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ANTHROPOMETRY, BODY COMPOSITION AND SOMATOTYPES OF BOTSWANA NATIONAL KARATE PLAYERS: A DESCRIPTIVE STUDY

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ABSTRACT

The present study was undertaken to assess the physique, body composition and somatotypes of Botswana national karate players camped in preparation for the 1999 All Africa Games held in Johannesburg, South Africa. In total, ten male and seven female karate players took part in the descriptive research. The mean somatotype rating for males were: 2.5± 1.1 – 3.9±0.9 – 3.0±1.2 and for females: 4.4±0.8 – 4.7±1.2 – 1.3±1.1 (endomorphy, mesomorphy and ectomorphy, respectively). This exploratory study has revealed that anthropometric factors of height, body mass, % body fat, BMI and somatotypes are important for high profile sport like karate.

Key words: karate, anthropometry, somatotype

INTRODUCTION

Researches are conducted in line with the specific demands for success in various sports. As is the practice in most parts of the world where sport is a big business, various sport scientists make their inputs into the training continuums of various teams with the ultimate aim of success. With the emergence of sport scientists in Africa, national teams now realize that they need the inputs of their scientists during the whole phase of training. It is therefore proper, for a start, to conduct baseline studies with the main intention of providing scientifically-backed suggestions for the improvement of training or the modification of available schedules. Also, since karate is a relatively new competitive sport in this part of the world, there is a need to vigorously acquire a bank of information on various aspects of the elite athlete; particularly as they relate to the physico-physiological, motor performance, physique and other anthropometric variables. This would serve as a reference point for comparison and for projecting on the success-failure ratio of athletes prepared for competitions.

Karate, like other dynamic sports, requires quick and sharp movements which are facilitated through adequate body physique. Coaches, trainers and sport scientists acknowledge that preparations for karate competitions call for requisite profiles among which are body build, body composition and somatotypes. The present study was undertaken to assess the physique, body composition and somatotypes of Botswana National karate players camped in preparation for the 1999 All Africa Games held in Johannesburg, South Africa, with a view to obtaining a comprehensive information on the preparedness of the athletes for the major competition and providing the coaches with necessary suggestions for improvement. It was also the aim of this study that data collected would be beneficial for use by both African and non-African sport scientists.

METHODS

Participants: Ten male (26.4 ± 3.0 yrs.) and seven female (22.4 ± 3.7 yrs.) karate players took part in the descriptive research. They were selected into the national team based on their previous performance records in national and regional karate championships. The evaluation was done at the invitation of the Botswana National Sports Council.

Tests: The kinanthropometric assessments involved the use of restricted profiles [14] which, in addition to stature and body mass, consist of nine skinfolds (triceps, subscapular, biceps, iliac-crest, supraspinale, abdominal, front thigh, medial calf and medial axilla), five girths (arm-relaxed, arm-flexed and tensed, waist, gluteal and calf) and two breadths (humerus and femur). These profiles were assessed according to the protocol of the International Society for the Advancement of Kinanthropometry [11]. For the same-day test-retest reliability, three successive measurements, per site, were taken on each player.

Data Collection: All measurements were taken in the Human Performance Laboratory, University of Botswana on the reporting date for camping. Athletes were duly informed of the test protocols and evaluation procedures prior to the assessment. They then signed the informed consent form and cooperated with the researchers. Their gender, ages (in yrs) and body masses (in kg) were first recorded followed by measurements of their skinfolds (in mm), skeletal diameters (in cm) and circumferences (in cm). Skinfolds were taken at the appropriate sites with a Harpenden skinfold caliper. Skeletal diameters were measured to the nearest mm at the appropriate sites using a broad blade anthropometer while circumferences were measured to the nearest cm using the 2.0-meter long retractable flexible steel tape, with an end tab before the zero marking.

Body density was computed from the anthropometric data using the equations for males [19] and for females [21]. Lean body weight was determined using equation of Withers et al. [20], while percent body fat was determined using equation of Siri [17]. Body mass index (BMI) was determined from the measures of stature and body mass using the equation [1]. The Heath-Carter method of somatotyping in which anthropometry is used to estimate criterion somatotype was employed to determine the somatotypes of the karate players [3]. The equations for decimalised anthropometric somatotype [4] were employed in computing the somatotypes of the participants. The resulting somatotype values were then displayed on a standard somato-chart.

Analyses of data: Descriptive statistics of mean, standard deviation and variation coefficients were applied to the data using the Statistical Package for Social Sciences. Since gender was acknowledged to influence physique and other anthropometric measurements, the data for males and females were analysed separately. No efforts were made to compare the results of both groups as this was not part of the assessment objectives.

RESULTS

Data on the age, body mass, physique and body composition variables of the male and female karate players are shown in Table 1.

Table 1. Age, body mass, physique and body composition of the karatekas.

Variables	Mean		SD		SE	
	Males (n=10)	Females (n=7)	Males	Females	Males	Females
Age (yrs)	26.4	22.4	3.0	3.7	1.0	1.4
Stature (cm)	176.0	158.2	7.0	3.5	2.2	1.3
Weight (kg)	68.2	59.6	8.9	4.5	2.8	1.7
Body fat (%)	12.2	18.6	4.6	3.2	1.5	1.2
BMI (kg/m^2)	22.0	23.8	2.5	2.5	0.8	1.0
Endomorphy	2.5	4.4	1.1	0.8	0.3	0.3
Mesomorphy	3.9	4.7	0.9	1.2	0.3	0.4
Ectomorphy	3.0	1.3	1.2	1.1	0.4	0.4

DISCUSSION

The focus of this descriptive study on the anthropometry, body composition and somatotypes of Botswana national karate players was to provide baseline data on karate players from one of the developing nations in Africa. It is worthy of note that data on karate players at the African level are very few. The karate players in the present study were therefore described in terms of how they compared with those in available studies at the African level. Where possible, reference was made to how the present athletes compared with their counterparts elsewhere in the world.

The mean age of 26.4 ± 3.0 yrs for males falls between the age-range of 23.8 yrs for Italian elite karate players [8] and the 28.5 ± 4.2 yrs obtained in a study on karate practitioners [22]. Also, the mean of 22.4 ± 3.7 yrs compares favorably with the 23.0 ± 2.3 yrs obtained on African female elite karate players [6]. These mean ages are therefore in line with the optimum age for successful performance in karate; as performance in karate requires a balance between the youthful vigor employed in karate training and competition and the gains of experience [18]. With additional years of exposure, the young karate player becomes more mature and experienced.

The importance of stature in the determination of ultimate success in elite sports has been over-emphasized [2, 5, 13]. The relevance of height for success varies from sport to sport. For instance, it was found that elite athletes in track and field athletics, rugby, handball, volleyball and basketball players and rowers are significantly taller than the normal population while gymnasts, bowlers, judokas, skiers, boxers and wrestlers were found to be significantly shorter than the normal population [12]. It would thus appear that excessive height is not very beneficial to success in combat sports, including karate. It was therefore concluded that players' heights and body masses are critical variables used in the recruitment and selection of athletes [13] because they have been found to have significant effects on performance. Hence, these variables were considered very important in a descriptive study of this nature. The female karate players in this study had a mean stature of 158.2 ± 3.5 cm. This value was slightly lower than the 163.5 ± 8.6 from female African elite karatekas [6]. Shortness in stature has been found to be particularly advantageous in acceleration when changing direction (agility) [7] as demanded by most combat sports including karate. A tall stature has the disadvantage of slower speed of movement and reaction time though with an advantage of a longer reach [13].

Body weight values of 68.2 ± 8.9 kg and 59.6 ± 4.5 kg were obtained for males and females, respectively. The male value was lower than the 72.3 kg for male Italian karate players [8] while the female value compared favorably with the 60.4 ± 6.4 kg for female African elite karate players [6]. Also, mean % body fat of 12.2 ± 4.6 for males and 18.6 ± 3.2 for females were obtained in this study. These values were higher than the 8.2% and 15.4% obtained on Czech male and female taekwondo black-belters, respectively [10]. In many sports requiring agility, excessive body weights and % body fats are not beneficial [13] as they constitute excess burden and impede fast bodily movements [16]. Therefore, the present athletes are within weight limits that allow for optimum mobility of elite athletes. However, their slightly higher % body fat may retard their mobility.

BMI has been referred to as the traditional measure of obesity and as an index of weight relative to stature [15]. However, other researchers view it, at best, as a measure of heaviness and not fatness [1]. BMI is influenced nearly to an equal degree by the body's lean and fat components [9]; suggesting that it is as much a measure of lean tissue as it is of fat. Whatever their views, excessive BMI could have serious health and performance implications. In the present study, the male and female athletes had a BMI of 22.0 ± 2.5 $kg{\cdot}m^{-2}$ and 23.8 ± 2.5 $kg{\cdot}m^{-2}$, respectively. These values are slightly higher than the 21.9 $kg{\cdot}m^{-2}$ and 22.0 $kg{\cdot}m^{-2}$ for male and female Czech taekwondo black-belters [10]. This slight difference may be a result of the difference in proficiency and fitness levels by both groups of karate players. The values are however suggestive of the absence of serious cardiovascular risk factors.

