl. Physiol. 33: 807–809.

9. **Dishman R. K.** (1988) Supervised and free-living physical activity: No differences in former athletes and non-athletes. Am. J. Prev. Med. 8: 153–160.

10. **Dufaux B., Assmann G., Hollmann W.** (1982) Plasmalipoproteins and physical activity — A review. Int. J. Sports Med. 3: 123–126.

11. **Fardy P. S., Maresh C. M., Abbott R., Kristiansen T. A.** (1978) Comparison of habitual lifestyle, aerobic power and systolic time intervals in former athletes and non-athletes. J. Sports Med. Phys. Fit. 18: 287–299.

12. **Friedewald W. T., Levy R. I., Fredrickson D. S.** (1972) Estimation of the concentration of low density lipoprotein cholesterol in plasma, without use of preparative ultracentrifuge. Clin. Chem. 18: 499–509.

13. **Grimby G., Saltin B.** (1966) Physiological analysis of physically well trained middle aged and older athletes. Acta Med. Scand. 179: 513–523.

14. **Hagberg J. M.** (1987) Effect of training on the decline of $\dot{V}O_2$ max with aging. Fed. Proc. 46: 1830–1833.

15. **Heath G. W., Hagberg J. M., Ehsani A. A., Holloszy J. D.** (1981) Physiological comparison of young and older endurance athletes. J. Appl. Physiol. 51: 34–40.

16. **Huttunen J. K., Länsimies E., Vuotilainen E.** (1979) Effect of moderate physical exercise on serum lipoproteins. A controlled clinical trial with special reference to serum high density lipoproteins. Circulation 60: 1220–1229.

17. **Kannel W. B., Castelli W. P., Gordon T.** (1979) Cholesterol in the prediction of atherosclerotic disease — a new perspective based on the Framingham Study. Ann. Intern. Med. 90: 85–91.

18. **Kasch F. W., Wallace J. P., Van Camp S. P., Verity L.** (1988) A longitudinal study of cardiovascular stability in active men aged 45 to 65 years. Phys. Sportsmed. 16: 117–124.

19. **Kissebach A. H., Vydelingum N., Murray R., Evans D. J., Hart A. J., Kalkoff R. K., Adams P. W.** (1982) Relation of body fat distribution to metabolic complications of obesity. J. Clin. Endocrinol. Metab. 54: 254–260.

20. **Klissouras V.** (1971) Heritability of adaptive variation. J. Appl. Physiol. 31: 338–344.

21. **Krotkiewski M., Björntorp P., Sjostrom L., Smith U.** (1983) Impact of obesity on metabolism in men and women — importance of regional adipose tissue distribution. J. Clin. Invest. 72: 1150–1167.

22. **Lakka T. A., Salonen J. T.** (1992) Physical activity and serum lipids: A cross-sectional population study in Eastern Finnish Men. Am. J. Epidemiol. 136: 806–818.

23. **Lohman T.** (1988) Anthropometric standardization reference manual. Champaign, Illinois, Human Kinetics.

24. **Malaspina J. P, Bussiere H., LeCalve G.** (1981) The total cholesterol/HDL cholesterol ratio: a suitable atherogenesis index. Atherosclerosis 40: 373–375.

25. **Marti B., Howald H.** (1990) Long-term effects of physical training on aerobic capacity: controlled study of former elite athletes. J. Appl. Physiol. 69: 1451–1459.

26. **Montoye H. J., Block W. D., Gayle R.** (1978) Maximal oxygen uptake and blood lipids. J. Chron. Dis. 31: 111–118.

27. **Paffenbarger R. S., Hyde R. T.** (1984) Exercise in the prevention of coronary heart disease. Prev. Med. 13: 3–22.

28. **Paffenbarger R. S., Hyde R. T., Wing A. L., Hsieh C. C.** (1986) Physical activity, all-cause mortality and longevity of college alumni. N. Engl. J. Med. 314: 605–613.

29. **Paffenbarger R. S., Hyde R. T., Wing A. L., Steinmetz C. H.** (1984) A national history of athleticism and cardiovascular health. JAMA 252: 491–495.

30. **Patton J. F., Vogel J. A., Bedynek J., Alexander D., Albright R.** (1982) Coronary risk factor screen and aerobic capacity in a cohort of over 40 aged military personnel. Med. Sci. Sports. 14: 170P.

31. **Perusse L., Lortie G., Leblanc C., Tremblay A., Theriult G., Bouchard C.** (1987) Genetic and environmental sources of variation in physical fitness. Ann. Hum. Biol. 14: 425–434.