In appraising the physique of athletes in various sports, the technique of somatotyping has been widely applied [3]. According to this technique, the magnitude of each of the three components of physique is always expressed in a three-number rating: representing endomorphy, mesomorphy and ectomorphy in that order. Ratings on each component of 2–2½, 3–5, 5½-7, and 7½ and above are considered low, moderate, high and very high, respectively [4]. With the mean somatotype rating of 2.5 ± 1.1 – 3.9 ± 0.9 – 3.0 ± 1.2 for males and 4.4 ± 0.8 – 4.7 ± 1.2 – 1.3 ± 1.1 for females, the present male karate players could be said to be low on endomorphy, moderate on mesomorphy and ectomorphy, while the females could be said to be moderate on endomorphy and mesomorphy and very low on ectomorphy. However, the values for the females are similar to the 3.8 ± 1.9 – 4.3 ± 1.1 – 2.1 ±1.0 obtained on female Africa elite karate players. In summary, the male karate players could be described as ectomorphic-mesomorphs, while the females were endomorphic-mesomorphs.

CONCLUSION

This exploratory study has revealed that anthropometric factors of height, body mass, % body fat, BMI and somatotypes are important for high profile sport like karate. Since karate is a relatively new sport in Botswana, the information gathered on the participants would be quite valuable to both the players and coaches in their preparation for international championships.

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ADAPTATION OF HUMAN SKELETAL MUSCLE TO NINE WEEKS OF INTERMITTENT RESISTANCE TRAINING

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ABSTRACT

Twelve persons were randomly assigned to a training group (n=6) or a control group (n=6). The training consisted of intensive, intermittent elbow extensions three times a week at 55 per cent of 1RM for nine weeks. Needle biopsies were taken from the lateral head of the triceps muscle one week before and 2–3 days after termination of the training period. Following training, the mean percentage of type I fibres in m. triceps brachii had increased from 42.4 per cent to 58.2 per cent ($P < 0.03$) and the mean percentage of type IIB fibres had decreased from 22.8 to 8.1 per cent ($P < 0.03$). There was no change in distribution of type IIA fibres. The mean diameter of type I fibres increased from 56.0 to 64.2 μm (14.6%) ($P < 0.05$), type IIA diameter from 65.3 to 76.5 μm (17.1%) ($p<0.03$). Type IIB fibre diameter showed no significant change. NADH-TR activity in all fibre types was unchanged following training. We observed no significant changes in the control group. Taken together, these results suggest that increased amount of contractile of activity may be more important than the type of activity in transforming fast muscle fibres to slower fibres in an untrained non-postural muscle.

Key words: exercise, fibre type transformation, hypertrophy, intermittent training, non-postural muscle

INTRODUCTION

The responses of human skeletal muscle to continuous, low intensity training have been extensively studied. Results from several exercise studies with repeated low intensity contractions show that the percentage of type IIB muscle fibres decreases with an concomitant increase in the percentage of either IIAB, IIA, IIC, or type I fibre types [e.g. 8, 10, 19, 21].

On the other hand, studies of the response of human muscles to intermittent, high intensity exercise show equivocal results. Some studies report increased percentage of type I fibres and decreased percentage of type IIB fibres [4, 20]. Jansson et al. [11] and Jacobs et al. [12] however, reported decreased percentage of type I fibres and increased percentage of type II fibres. Such discrepancies may be ascribed to differences in the pretraining status and type characteristics of the exercised muscles, or to the amount and type of activity.

In line with the above-cited references [4, 8, 10, 11, 12, 19, 20, 21], several experimental studies using animal models have shown that increased contractile activity may transform a fast muscle to a slow muscle. This effect is quite pronounced when fast muscles (e.g. m. extensor digitorum longus or m. tibialis anterior) are chronically stimulated with a low frequency impulse pattern (for review, see reference 18). Interestingly, also an intermittent impulse pattern results in fast-to-slow fibre type transition, but the effect is less extensive than with chronic electrical stimulation [15, 17]. Both animal and human studies therefore indicate that the impulse pattern or exercise modality may be of less importance than the level of activity in a fast-to-slow muscle fibre transformation process.

So far, most human exercise studies in this field have concentrated on the responses of m. vastus lateralis to a running or cycling training regime, but this approach makes it difficult to separate the effect of the specific training from the effect of daily locomotor and postural activity. By using non-postural muscles, one may assume better control over parameters that influence the adaptive processes in skeletal muscle. In addition, there is little information about the effect of logitudinal resistance exercise on non postural/upper body muscles.

Using a previously untrained non-postural muscle, Schantz and Henriksson [19] observed fast-to-slow fibre transformation in the m. triceps brachii after low intensity, continuous contractions. In light of this, and the previous cited studies, we wished to investigate the adaptive responses of the m.triceps brachii subjected to an increased amount of high intensity, intermittent contractions.

MATERIAL AND METHODS

Subjects

Following written informed consent and ethics committee approval, five female and seven male students, age 26.6± 1.7 yr., height 172.6±1.4 cm and weight 67.3±3.6 kg (mean ±SE), were randomly assigned to a control group (n=6) or a training group (n=6). All subjects were healthy and untrained in the elbow extensor muscles at the beginning of the study. They were instructed to maintain their habitual level of activity, but not to engage in activities that would otherwise involve extensive use of the m. triceps brachii.

Exercise

The training consisted of series of intensive, intermittent elbow extensions (triceps pushdown). The participants were instructed to keep the pace at one repetition per second. Each series lasted 30 seconds, followed by a 15 second rest period. Four consecutive series (one set) were followed by two minutes rest. The first five weeks the participants performed four sets, while they performed five sets during the last four weeks of the training programme. The training programme was performed three times a week. Total weekly training amounted to 1400–1800 repetitions. The training resistance was 55–60 per cent of one repetition maximum (1RM) during the training period. 1RM was tested at the first training session each week throughout the nine weeks of training and the resistance was adjusted accordingly.

One week before training needle biopsies [2] were obtained from the upper-middle portion of the lateral head of the non dominate m. triceps brachii. Two to three days after termination of the training period, post training biopsies were obtained from an incision close to the previous biopsy scar. Care was taken to obtain biopsies from the same depth of the muscle belly. The non-dominant arm was chosen because it was supposed to be the more untrained one at the beginning of the study. The biopsy samples were frozen in isopentane, precooled to its freezing point in liquid nitrogen, and stored at –80 °C until analysis.

Analyses

Serial cross-sections, 10 µm thick were cut in a Leitz 1720 cryostat and incubated for myofibrillar ATPase at pH 9.4. Before the ATPase incubation the serial sections were sequentially pre incubated for ten minutes in an alkaline buffer followed by four minutes preincubation in an acid buffer [26]. The alkaline buffer was 50 mM 221-AMP buffer with pH 10.1 or pH 10.3, containing 20 and 50 mM $CaCl_2$, respectively. The acid buffer was 50 mM acetate buffer, pH 4.25 or pH 4.6. The pre-incubations took place in a water bath at 23°C. Staining intensities of the different fibretypes after preincubations 10.1/4.25 are in the order of IIB = I > IIA. After preincubations 10.3/4.6 the relative intensities are IIB > IIA > I. After staining, the optical density of individual muscle fibres was measured as described by Dahl and Roald [5] to provide a numerical estimate of the relative reaction intensity in each section. Absorbance values for each fibre after both acid and alkaline treatment were plotted in a two-dimensional plot giving rise to clusters of fibres with nearly similar reaction to the treatments. On the average 220 fibres (range 200–350) were classified in each section. The lesser diameter of each muscle fibre was measured on a digitizing tablet [3] on sections stained for NADH-TR [14].

Statistics

The statistical significance of the differences between pre- and post values was tested by Wilcoxon Signed Rank Test. Statistical significance was accepted at $P < 0.05$. Power of test was 52 per cent, mostly due to small test group size. The methodological error, i.e. the coefficient of variation (CV), was calculated from densitometric determinations of two different biopsies from the same incision [6]. The CV of fibre type distribution was 7.8 per cent. The CV of differences in staining intensity (duplicate densitometric determinations of serial sections from the same biopsy), was 2.0 per cent. The CVs of lesser fibre diameter calculated from two biopsies from the same incision and from duplicate determinations from two serial sections from the same biopsy, were 2.3 per cent and 0.9 per cent, respectively. Accordingly, the CVs of NADH-TR activity was 6.8 per cent and 4.3 per cent.

RESULTS

A significant increase ($P < 0.03$) from 42.4 percent to 58.2 percent in type I fibres was observed in the training group after nine weeks of training

(Table 1). The increase was balanced by a significant reduction (P < 0.03) from 22.8 to 8.1 percent in the percentage of type IIB fibres. The percentage of type IIA fibres was unchanged. No significant differences were found between the first and the last biopsy in the control group.

In addition there were no significant differences between the first biopsies of the exercise and the control group. This suggests that the two different groups initially were statistically similar with regard to muscle fibre type characteristics, and that the differences between pre and post exercise biopsies are due to the training.

In the training group, the lesser diameter of all fibre types (Table 1) was increased in the post training biopsies. The mean diameter of type I fibres increased 14.6% from 56.0 to 64.2 μm (P<0.05), the mean diameter of type IIA fibres increased 17.1% from 65.3 to 76.5 μm (P < 0.03). The mean diameter of type IIB fibres was also increased (14.1%), but the difference was not significant. There were no significant differences between the two biopsies in the control group regarding lesser diameter.

Table 1. Fibre type percentage, lesser fibre diameter and NADH-TR optical density (OD) values in m. triceps brachii after nine weeks of intermittent resistance training

	TRAINING GROUP (n=6)			**CONTROL GROUP (n=6)**		
	Fibre types %	Fibre diam μm	NADH-TR OD	Fibre types %	Fibre diam. μm	NADH-TR OD
Pre Exercise						
Type I	42.4±2.8	56.0±4.1	25.1±1.8	43.4±4.9	63.2±2.2	22.1±2.9
Type IIA	34.8±3.7	65.3±3.7	15.8±1.5	37.7±5.5	77.2±3.9	13.8±1.6
Type IIB	22.8±2.4	52.3±11.5	14.2±0.6	18.9±5.5	62.4±12.7	12.6±1.3
Post Exercise						
Type I	58.2±2.0*	64.2±4.5**	23.3±1.3	44.7±5.4	65.1±2.7	21.6±3.1
Type IIA	33.6±3.7	76.5±4.4*	15.6±1.2	37.4±5.0	79.6±4.5	13.1±1.8
Type IIB	8.1±3.0*	59.7±13.1	13.6±2.7	17.8±5.5	62.6±12.9	12.3±1.1

Values are mean ± SEM. * P < 0.03, ** P < 0.05. Optical density values (OD) are arbitrary units.

Oxidative capacity of the different fibre types, were determined by opical density readings of NADH-TR stained fibres. OD readings were about 40% higher in type I fibres than in type IIA and type IIB fibres, while there was little difference between type IIA and type IIB fibres (less than 10 per cent). There was no statistically significant change in oxidative capacity after exercise in the training group.

DISCUSSION

The major finding in this study is the increased percentage of type I fibres at the expense of type IIB fibres. This is intriguing because the tendency of fibre type transformation in the fast to slow direction also has been shown in the same muscle group after eight weeks of cross country skiing, a typical continuous low force activity [19]. Consequently, one has to question the importance of different training regimes as a stimulus to fibre type transformation. In this regard Simoneau et al. [20] and Cadefau et al. [4] observed transformation of fast fibres to slow fibres in the vastus lateralis muscle after intense intermittent running. Previous experiments also show that continuous low intensity running induce fibre type transformation of type IIB fibres to type IIA fibres in the vastus lateralis muscle [8, 21].

Until recently it was believed that resistance training did not affect the fibre type distribution of the exercised muscles [9]. However, Staron et al. [22, 23] and Hather et al. [7], have shown that resistance training at about 80-85 per cent of 1RM induces fibre type transformation in the fast fibre subgroups. These studies show a decreased percentage of type IIB fibres and an increased percentage of type IIA fibres in the vastus lateralis after training. The observations of Hather et al. [7] have been substantiated by SDS-polyacrylamide gel electrophoresis on the same material [1]. Adams el al. [1] found parallel changes in fibre type distribution observed by traditional ATPase (reduced IIB, increased IIA percentage) as revealed by densitometric quantification of myosin heavy chain composition (reduced MyHC IIB, increased MyHC IIA). This tendency was confirmed in a study of Jürimäe et al. [13] who investigated the effect of resistance exercise on fibre type characteristics in m. triceps brachii. Jürimäe et al. [13] found a significant reduction of the MyHC IIB isoform and a non-significant increase in MyHC IIA and MyHC I isoforms after 12 weeks "body-builder-type" resistance training.

In summary, it seems that both intermittent and continuous training regimes, applied to postural as well as to non postural muscles may induce fibre type transformation in the fast to slow direction. This may support the notion that the type of training (intermittent or continuous) may be less important than the amount of training in transforming muscle fibre types in the fast to slow direction in untrained muscles. We are currently investigating this hypothesis in a more comprehensive exercise study.

Few studies have investigated the effect of resistance training on fibre size in the triceps muscle, but MacDougall et al. [16] showed significant increases in the area of both type I (15%) and type II fibres (17%) in the male triceps brachii muscle after heavy resistance training. They also found significant increases in mean fibre type II/I area ratio with training, which could indicate a more extensive involvement of type II muscle fibres in the adaptive response to training. The present study, however, revealed the same type II/I diameter ratio before and after training (1.14 and 1.16, respectively).

One possible explanation is that both fibre type groups in our study were untrained and equally susceptible to training. This notion is supported by the fact that the mean fibre diameter of type I and type IIB fibres prior to training was of nearly the same size (56.0 and 52.3 μm, respectively). This implicates that, prior to this study, type IIB fibres have seldom been recruited in a manner that stimulates hypertrophy. Another explanation is that the resistance used in the present study was insufficient to induce a maximal hypertrophy of type II fibres. The training resistance in strength training studies has most often ranged from 70 to 100 per cent of the subjects' 1RM, and heavy resistance (i.e. high tension) has been regarded as a prerequisite for hypertrophy. The present study employed a medium resistance (about 55% 1RM). 1RM increased only by 9.8 per cent ($P<0.01$) after nine weeks of training (data not shown). This is not surprising considering the medium resistance and the high number of repetitions of the present study.

The present study did not find any significant increase in oxidative capacity after nine weeks of intermittent resistance exercise. This is in accordance with other resistance training studies [e.g. 24, 25] which however employed heavier training loads than the present study. A common feature between the present study and the above cited studies are however significant muscle fibre hypertrophy. In the present study, mean fibre diameter increased 14–17 per cent, while the oxidative capacity was unchanged from the pre-training state. Since NADH-TR is a mitochondrial enzyme, this implies a dilution of mitochondrial concentration in the hypertrophied muscle fibres. In turn, this will cause lower activity of the NADH-TR enzyme expressed per unit of muscle. The results from the present study therefore suggest that intermittent resistance exercise with sub-maximal loads is not beneficial for developing local oxidative capacity.

Taken together the results in this study show that training with medium resistance, but high speed and many repetitions may recruit all major fibre types and stimulate to hypertrophy and possibly fibre type transformation if the muscles in question are sufficiently untrained before the training starts.

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REPORTED HEALTH, PHYSICAL ACTIVITY AND BODY IMAGE IN 11 TO 17 YEAR OLD RURAL TEENAGERS

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ABSTRACT

In a group of 11-, 13-, 15-, and 17-years-old rural pupils (N=780), the perception of their health, body image and physical activity in leisure time was studied. The survey was based on the Health Behavior in School-Aged Children (HBSC) a WHO Cross-National Study. The majority (84.7%) of subjects considered themselves as 'healthy', or 'very healthy'; chronic diseases were found in 11% of rural adolescents. Many adolescents have common ailments and emotional states. The most frequent were nervousness (39%), irritability or bad mood (29%) and headache (18.8%). The majority of rural youths studied (77%) reported their fitness as 'very good' or 'good'. Every fourth boy and every second girl do not intense exercise enough, and exercise too seldom every week outside school hours. Due to the discontent with their appearance, 4.7% of boys and 14.8% of girls used slimming diets, and another 9.7% of girls and 26% of boys thought they ought to go on a diet to loose weight. The results of this study can be useful for planning health care and health education for rural adolescents.

Key words: rural adolescents, reported health, physical fitness, physical activity, body image

INTRODUCTION

Health is a fundamental value, which enables an individual to develop properly and to meet personal aspirations. Looking after one's own health in all its aspects (physical, mental and social) is very important at every level of development, but especially at the age of adolescence, as the health habits and behavior acquired in the young age build the health basis for the subject's adult life.

Children and adolescents need an optimal level of physical activity at each stage of their development. Energy expenditure, which is the effect of physical labour, enables maintaining optimum body mass and prevents overweight [6]. Motor activity in childhood and adolescence is very important for preventing atherosclerosis and other disorders of the circulation system [9,11,12]. Compensating excessive stress and overpressure of mental work, physical activity prevents disorders of mental health. In addition, undertaking physical activity helps adolescents build a healthy image of themselves in relationships with their peers.

Reduced physical activity (hypoactivity) often accompanies a course of disease, which is natural in some cases. However, a course of disease does not always justify such a reduction; it is often overprotective parents (or even doctors), who keep their children away from physical exertion and isolate them from their peer group. As a result, low activity would lead to a low efficacy of struggling against the disease [16].

The aim of this investigation was to present and estimate the way rural teenagers perceive their own health, build the image of their bodies and undertake physical activity. This study included the following specific items:

- general appreciation of health, chronic diseases and indispositions (disorders), and concomitant emotional states,
- general appreciation of fitness and leisure physical activity,
- appreciation of body appearance, build and body mass.