32. **Pollock M. L.** (1974) Physiological characteristics of older champion track athletes. Res. Quart. 45: 363–373.

33. **Pollock M. L, Foster C., Knapp D., Rod J. L., Schmidt D. H.** (1987) Effect of age and training on aerobic capacity and body composition of master athletes. J. Appl. Physiol. 62: 725–731.

34. **Powell K. E., Thompson P. D., Caspersen C. J., Kenrick J. S.** (1987) Physical activity and the incidence of coronary heart disease. Ann. Rev. Public Health 8: 253–287.

35. **Pyorala K., Karvonen M. J., Taskinen P., Takkunen J., Kyronseppa H., Peltokallio P.** (1967) Cardiovascular studies of former endurance skiers. Am. J. Cardiol. 20: 191–205.

36. **Robinson S., Dill D. B., Robinson R. D., Tzankoff S. P., Wagner J. A.** (1976) Physiological aging of champion runners. J. Appl. Physiol. 41: 46–51.

37. **Rogers M. A., Hagberg J. M., Martin W. H., Ehsani A. A., Holloszy J.O.** (1960) Decline in $\dot{V}O_2$ max with aging in masters athletes and sedentary men. J. Appl. Physiol. 68: 2195–2199.

38. **Saltin B., Grimby G.** (1968) Physical analysis of middle-aged and old former athletes. Comparison with still active athletes of the same ages. Circulation 38: 1104–1115.
39. **Schnabel A., Kindermann W.** (1982) Effects of maximal oxygen uptake and different forms of physical training on serum lipoproteins. Eur. J. Appl. Physiol. 48: 263–268.
40. **Sharkey B. J.** (1990) Physiology of fitness. Third edition. Human Kinetics. Champaign, Illinois, p. 371–383.
41. **Shephard R. J.** (1986) Exercise in coronary heart disease. Sports Med. 3: 26–49.
42. **Stamford B. A.** (1988) Exercise and the elderly. Exerc. Sport Sci. Rev. 16: 341–379.
43. **Stephens K. E., Van Huss W. D., Olson H. W., Montoye H. J.** The longevity, morbidity and physical fitness of former athletes- an update. In H. M. Eckert & H. J. Montoye (eds.), Exercise and Health. Champaign, IL: Human Kinetics, pp 101–119.

Correspondence to:
Prof. Toivo Jürimäe
University of Tartu 18 Ülikooli Street
EE 2400 Tartu ESTONIA

THE LIFELONG CHANGES OF PRECONDITIONS FOR AEROBIC ENDURANCE PERFORMANCE IN WOMEN

M. Kohoutek and V. Bunc
Faculty of Physical Education and Sport, Charles University,
Prague, Czech Republic

ABSTRACT

In this study the lifelong curves of maximal oxygen uptake and Cooper test indicators in women were constructed to judge both physiological and kinanthropological level of diagnostics. In order to construct them, the average performance values of Cooper test original and those of chosen experts were used. Similarly original and transformed values of $\dot{V}O_2$ max were processed.

A very similar trend can be seen in both groups of indicators: live performance maximum up to the age of 16 followed by mild regular regression (nearly linear course) toward the old age. A little later the top of motor performance and a rather higher level of motor performance values throughout the lifelong development can be attributed to the movement experience and performance motivation. Our results support good validity of Cooper test as a field diagnostics parallel of laboratory testing of aerobic preconditions.

KEY WORDS: Aerobic endurance performance, Motor development, Lifelong trend.

INTRODUCTION

The maximal oxygen uptake ($\dot{V}O_2$ max) is a basic indicator of presuppositions for endurance performance in aerobic regime of the muscle work (the main criterion of the aerobic capacity). The lifelong development of its level has already been satisfactory defined. The values differences belonging to the researched age categories are consequences of different methodological approaches (type of workload within the spiroergometry: treadmill, cycling ergometer) and are influenced by the range and also by type of the research sample (in most cases the cross-section investigation, a low n in the small number of the longitudinal studies).

According to physiological cross-section and also longitudinal studies the values of $\dot{V}O_2$ max manifest in both men and women a significant growth till about 20 years of age during the physical development, followed by regression toward the old age [1, 2, 3, 4, 7, 12, 18].

In converted values $\dot{V}O_2$ max to 1kg weight regression from the adulthood to the old age is mild and nearly linear (about 0.40 ml $\times$ min.$^{-1}$ $\times$ kg^{-1} for one year [7]. The value curve is on higher level in sportively active population than in non active during the lifelong period [4, 11, 12, 15] and age conditioned regression is lower [11]. The development of $\dot{V}O_2$ max is in progress on a significantly lower level in women than in men*. The differences between men and women are surprisingly stabile in adulthood [19].