MATERIAL AND METHODS

The study was conducted in the South Podlasie region, in February 1999 and involved 780 students (361 boys and 419 girls) aged 11–17 years. The survey was based on the Health Behaviour in School-Aged Children (HBSC), a WHO Cross-National Study. The survey was organized and carried out according to Research Protocol for the 1997–98 survey [4]. The data were analysed by the EPI.V 6.04 software, the level of $p<0.05$ being considered significant.

RESULTS

1. General appreciation of health, incidence of some disorders and emotional states in rural youths

The majority (84.7%) of subjects considered themselves as 'healthy', or 'very healthy'. The others defined themselves as 'not really healthy' (Table 1). Girls estimated their health worse; they felt 'not really healthy' more often than 'very healthy'. With increasing age, the number of young people of both sexes, who estimated their health positively, decreased. Every fifth boy and nearly every second girl at the age of 17 considered themselves as 'not really healthy'.

Table 1. Self-reported general health of rural youths (n = 780)

Perceived general health	Boys, %					Girls, %				
	Total	Age (years)				Total	Age (years)			
		11	13	15	17		11	13	15	17
very healthy	34.6	45.5	44.2	23.1	19.4	19.3	37.6	20.4	12.2	6.9
healthy	56.2	48.5	51.6	64.2	61.3	59.2	54.5	67.6	62.6	49.4
not very healthy	9.1	5.9	4.2	12.7	19.4	21.5	7.9	12.0	25.2	43.7

Chronic diseases were found in 11% of rural adolescents (Table 2). The percentage was slightly higher in girls (11.5%) than in boys (10.5%). The incidence of chronic diseases in boys was found to decrease slightly increasing with age. The most commonly reported disorder was headache (found in nearly every fifth student). The number of girls often suffering from headaches increased with age. Almost 12% of subjects had frequent bellyaches. Girls suffered from this indisposition considerably more often than boys (16.2% and 7.5%, respectively). Over 8% of all young people had backaches; the percentage increased with age in both sex groups.

According to the survey, almost every third boy and every second girl were often in the state of nervousness. With increasing age, the number increased; at the age of 17, 35.5% of boys and 70.1% of girls frequently experienced that emotional state. Almost every third student had been irritated or in a bad mood during the six-month period before the examination. Girls were more susceptible to those kinds of emotional states (36.8%) than boys (21,9%). It was noted that the number of girls who were often in a bad mood or had a feeling of irritation, increased with increasing age (11-year olds — 25.7%, 17-year olds — 46%).

Table 2. The percentage of rural youths who often (once a week to almost every day) complained of various indispositions and emotional states during the six months prior to the study (N = 780)

Specification	Boys, %					Girls, %				
	Total	Age (years)				Total	Age (years)			
		11	13	15	17		11	13	15	17
Chronically ill	10.5	11.9	10.5	9.7	9.7	11.5	7.9	13.9	13.0	10.3
Headache ***	11.6	8.0	10.4	13.4	19.4	26.0	14.9	20.4	32.5	36.8
Bellyache ***	7.5	8.0	7.3	6.0	12.9	16.2	18.8	14.8	14.6	17.2
Backache	6.6	5.0	3.1	8.9	9.7	9.6	7.9	7.4	10.6	12.6
Depression ***	11.4	8.0	6.2	8.9	22.6	21.2	9.0	13.0	26.0	36.8
Irritability and bad temper***	21.9	26.0	16.7	21.6	25.8	36.8	25.7	38.0	38.2	46.0
Feeling nervous ***	29.6	28.0	27.1	31.3	35.5	48.2	26.7	44.4	53.7	70.1
Sleeplessness	12.7	16.0	10.4	11.9	12.9	13.8	12.9	9.3	16.3	17.2
Feeling dizzy **	8.0	7.0	8.3	6.7	16.1	12.2	5.0	12.0	17.1	13.8

Significantly different between boys and girls: ***p<0.001, **p<0.01, * p<0.05

In addition, over 11% of boys and 21.2% of girls often experienced a feeling of depression. The state was more common for girls (15- and 17 years old in particular) than for boys. Many subjects (13.8% of girls and 12.7% of boys) complained of sleeplessness more than once a week or almost every day. One subject out of 10 often suffered from dizziness. The number of girls who had frequently felt dizzy during the six months before the examination grew with age.

The most common emotional states reported by all boys and girls were nervousness (37%) and irritation with a bad mood (25%). Sleeplessness was a problem for 16% and depression for 13% of subjects.

2. General appreciation of fitness and leisure physical activity

The majority of rural youths studied (77%) reported their fitness as 'very good' or 'good' (Table 3). Only 3.7% considered their fitness to be 'bad'. Boys considered themselves fit more often than girls (34.3 and 21.7%, respectively). The percentage of subjects who rated their motor fitness as 'very good' or 'good' decreased with age; the number of boys dropped from 47 to 25.8%, while that of girls from 35.6 to only 6.9%.

Table 3. Self-reported general fitness of rural youths (n = 780)

Reported physical fitness	Boys, %					Girls, %				
	Total	Age (years)				Total	Age (years)			
		11	13	15	17		11	13	15	17
very good*	34.3	47.0	33.3	27.6	25.8	21.7	35.6	21.3	21.1	6.9
good	47.4	42.0	50.0	50.0	45.2	50.6	46.5	62.0	44.7	49.4
quite good	15.0	8.0	13.5	18.7	25.8	23.6	15.8	13.9	28.5	37.9
bad	3.3	3.0	3.1	3.7	3.2	4.1	2.0	2.8	5.7	5.7

*Significantly different between boys and girls ($p<0.001$)

41.3% of boys and 23.9% of girls in the age of 11 to 17 years exercised 4 times a week or more (Table 4). About 32% of boys and 28% of girls exercised 2–3 times a week. Every fourth boy and every second girl exercised only occasionally — once a week and less or never. The number of boys and girls exercising regularly was the highest at the age of 11 years. As they reach the age of 17, the number of boys and girls, who engage in motor activity four times a week or more decreased from 56 to 32.3% (boys) and from 33.7% to 14.9% (girls). In the year under study, 30.7% of boys and 11.5% of girls devoted at least 4 hours a week of their leisure time to exercise. One student out of four exercised 2-3 times a week after school. The others exercised one hour a week or less, or did not exercise at all. Among those who exercised at least 4 hours a week, 11 year-old boys and 13 year-old girls prevailed (36 and 15.7%, respectively).

3. Self-image of your body

Almost 60% of rural youths considered themselves to be 'good' or 'very good-looking' (Table 5). Only few said they were 'not very good-looking', or 'bad-looking'. In general, girls were less satisfied with their appearance than boys. With increasing age, the number of those who appreciated the way they look decreased, while the number of those perceiving their appearance as 'average' rose (at the age of 17 — one boy out of four and one girl out of two).

Girls think about the changes in their bodies more often than boys (68% and 48.8%, respectively). With increasing age, the number of teenagers dissatisfied with their perceived image increased, especially among girls.

Concerning body mass, every second boy and every fourth girl considered their body mass to be just right. However, the number decreased with increasing age, as increasingly more girls perceived themselves to be fat (from 22% of girls at the age of 11 to over 71% at the age of 17 years). As boys grew up, the number of those perceiving themselves as slim increased from 16 to 41.9%.

Due to the discontent with their appearance, 4.7% of boys and 14.8% of girls used slimming diets, and another 9.7% of girls and 26% of boys thought they ought to go on a diet to lose weight. The number of girls who considered losing weight increased with increasing age.

DISCUSSION

The era of political transformation brought many changes to the Polish society, which also included rural families. Pauperization of large groups of people, income differences, lack of stabilization, struggling with every-day problems, had an impact on the health condition of rural children in the past decade.

According to the results of this study, 34.6% of boys and 19.3% of girls considered themselves as "very healthy". The situation seems to be less optimistic than the situation presented in the report of Woynarowska

Table 4. Number of hours and frequency of intense exercise per week in leisure time (n = 780)*

Physical exercise per week	Boys, %					Girls, %				
	Total	Age (years)				Total	Age (years)			
		11	13	15	17		11	13	15	17
Freqency										
4 times or more	41.3	56.0	42.7	31.3	32.3	23.9	33.7	28.7	17.9	14.9
2-3 times	31.6	20.0	34.4	36.6	38.7	27.7	27.7	35.2	26.8	19.5
Once, rarely, never	27.1	24.0	22.9	32.1	29.0	48.4	38.6	36.1	55.3	65.5
Hours										
4 hours and more	30.7	36.0	20.8	32.8	35.5	11.5	7.9	15.7	14.6	5.7
2 - 3 hours	25.2	23.0	25.0	27.6	22.6	24.6	26.7	25.0	23.6	23.0
1 hour, less, never	44.0	41.0	54.2	39.6	41.9	64.0	65.3	59.3	61.8	71.3

* The weekly frequency of free-time exercising, at an intensity resulting in fatigue, sweating and short breath.
Significantly different between boys and girls ($p<0.001$)

Table 5. Body image and dieting to lose weight (n = 780)

Appearance — look:	Boys,%					Girls, %				
	Total	Age (years)				Total	Age (years)			
		11	13	15	17		11	13	15	17
very good	16.1	28.0	12.5	9.7	16.1	11.7	31.7	13.0	0.8	2.3
good	53.7	55.0	60.4	51.5	38.7	36.8	42.6	40.7	37.4	24.1
average	20.2	11.0	18.8	26.9	25.8	35.3	15.8	35.2	38.2	54.0
not very good	3.9	1.0	2.1	5.2	12.9	7.2	4.0	4.6	11.4	8.0
not good at all	1.4	0.0	3.1	0.0	0.0	5.0	0.0	1.9	9.8	8.0
don't think about it	4.7	5.0	3.1	6.6	6.6	4.1	5.9	4.6	2.4	3.4
There is something about their body they would like to change (e.g. build, apperance)	48.8	34.0	50.0	56.7	58.1	68.0	39.6	68.5	82.9	79.3
Weight — they are:										
too thin	27.4	16.0	20.8	37.3	41.9	15.3	17.8	16.7	13.0	13.8
the right size	48.8	59.0	53.1	38.8	45.2	28.9	42.6	34.3	26.8	9.2
too fat	12.5	11.0	17.7	10.4	9.7	45.8	21.8	38.0	54.5	71.3
don't think about it	11.4	14.0	8.3	13.4	3.2	10.0	17.8	11.1	5.7	5.7
Are on a diet to lose weight:										
no, because their weight is fine	85.6	79.0	83.3	91.0	90.3	59.2	80.2	65.7	49.6	40.2
no, but they do need to lose weight	9.7	11.0	12.5	8.2	3.2	26.0	13.9	21.3	28.5	42.5
yes	4.7	10.0	4.2	0.7	6.5	14.8	5.9	13.0	22.0	17.2

[15], who stated that Polish girls perceived their health rather negatively. Polish youths rate their perceived health relatively low, compared, for example, with the percentage of those 'very healthy' in Sweden, which was over two time higher than in Polish subjects [3].

However, chronic diseases and other ailments have to be taken into consideration to make the picture complete. About 11% of rural youths were affected by chronic diseases. The study conducted by King et al. [5] on adolescents in Canada showed that up to 1/3 of schoolchildren (almost three times higher than in Poland) stated to be chronically ill (diabetes, asthma, cardiac diseases, hearing disorders). Data reported by the School Health Education Unit at Exeter University [7] showed that 16–19% of respondents aged 12–15 years reported they suffered from asthma.

According to Billie [1] and Rother [10], about 40% of pre-school, and 70% of school children complained of periodical headaches. In USA, as many as 58% of children and adolescents use medical treatment due to this indisposition [3]. As the results of present study demonstrated, most respondents had frequent headaches and one student out of 5 reported having headache every day or at least twice a week. Other indispositions often mentioned by the subjects, were bellyaches (12%) and backaches (8%). Comparing the results of current study with the average for the whole Poland [15], it should be emphasized that different health disorders were more frequent in the group of youths from the Southern Podlasie region.

Physical fitness is one of the most important elements in the analysis of health condition of countryside youths. Physical exercise, properly designed in terms of manner, place and intensity, may help to keep fit for the whole life [13]. As the results of present study showed, rural youths, especially boys, were very confident about their physical abilities (41.3% of boys and 23.9% of girls exercised 4 times a week or more). However, the percentage of girls exercising little or never (64%) is alarming. This result is unsatisfactory in comparison with Woynarowska study [15]. Her study revealed that 60% of the whole rural population in Poland exercised one hour weekly, or less, or did not exercise at all. Insufficient motor activity is a problem in many Western European countries and in the USA. Only 28% of youths (11–15 years of age) in Sweden and 40% in the USA exercise 4 times a week or more [3]. Children and adolescents should be encouraged to engage in at least moderate, i.e. resulting in feeling warm and in accelerated breathing, physical exertions for one hour (or at least half an hour) every day. This could be walking, PE-classes at school, games, and all other kinds of sports that are being conducted progressively, or cumulate over the day [14].

Nine percent of youths perceive their appearance negatively, even though more than a half of them (58.4%) would like to change something about their outlook. One subject out of 5 considered himself too slim, and one out of 3 — overweight. The data of Baldwin [2] showed that 10% of girls and 13% of boys aged 14 were overweight. Due to dissatisfaction with their appearance, 4.7% of rural boys and 14.8% of girls took up dieting, and another 9.7% and 26%, respectively, considered starting a slimming diet. Almost identical results were reported by Woynarowska [15] for Polish adolescents aged 11–15 years. Poland is among countries with a relatively low percentage of youths who are (or realize they need to be) on slimming diets. In USA, 44% of adolescents aged 11–15 years are on a diet to loose weight [3]. This interest in their own appearance is a positive factor, which can be advantageous in health-oriented education programmes [8].

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CHANGES IN MOOD STATE PARAMETERS AFTER INTENSIFIED TRAINING PERIOD IN MALE COMPETITIVE ROWERS

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ABSTRACT

The effect of intensified training period on mood state parameters were investigated in male competitive rowers. Fourteen national level rowers (18.6±2.0 yrs; 186.9±5.7 cm; 82.4±6.9 kg) were monitored over a six-day training camp. The training regimen consisted mainly of low-intensity on-water rowing and resistance training, in total 19.2±3.9 h, corresponding to a 50% increase in training load. 2000 metre rowing ergometer performance time increased significantly from 395.9±10.8 to 404.2±11.9 s as a result of six-day training period. Mean power (from 361.9±28.5 to 349.0±32.8 W), blood lactate concentration measured five minutes after the test (from 19.2±2.9 to 16.2±2.3 $mmol \cdot l^{-1}$) and maximal heart rate (from 184.6±7.5 to 179.2±7.4 $beats \cdot min^{-1}$) decreased significantly over the training period. Maximal oxygen consumption values remained unchanged. The subjective ratings of fatigue and muscle soreness increased significantly as a result of short overreaching training period and were significantly related to the training volume ($r>0.52$). The reduced maximal performance indicates a state of fatigue/overreaching in rowers. It was concluded that the appropriate and simple tool for monitoring a short-term overload training period is a self-reported ratings of well-being on a daily basis.

Key words: overreaching, fatigue, rowing performance, mood state parameters

INTRODUCTION

The overtraining syndrome has been reported to describe a long-term decrement in performance capacity induced by an accumulation of training and non-training stress [6,11]. Overtraining is considered to occur in response to large volumes and/or high intensities of training with inadequate recovery periods between training sessions. Many indicators of overreaching and overtraining have been proposed using different physiological and psychological parameters. Despite determined efforts by researchers, there is currently no single marker that allows diagnosis of the disorder [3]. In fact, many physiological markers may vary similarly during training and overtraining [1]. Athletes have been classified as either overtrained or not overtrained when in fact the condition is on a continuum [6]. When the overtraining syndrome requires a recovery period of several months up to a year [13], the overreaching, a result of short-term overtraining, can be reversed with a resting period of a few days, maybe a week [5].

Although there is a variety of symptoms reported on overreached and overtrained athletes, the main symptoms are reduced performance and pronounced fatigue [6,13]. Other parameters that have been studied as possible markers of overreaching and overtraining include various blood circulatory indices at rest and/or during exercise [5,12], resting and/or exercise heart rate (HR) and oxygen consumption [5], and different mood state indices [6,12]. The identification of easily monitored, reliable indicators of overreaching may aid to monitor intensive exercise training and following recovery periods in athletes. Therefore, the purpose of this investigation was to investigate whether a short-term overreaching state in rowers, as indicated by a decrease in performance parameters, is reflected by similar changes in different mood state parameters.

MATERIALS AND METHODS

Subjects

Fourteen national level male rowers (18.6±2.0 yrs; 186.9±5.7 cm; 82.4±6.9 kg) volunteered to participate in this study. The rowers had trained regularly for the last 4.1±1.8 yrs. The training period and tests constituted their first training camp on water after winter training period at the prospect of the coming season. Subjects were informed about the procedures and the aims of the investigation, and their written consent was obtained. This study was approved by the Medical Ethics Committee of the University of Tartu.

Procedures

The training during the six-day training period amounted to 19.2±3.9 h, which was equivalent to an average increase in training load by approximately 50% compared with their average weekly training during the preceding four weeks. In total, 12 training sessions were completed during overreaching training period compared to six training sessions during previous four weeks. Eighty five percent was low-intensity endurance training (rowing or running), 5% was high-intensity anaerobic training (rowing) and 10% was resistance training. Maximal 2000 metre rowing ergometer test was performed before (Test 1) and after (Test 2) the six-day training period. Subjects were only allowed to train easy or not at all on the afternoon before the final test day. Early morning body mass and HR were recorded daily. In addition, rowers were asked to record daily subjective ratings of quality of sleep, fatigue, stress and muscle soreness on a scale of one to seven from very, very low (point 1) to very, very high (point 7) [6].