The regression of values of $\dot{V}O_2$ max in women seems to be less sheer when compared to men [18].

The motor endurance tests are the field diagnostics parallel for measurement of aerobic endurance presuppositions (running for the time 6, 8, 12, 15, 30 min, 2 km-walking, 12 min-swimming etc. [13, 17]. The Cooper test (12 min-running) spread in central Europe in the 70 s and 80 s and since has been used in many, mostly cross-sectional investigations.

Most of measurements were realized in school population [8, 16, 20, 21], less in sporting population [9] and the least in adults, even if selected [14]. According to the research results that were done in large

---

* The comparison is not quite objective; it is significantly influenced by a different level of exercise activity; on the other side, women have got a better morphological preconditions for endurance performance.

samples of probands [8, 16] the non selected population of women reaches the top of aerobic endurance performance already before and at about the age of 16. Then a relative sharp regression of performance can be seen. The testing of sportively active women has shown that this premature start of performance regression is probably the consequence of low motivation [14].

PURPOSE

This study was worked out with respect to possible difference between some indicators of aerobic performance acquired by the use of motor tests — on one hand, and in the laboratory — on the other hand. The purpose was to compare the lifelong development, both laboratory and field indicators of aerobic endurance performance on the basis of synthesis of procurable data from literature and data of ours. The aim of the chosen methodological approach was to consider the trend of development of the discussed aerobic endurance performance presuppositions.

METHOD

The data from cycle ergometry transformed to the values corresponding with the treadmill data were used for construction of longlife curves course of $\dot{V}O_2$ max values [5, 6]*.

In some age categories, $\dot{V}O_2$ max data, that were derived from the generally valid subrogation relationship between run velocity and $\dot{V}O_2$ max, were worked up [6].

On the level of field diagnostics (motor tests) the average values of performance in Cooper test for the chosen age categories were run up from the results of measurements in big research samples [8, 14, 16, 20].** These data were complemented with the value of average per-

---

* It was confirmed that the values of treadmill test results are on average 9% higher than values from cycle ergometry.

** Number of tested persons: Motor tests:
MORAVEC *et al* [16]: representative sample of Czech and Slovak Rep., 21.692 pupils, age: 7–18; DRABIK [8]: region of Poland, 12.276 pupils,

formance of the group of 60–75 years old women (n = 14: original, non published data). The polynom and logarithm model curves were studied with respect to their best similarity to those constructed on the basis of real values. None of them responded to the natural trend of longlive changes. Therefore the longlive curve of performance in Cooper test and also the curve of changes of $\dot{V}O_2$ max were constructed not by the use of model values but real values of the test results.

RESULTS

The course of both curves ($\dot{V}O_2$ max, Cooper test — Table 1, Figure 1) confirms the stated hypotheses:

— the top of performance about 15–16 years of age followed steady and even, nearly linear performance regression.

— the course of both curves is approximately the same, even if motor performance indicators are on a higher level within nearly the whole scope.

Results indicate that the physiological indicator is running slightly ahead of motor performance indicators in the phase of greater growth.

Table 1 The average values of chosen indicators of the aerobic endurance performance

Age	Cooper test (m)		$\dot{V}O_2$ max
	n	$\bar{x}$	(ml × min^{-1} × kg^{-1})
7	1226	1568	33.3
10	1941	1927	39.7
14	3099	2145	42.3
16	2385	2185	41.5
18	1667	2166	40.4
35	127	1930	36.6
50	52	1795	29.7
70	14	1535	23.1

age: 8–19; SEMETKA [20]: representative sample of Slovak Rep., 11.931 pupils, age: 7–14; KOVAR *et al.* [14]: members of Czech Phys. Educ. Ass., 8.180 persons. age: 6–60.

$\dot{V}O_2$ max.: values of about 1.100 women, either directly measured or derived, include longitudinal studies [6]; i.e. 250–350 probands in each age category studied, on the average.