Performance Testing

Maximal 2000 metre rowing ergometer test was performed on a wind resistance braked rowing ergometer (Concept II, Morrisville, USA). The rowers were fully familiarized with the use of this apparatus. Power and stroke frequency were delivered continuously by the computer display of the rowing ergometer. HR was measured continuously and stored at 5 s intervals during exercise tests by sporttester Polar Vantage NV (Kempele, Finland). Expired gas was sampled continuously for the measurement of maximal oxygen consumption ($\dot{V}O_{2max}$; TrueMax 2400 Metabolic Measurement System, Parvo Medics, USA) [9]. The analyzers were calibrated prior to the test using commercial gases of known concentration. Fingertip capillary blood (20 μl) was sampled five minutes after the completion of the test. Blood lactate was determined from these samples enzymatically (Lange, Germany) [4]. Two parameters were considered to represent rowing performance: the time (T_{2000} in sec) and the average workload (P_{2000} in W) [9].

Statistical Analysis

Descriptive statistics (mean±standard deviation [SD]) for each of the dependent variables were determined. Wilcoxon matched-pairs signed-ranks test was used comparing results from Test 1 with Test 2. Spearman correlation coefficients were calculated for correlation analysis. For all tests, the level of significance was set at $p \leq 0.05$.

RESULTS

2000 metre rowing ergometer performance time was significantly increased from Test 1 to Test 2 (Table 1). While mean power, mean maximal HR and blood lactate concentration measured five minutes after the test were significantly lower in Test 2 compared to Test 1. $\dot{V}O_{2max}$ values remained unchanged between the tests. Morning HR and body mass values were not significantly changed after the training period (Table 2). The subjective ratings of fatigue and muscle soreness increased significantly from Test 1 to Test 2 (Table 2).

Table 1. 2000 metre rowing ergometer performance before (Test 1) and after (Test 2) the training period (Mean±SD).

	Test 1	**Test 2**
Time (s)	395.9±10.8	404.2±11.9*
Power (W)	361.9±28.5	349.0±32.8*
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)	4.85±0.70	4.83±0.61
$\dot{V}O_{2max/kg}$ ($ml \cdot min.^{-1} kg^{-1}$)	60.4±6.1	60.3±5.0
La 5' recovery ($mmol \cdot l^{-1}$)	19.2±2.9	16.2±2.3*
Mean HR ($beats \cdot min^{-1}$)	184.6±7.5	179.2±7.4*

$\dot{V}O_{2max}$, maximal oxygen consumption; La, blood lactate concentration; HR, heart rate

* Significantly different from Test 1; $p<0.05$.

Table 2. Morning heart rate, body mass and subjective ratings of quality of sleep, fatigue, stress, and muscle soreness before (Test 1) and after (Test 2) the training period (Mean±SD).

	Test 1	Test 2
HR (beats·min^{-1})	56.8±9.9	57.6±10.4
Body mass (kg)	81.6±9.6	81.5±9.6
Sleep	3.3±1.4	3.4±1.6
Fatigue	3.1±1.2	3.9±1.3*
Stress	3.1±1.7	3.3±1.7
Muscle soreness	3.1±1.5	3.8±1.4*

HR, heart rate
* Significantly different from Test 1; $p<0.05$.

Training volume (19.2±3.9 h) of the six-day training period was significantly related to the following parameters measured in Test 2: T_{2000} (r=0.63), P_{2000} (r=–0.62), $\dot{V}O_{2max}$ (r=–0.65), body mass (r=–0.70), and subjective ratings of fatigue (r=0.52) and muscle soreness (r=0.53). In addition, the change in the mean HR was significantly related to the changes in the subjective ratings of fatigue (r=–0.57) and muscle soreness (r=–0.49).

DISCUSSION

The main diagnostic criterion of overtraining has been reported to be a significant decrease in performance capacity, without a return to baseline after a sufficient period of rest [6,13]. The decrease in rowing performance as illustrated by significant increases in T_{2000} and decreases in P_{2000}, mean HR and blood lactate values (see Table 1) was thought to reflect a state of fatigue or maybe overreaching in our subjects. However, it has to be considered that success in rowing is characterised by the amount of time spent on water as low-intensity endurance training [8].

The results of our study indicate that self-reported mood state indices have important implications in the diagnosis and monitoring of short-term overreaching in competitive rowers. However, only few investigations have focused on the self-assessment by athletes for monitoring overreaching and overtraining [1,7,12]. In addition, different questionnaires have also been used to assess training stress in athletes [1,10]. However, questionnaires cannot be used on a daily basis to monitor the effects and following recovery of high volume training loads. This study focused to find out which specific self-ratings of well-being items could be used on daily basis to monitor training stress during the training period of dramatically increased training volume in competitive rowers. The self-rated items of fatigue and muscle soreness demonstrated a close association with the increased training time ($r>0.52$; $p<0.05$). However, it must be considered that the use of such measures to identify athletes showing a tendency toward overtraining syndrome is very much dependent on the interpretation by the reviewer (e.g. coach) [6]. Although the reliability of the self-assessment scores may be questioned, it appears that conscientious recording of how the rower feels may provide useful information for the coach when completed on a daily basis.

Similarly to the results of our study, body mass has usually been reported to remain unchanged in cases of presumed overreaching in the endurance range [2,12]. An increase in the morning resting HR is also not obligatory [12] or only slight [2] during overreaching in endurance athletes. Morning resting HR values in our group of rowers were also not affected by a short-term overreaching training period (see Table 2). Loss of body mass and increase in morning resting HR have been reported to be symptoms of overreaching mainly in speed and power athletes [7].

Reduced blood lactate formation after maximal exercise has previously been reported and explained as a result of depleted glycogen stores in overtrained athletes [7]. This was also the case in our study (see Table 1). Maximal blood lactate values have been suggested to use as single markers to make a distinction between overtraining and overreaching in long duration endurance events [1]. In contrast, it has been reported that factors unrelated to overtraining state may influence maximal blood lactate levels (e.g. diet) and inconsistent changes have been found in overtrained athletes [6]. In this study, an increased training volume was not related to the measured maximal blood lactate level after maximal 2000 metre rowing ergometer test in Test 2. Further studies using a sufficient periods of rest after overreaching training period are needed to find out the suitability to use maximal blood lactate value as a marker of overreaching in rowers.

In summary, the reduced maximal performance in rowers was interpreted to reflect a state of fatigue or maybe overreaching. According to the results of present study, the most appropriate and simple tool for monitoring a short-term overreaching training period is a self-analysis using daily training logs. Comprehensive physiological testing is less sensitive to characterize dramatic increase in training volume of rowers. At present, it appears that conscientious self-analysis by the athlete who trains with high training loads are the most efficient method of monitoring possible short-term overreaching. Long term daily records of self-analysis can be kept with relative ease and compared with the more sophisticated physiological methods when necessary.

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INFLUENCE OF ANTHROPOMETRICAL PARAMETERS TO THE BODY RESISTANCE IN PREPUBERTAL CHILDREN WITH DIFFERENT BODY MASS INDEX

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ABSTRACT

The purpose of this study was to investigate the possible relationships between skinfold thickness, girth, length and breadth/length parameters and body resistance in 9–11 year old children with different body mass index (BMI). The subjects were 104 boys and 105 girls. Body stature and body mass were measured and BMI calculated. Boys and girls were divided into six BMI categories — under 15, 15–16, 16–17, 17–18, 18–19 and over 19. Nine skinfolds, 13 girths, eight lengths and eight breadths/lengths were measured. Body resistance was measured with a multiple-frequency impedance device (MULTISCAN 5000, UK) at 50 kHz. Stepwise multiple regression analysis indicated that skinfold thickness values influenced body resistance by 4.8% and 9.2% ($R^2 \times 100$) in the whole groups of boys and girls, respectively. The influence of skinfolds thicknesses was very different in the homogeneous subgroups selected by BMI (from 30.0% to 70.2% in boys and from 7.8% to 40.8% in girls). Girth parameters characterized 51.2% in girls and 31.1% in boys of the total variance in the whole groups of studied children. The influence of girth parameters to the body resistance was higher in both extreme groups (BMI <15 and BMI>19) than in whole groups of boys and girls. The importance of length parameters in the whole groups of boys (12.5%) and girls (5.1%) was relatively low. The breadth/length parameters influenced body resistance by 28.1% and 15.8% in the whole groups of boys and girls, respectively. The influence of breadth/length values was lower in the used subgroups than in the whole groups, except in boys and girls of the thinnest group (BMI<15). In conclusion, the traditional use of body stature as a single anthropometric measure used in the presentation of prediction equations for body composition measurement is not acceptable. It is important to add girth and/or breadth/length parameters to stature in the prediction of body composition in prepubertal children with different body constitution.

Key words: anthropometry, body resistance, BMI, children

INTRODUCTION

The theoretical basis for the bioelectrical impedance analysis (BIA) was proposed in the 1970's [8,10]. The BIA method is based on the Ohm´s Law which relates the impedance of a cylindrical conductor to its volume, and length to the power of two. In prediction equations for BIA, the length of the biological conductor is taken to be the body stature [8,10]. An electrical signal of known frequency is transmitted across a tissue bed and the impedance to this transmission is related to the conduction properties of the tissue. Electrolyte-containing fluids have a relatively low impedance while tissues devoid of fluids such as bone have a high impedance [11]. Total body impedance, measured at the constant frequency of 50 kHz (800μA), primarily reflects the volumes of water and muscle compartments comprising the fat-free mass (FFM) and the extracellular water volume [11].

Different segments of the body contribute to the resistance of the whole body to an extent that is out of proportion to their contribution to body mass [3,5]. For example, the arm contributes only about 4% of body mass but as much as 45% to the resistance of the whole body in adults [5]. The thinner segments of the body provide the greatest resistance, especially when these segments are also long [5]. The influence of different anthropometric variables on the body resistance in children is poorly studied. However, the percentage of body water in boys from birth to 10 years of age has been reported to decrease as does the ratio of extra- and intracellular water [4]. Variation in hydration of FFM is relatively high in children [7].

Body mass has been reported to be a good predictor of FFM in young males from the simple anthropometric parameters. This is not surprising, but the fact that body mass has a stronger predictive value than does stature is important because stature is the most commonly used measurement in classical BIA prediction equations [6]. Houtkooper et al. [9] have also indicated that more information is needed regarding the size and shape of the conductor than provided by body stature in children aged 10–14 years. The purpose of this study was to investigate the possible relationships between skinfold thickness, girth, length and breadth/length parameters and body resistance in 9–11 year-old children with different body mass index (BMI).

MATERIAL AND METHODS

The subjects of this investigation were 104 boys and 105 girls, 9–11 year of age. The children were from several schools in Tartu, Estonia (about 100,000 inhabitants) and all children were of Estonian origin. School physical education consisted of 2–3 physical education lessons per week. All children, parents and teachers were throughly informed about the purposes and contents of the study and written informed consent was obtained from the parent or the adult proband before participation. This study was approved by the Medical Ethics Committee of the University of Tartu (Estonia).

Measurements were performed in the morning at school after emptying the bladder. All children had a light traditional breakfast. The children did not exercise before the testing. All children were classified prepubertal Tanner stage 1 as pubic hair and genitalia (boys), and breast (girls) ratings were both scored as stage [14].

Stature was measured using a Martin metal anthropometer in cm (±0.1 cm) and body mass with medical scale in kg (±0.05 kg) and BMI (kg/m^2) was calculated. Boys and girls were divided into six BMI categories (underweight to slightly obese)-under 15, 15–16, 16–17, 17–18, 18–19 and over 19, respectively.

Nine skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf, mid-axilla), 13 girths (head, neck, arm relaxed, arm flexed and tensed, forearm, wrist, chest, waist, gluteal, thigh, thigh mid trochanter-tibiale laterale, calf, ankle), eight lengths (acromiale-radiale, radiale-stylion, midstylion-dactylion, iliospinale-box height, trochanterion-box height, trochanterion-tibiale laterale, tibiale laterale to floor, tibiale mediale-sphyrion tibiale) and eight breadths/lengths (biacromial, biiliocristal, foot length, sitting height, transverse chest, A-P chest depth, humerus, femur) were measured. Three series of anthropometric measurements were taken by a trained anthropometrist who had previously shown test-retest reliability of r>0.90. Skinfold thicknesses were measured using Holtain (Crymmych, UK) skinfold calipers. Other anthropometrical parameters were measured using the Centurion Kit instrumentation (Rosscraft, Surrey, BC, Canada). Calibration of all equipment was conducted prior to and at regular intervals during the data collection period. All anthropometric parameters were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry [13].

Body resistance was measured with a multiple-frequency impedance device (MULTISCAN 5000, Bodystat Ltd, UK). Children were placed in a supine position with limbs slightly abduced. Skin current electrodes were placed at the right dorsal surface on the hand and on foot at the metacarpals and metatarsals, respectively, after the skin was cleaned with 70% alcohol. The distance between the source and receiving electrodes was all times greater than 5 cm [3]. Only the resistance measured at 50 kHz was used. The analyzer was calibrated before each test by using the standard resistor provided by the manufacturer. All measurements of children were performed on the same day and were completed within one hour of the commencement of testing.

Standard statistical methods were used to calculate mean ($\bar{X}$) and standard deviation (±SD). Statistical comparisons between boys and girls were made using independent t-tests. Spearman correlation coefficients were used to determine the relationships between dependent variables. The effect of different anthropometric parameters on the body resistance was analyzed by stepwise multiple regression analysis. Prediction errors for the equations were evaluated using standard error of estimate (SEE). Significance was set at $p<0.05$.

RESULTS

The mean data for anthropometric parameters of boys and girls are presented in Table 1. Boys were older and their body mass and BMI were higher ($p<0.05$). The skinfold thicknesses on the triceps, subscapular, biceps and mid-axilla sites were significantly higher in girls ($p<0.05$). There were no significant differences in the length parameters between boys and girls (except radiale stylion and midstylion-dactylion). Most of the measured breadth/length and girth parameters were higher in boys ($p<0.05$). The mean body resistance at 50 kHz was 578.8±58.3Ω and 626.8±56.6Ω in boys and girls, respectively ($p<0.01$).

Table 1. Mean anthropometric variables in prepubertal children (X±SD)

	Boys (n=104)	Girls (n=105)
Age (yrs)	10.09±0.84	9.79±0.72*
Stature (cm)	143.39±7.27	141.49±7.34
Body mass (kg)	35.27±5.71	33.29±6.43*
BMI ($kg \cdot m^{-2}$)	17.07±1.78	16.50±2.15*
Skinfolds (mm)		
Triceps	9.97±3.01	11.17±3.91*
Subscapular	7.33±3.50	8.42±5.06*
Biceps	6.63±2.53	7.50±3.38*
Iliac crest	8.67±4.82	9.30±5.46
Supraspinale	5.13±2.65	6.20±3.84
Abdominal	8.73±5.07	9.67±6.20
Front thigh	16.46±5.59	18.02±5.85
Medial calf	12.32±4.49	13.32±5.18
Mid axilla	5.40±1.95	6.22±3.65*
Girths (cm)		
Head	53.25±1.43	52.55±1.56*
Neck	28.00±1.87	26.74±1.35*
Arm relaxed	20.08±2.00	19.62±2.32*
Arm flexed and tensed	21.70±2.01	20.98±2.36*
Forearm	19.79±1.39	18.95±1.57*
Wrist	13.58±0.86	12.94±0.81*
Chest	68.44±4.66	65.98±6.04*
Waist	59.96±4.39	56.39±5.08
Gluteal	71.62±5.47	71.57±6.31
Thigh	42.44±4.15	42.40±4.94
Thigh mid troch-tibiale laterale	39.10±3.52	38.99±3.98
Calf	28.44±2.37	28.25±2.48
Ankle	18.66±1.48	18.26±1.41*
Lengths (cm)		
Acromiale radiale	30.34±1.80	30.02±1.91
Radiale-stylion	22.88±1.51	22.41±1.50*
Midstylion-dactylion	16.64±1.07	16.19±1.06*
Iliospinale box height	82.67±5.10	81.30±4.88
Trochanterion box height	76.00±4.61	74.94±5.40
Trochanterion-tibiale laterale	38.94±2.73	38.71±2.85
Tibiale-laterale to floor	37.02±2.54	36.48±2.58
Tibiale mediale-sphyrion tibiale	29.33±2.21	29.05±2.06

Table 1 (continued)

	Boys (n=104)	Girls (n=105)
Breadths/lengths (cm)		
Biacromial	31.76±1.86	30.94±2.03*
Biiliocristal	21.87±1.56	21.88±1.63
Foot length	22.32±1.63	21.91±1.30*
Sitting height	75.67±3.57	74.46±3.83*
Transverse chest	21.90±2.59	20.73±1.35
A-P chest depth	15.07±2.19	14.42±2.59*
Humerus	6.10±0.38	5.82±0.35*
Femur	8.82±0.46	8.36±0.47*

* Significantly different from boys; $p<0.05$

The Spearman correlation analysis indicated that stature significantly influenced body resistance in girls (r=–0.19). For both genders, body mass (boys: r=–0.43 and girls: r=–0.42) and BMI (boys: r=–0.50 and girls: r=–0.45) were most important predictors. All skinfold thicknesses correlated significantly with body resistance in girls (r=0.20–0.35), while only iliac crest (r=0.20), supraspinale (r=0.21) and mid-axilla (r=0.22) sites correlated significantly with body resistance in boys. As a rule, the girth parameters correlated significantly (r=–0.19–0.62) with body resistance in boys and girls. There were only a very few length parameters which influenced significantly body resistance. Most of the measured breadth/length parameters correlated significantly with body resistance at a relatively low level (r=0.20–0.53).