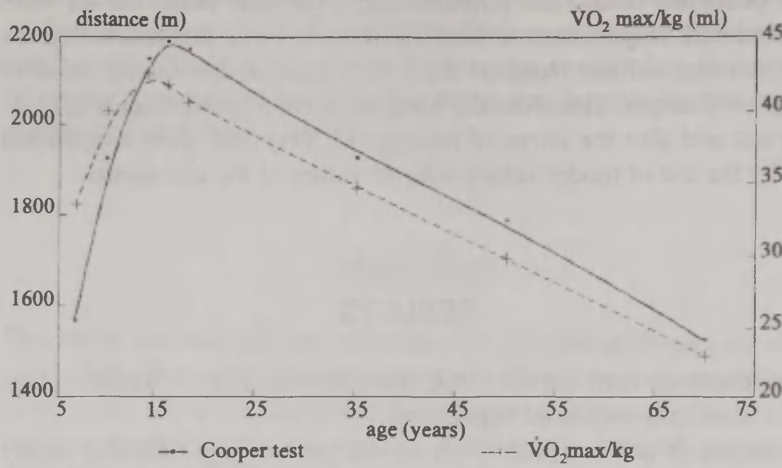

Figure 1. The comparison of motor and physiological indicators of aerobic endurance performance in women.

Sources: Cooper test: Semetka [20], Kovar *et al.* [14], Drabik [8], Moravec *et al.* [16], Kohoutek 1992 (non published). $\dot{V}O_2$ max: Bunc [5, 6] (longitudinal studies, cross-sectional research, derived values)

$\bar{x}$: The average value performance on the basis of average performances according to the chosen experts (above).

DISCUSSION

The course linearity of values of $\dot{V}O_2$ max corresponds to the knowledge from literature about the yearly regular regression up to the old age [10] and it also corresponds to normative constructed by Bunc [6] using original data of Czech experts, too [18, 19]. Judging from the course of $\dot{V}O_2$ max curve, the linear regression would theoretically end on the zero level. Because of the lack of information in the old age we suppose that a certain minimum niveau of $\dot{V}O_2$ max continues in this period as well. A small shift toward the top of performance in motor performance indicators can undoubtedly be attributed to the exercise experience.

There has not been enough information about performance according to Cooper test in adulthood and old age so that the motor performance curve of aerobic endurance could be materialized. The cyclic locomotion for a given distance as a test of aerobic endurance performance (walking, running) offer further possibilities how to get the valid data for the performance evaluation. Nevertheless, a very good lifelong coincidence of values of motor performance with values of $\dot{V}O_2$ max support a good validity of Cooper test and confirm the right-fulness of the utilization of motor endurance tests as a equivalent diagnostics mean of testing in the laboratory. The estimation of $\dot{V}O_2$ max from motor test have been described in literature [6]. The estimation reliability is about 10%.

CONCLUSION

1. The level of changes in motor performance and $\dot{V}O_2$ max in women have shown the same form within the lifelong observation.
2. The peak of the lifelong aerobic endurance performance in women without systematical exercise training is about 16 years of age.

REFERENCES

1. **Asmussen E., Fruensgaard K., Nörgaard S.** (1975) A follow-up longitudinal study of selected physiological functions in former physical education students — after forty years. J. Amer. Geriat. Soc. 23: 442–448.
2. **Astrand I., Astrand P., Hallbäck I., Kilbom A.** (1973) Reduction in maximal oxygen uptake with age. J. Appl. Physiol. 35: 649–654.
3. **Astrand P., Christensen E. H.** (1964) Aerobic work capacity. In: Oxygen in the animal organism. Oxford: Pergamon Press.
4. **Bringmann W.** (1982) Möglichkeiten der Herausbildung und Erfassung von Adaptationen bei Sporttreibenden. Medizin und Sport 22: 77–81.
5. **Bunc V.** (1994) A simple method for estimating aerobic fitness. Ergonomics 37: 159–165.
6. **Bunc V.** (1990) Jednoduchy zpusob odhadu urovne telesne zdatnosti. Cas. lek. ces. 129: 883–886. (In czech.)

7. **Dehn M. M., Bruce R. A.** (1972) Longitudinal variations in maximal oxygen intake with age and activity. J. Appl. Physiol. 33: 805–807.
8. **Drabik J.** (1989) Wytzymalosc i jej uwarunkowania somatotyczne u dzieci i mlodziezy w wieku 8–19 lat. Gdansk: AWF. (In polish.)
9. **Fort J.** (1989) Revize norem zakladni a specialni pohybove vykonnosti turistu v TSM. (Diplomova prace). Praha: Universita Karlova, Fakulta telesne vychovy a sportu. (In czech.)
10. **Hossack F. K., Kusumi F., Bruce R. A.** (1981) Approximate normal standards of maximal cardiac output during upright exercise in women. Amer. J. Cardiol. 47: 1080–1086.
11. **Kanstrup I. L., Ekblom B.** (1978) Influence of age and physical activity on central hemodynamics and lung function in active adults. J. Appl. Physiol. 45: 709–717.
12. **Koinzer K., Krüger U.** (1982) Die Alterspezifik von Anpassungen an physische Belastungen. Medizin und Sport 22: 82–85.
13. **Kopriva J.** (1992) Vzajemna validita 12 minutoveho plavani a vybranych motorickych testu vytrvalostniho charakteru. (Kandidatska disertace). Praha: Universita Karlova, Fakulta telesne vychovy a sportu. (In czech.)
14. **Kovar R.** *et al.* (1983) Vysledky testovani zakladni pohybove vykonnosti cleno ceske organizace CSTV. Praha: CUT CSTV. (In czech.)
15. **Monod H., Flandrois R.** (1985) Physiologie du Sport. Paris; Masson.
16. **Moravec R.** *et al.* (1990) Telesny, funkcny rozvoj a pohybova vykonnost 7–18 rocnej mladeze v CSFR. Bratislava: Sport. (In slovak.)
17. **Oja P., Laukkanen R., Pasanen M., Tyry T., Vuori I.** (1991) A 2-km walking test for assessing the cardiorespiratory fitness in healthy adults. Int. J. Sports Med. 12: 356–362.
18. **Seliger V., Bartunek Z.** (1976) Mean values of various indices of physical fitness in the investigation of Czechoslovak population aged 12–55 years. Praha: CSTV.
19. **Seliger V., Macek M., Skranc O., Piric J., Handzo P., Horak J., Rous J., Jirka Z.** (1975) Metody a vysledky celostatniho vyzkumu fyzicke zdatnosti obyvatelstva. II. Ciselne vysledky. Praha: Universita Karlova. (In czech.)
20. **Semetka M.** (1982) Telesny rozvoj a pohybova vykonnost 7–14 rocnej populacie na Slovensku. Trener 1:1–15.
21. **Zahnd R.** (1986) Der 12-Minuten-Lauf-test. Magglingen, 3, 24–25.

Correspondence to:
Milan Kohoutek
Faculty of Physical Education and Sports
Charles University
J. Martiho 31
16252 Prague 6, Czech Republic

INSTRUCTION TO AUTHORS

"Acta ..." is a multidisciplinary (publishing papers on diverse subjects from sports and exercise sciences) annual publication.

Manuscripts are accepted for consideration with the understanding that their contents have not been published elsewhere. Manuscripts are read through by the editor and by two reviewers in blind review process, which takes 8–10 weeks.

Manuscripts are to be submitted in English. Submit three clear copies of the manuscript to the editor. Maximum volume of text is 10 pages, maximum total volume is 15 pages. Type the manuscript double-spaced on one side of A4 paper with margin of 3 cm on the left side.

The manuscript should be arranged as following

1. Title page

Title of the article in capital letters, names of authors, authors institution, name and address of the principal author, up to 5 key words. For blind review, a second title page is needed that contains only the title.

2. Abstract (up to 200 words, separate sheets).
3. Text

The text should contain the following sections: Introduction, Materials and Methods, Results, Discussion, References, Acknowledgements if any. Tables and Figures should be presented on separate sheets. Figures should be professional in appearance and have clean, crisp lines. Identify each Figure by marking lightly on the back, indicating Figure number, top side and abbreviated title of manuscript. Legends for the Figures should be submitted on a separate sheet. Tables should be double-spaced on separate sheets and include a brief title. The SI units should be used in presenting results.
Each citation in the text must be noted by number in parenthesis and must appear in the reference list as well. Each entry in the reference list must be double-spaced, arranged alphabetically and numbered serially by author with only one reference per number. Non-english papers should be cited in the original language.

Entries in the reference list should be as follows:

1. Sarna S., Kaprio J. (1994) Life expectancy of former elite athletes. Sports Med. 17: 149–151.
2. Gurpide E. (1975) Tracer methods in hormone research. Springer Verlag, New York
3. Morgan W. P., Borg G. (1976) Perception of effort in the prescription of physical activity. In: The humanistic and mental health aspects of sports, exercise, and recreation, T.Craig (ed). Chicago: Am. Med. Assoc. 256–259
4. Paoletti R. (1994) Future directions in drug treatment of atherosclerosis. 8th Int. Dresden Symp. on Lipoproteins and Atherosclerosis. Abstracts. Dresden, June 10–12, 1994, 22.

Page proofs will be sent to the author for marking of printer's errors.

Ten reprints will be sent, free of charge, to the principal author.

Subscription rate: 20 USD (+postage) send to the editor. 1991–1995 issues are available.

ISSN 1406–9822