Stepwise multiple regression analysis indicated that skinfold thicknesses influenced the body resistance only by 4.8% and 9.2% ($R^2\times100$) in the whole group of boys and girls, respectively (Tables 2 and 3). However, the influence of skinfold thicknesses was very different (from 30.0% to 70.2% in boys and from 7.8% to 40.8% in girls) in different homogeneous subgroups selected by BMI.

Table 2. The regression summary between body resistance and skinfold thicknesses in boys with different BMI.

BMI	Skinfolds	Intercept	F	R^2×100	p	SEE
<15 (n=12)	 Mid-axilla	514.7 15.4	4.9	33.0	<0.05	42.5
15–16 (n=19)	 Iliac crest Biceps	461.7 17.0 6.3	8.0	50.0	<0.004	33.7
16–17 (n=24)	 Medial calf Triceps	437.3 8.3 7.4	9.0	46.2	<0.001	37.8
17–18 (n=20)	 Triceps Medial calf	492.6 17.9 –7.9	3.6	30.0	<0.05	49.1
18–19 (n=16)	 Triceps Iliac crest Mid axilla	397.9 19.6 6.4 –22.0	9.4	70.2	<0.002	30.9
>19 (n=14)	 Biceps	447.4 8.5	6.2	34.2	<0.03	31.5
Total (n=104)	 Mid-axilla	613.9 –6.5	5.1	4.8	<0.03	57.2

Table 3. The regression summary between body resistance and skinfold thicknesses in girls with different BMI

BMI	Skinfolds	Intercept	F	R^2×100	p	SEE
<15 (n=23)	 Iliac crest Subscapular	605.6 19.3 33.0	6.9	40.8	<0.005	39.2
15–16 (n=21)	 Iliac crest	590.4 7.8	3.0	9.5	<0.05	55.6
16–17 (n=15)	NO					
17–18 (n=17)	 Medial calf Iliac crest	549.2 6.9 –5.0	2.8	28.4	<0.05	33.0
18–19 (n=13)	 Medial calf	259.0 16.9	7.0	7.8	<0.05	26.4
>19 (n=16)	 Biceps Medial calf	489.2 15.5 –4.5	4.3	40.1	<0.05	47.0
Total (n=105)	 Medial calf	670.8 –3.3	10.4	9.2	<0.002	54.2

Wrist, neck, gluteal and relaxed arm girths, and neck, arm flexed and tensed and waist girths characterized by 51.2% and 31.1% of the total variance in the whole groups of boys and girls, respectively (Tables 4 and 5). Surprisingly, the influence of girth parameters to body resistance was higher in boys and in girls on both extreme subgroups (BMI<15 and BMI>19) than total groups (79.1% and 47.0% in BMI<15 and 66.5% and 40.0% in BMI>19).

Table 4. The regression summary between body resistance and girths parameters in boys with different BMI.

BMI	Girths	Intercept	F	$R^2 \times 100$	p	SEE
<15		240.0	17.0	79.1	<0.0009	25.1
(n=12)	Gluteal	17.2				
	Chest	–11.8				
15–16		607.2	3.6	31.3	<0.05	39.6
(n=19)	Neck	–6.9				
	Thigh	4.4				
16–17		549.8	3.7	25.9	<0.04	44.4
(n=24)	Wrist	51.7				
	Waist	12.6				
17–18		1002.0	10.4	45.1	<0.001	39.3
(n=20)	Chest	–23.2				
	Waist	19.2				
18–19		586.2	1.8	24.8	<0.05	35.2
(n=16)	Wrist	–19.0				
	Chest	2.9				
>19		378.9	12.9	66.5	<0.0008	31.5
(n=14)	Calf	–43.0				
	Gluteal	19.3				
Total		1131.7	25.9	51.2	<0.0000	41.6
(n=104)	Wrist	–41.6				
	Neck	–5.9				
	Gluteal	6.7				
	Arm-relaxed	–14.9				

Table 5. The regression summary between body resistance and girths parameters in girls with different BMI.

BMI	Girths	Intercept	F	$R^2 \times 100$	p	SEE
<15		1013.8	8.9	47.0	<0.002	37.1
(n=23)	Wrist	–90.7				
	Ankle	45.0				
15–16		656.1	3.4	19.3	<0.05	53.4
(n=21)	Gluteal	10.4				
	Ankle	–41.3				
16–17 (n=15)	NO					
17–18		546.5	4.0	27.4	<0.01	48.3
(n=17)	Neck	–29.7				
	Head	16.4				
18–19		86.9	3.5	19.9	<0.05	51.1
(n=13)	Arm relaxed	58.2				
	Waist	–13.6				
>19		1560.6	4.3	40.0	<0.04	47.0
(n=16)	Neck	–23.6				
	Calf	–9.1				
Total		1096.0	15.4	31.3	<0.0000	47.6
(n=105)	Neck	–19.9				
	Arm flexed and tensed	–14.9				
	Waist	6.7				

The importance of length parameters in whole groups of boys (12.5%) and girls (5.1%) was relatively low (Tables 6 and 7). The influence of length parameters was extremely high or contrary absent in some subgroups of boys. The influence of length parameters was lower or even absent in some subgroups of girls.

Table 6. The regression summary between body resistance and lengths parameters in boys with different BMI.

BMI	Lengths	Intercept	F	R^2×100	p	SEE
<15		118.0	8.5	45.9	<0.02	38.2
(n=12)	Radiale stylion	33.9				
15–16		165.0	5.4	40.5	<0.02	36.8
(n=19)	Iliospinale	13.4				
	Tibiale-laterale	–18.3				
16–17 (n=24)	NO					
17–18		776.1	9.4	63.9	<0.0008	36.3
(n=20)	Midstylion	–65.3				
	Iliospinale	24.2				
	Tibiale-laterale	–29.8				
18–19		1228.4	13.1	66.8	<0.0008	31.4
(n=16)	Radiale-stylion	–60.1				
	Iliospinale	8.5				
>19 (n=14)	NO					
Total		688.4	7.2	12.5	<0.0012	55.1
(n=104)	Radiale-stylion	–24.4				
	Iliospinale	5.4				

Table 7. The regression summary between body resistance and lengths parameters in girls with different BMI

BMI	Lengths	Intercept	F	R^2x100	p	SEE
<15		905.0	3.6	7.3	<0.05	47.9
(n=23)	Acromiale radiale	–8.2				
15–16		205.3	3.8	21.5	<0.03	52.7
(n=21)	Radiale stylion	41.2				
	Tibiale laterale	–13.1				
16–17 (n=15)	NO					
17–18 (n=17)	NO					
18–19 (n=13)	NO					
>19		1193.2	4.9	25.8	<0.04	50.4
(n=16)	Midstylion	–35.9				
Total		828.5	5.6	5.1	<0.02	55.4
(n=105)	Acromiale-radiale	–6.7				

The breadth/length parameters influenced the resistance on the whole groups of boys by 28.1% and by girls 15.8% (Tables 8 and 9). The influence was lower in used subgroups than in whole group, except in boys and girls on the thinnest group (BMI<15).

Table 8. The regression summary between body resistance and breadths/lengths parameters in boys with different BMI.

BMI	Breadths/lengths	Intercept	F	R^2×100	p	SEE
<15		–122.9	5.3	34.6	<0.05	42.0
(n=12)	Biiliocristal	35.9				
15–16		415.1	3.2	7.3	<0.05	44.6
(n=19)	A-P chest	12.4				
16–17		1055.4	3.3	24.1	<0.05	44.9
(n=24)	Humerus	–131.8				
	Foot length	15.3				
17–18		1238.6	4.4	19.1	<0.05	38.0
(n=20)	Sitting height	–8.9				
18–19		1546.2	3.9	19.8	<0.02	37.2
(n=16)	Humerus	–162.5				
>19		319.0	2.9	14.2	<0.05	36.0
(n=14)	Transverse chest	8.9				
Total		1078.7	39.8	28.1	<0.0000	49.7
(n=104)	Humerus	–81.9				

Table 9. The regression summary between body resistance and breadths/lengths parameters in girls with different BMI.

BMI	Breadths/lengths	Intercept	F	R^2×100	p	SEE
<15		1026.6	6.4	23.4	<0.02	43.5
(n=23)	Biiliocristal	–16.8				
15–16		290.1	5.5	16.0	<0.03	53.6
(n=21)	Biiliocristal	16.4				
16–17	NO					
(n=15)						
17–18		33.0	2.9	3.5	<0.05	34.7
(n=17)	Transverse chest	25.9				
18–19	NO					
(n=13)						
>19		1887.2	2.4	3.3	<0.05	41.5
(n=16)	Biacromiale	–32.7				
	Transverse chest	–10.1				
Total		956.3	9.6	15.8	<0.0002	52.4
(n=105)	Transverse chest	–12.4				
	A-P chest depth	–5.1				

DISCUSSION

Significant associations between body resistance and different anthropometric data can assist the selection of independent variables to be included in predictive equations. Baumgartner et al. [1] showed that 70% of the variance in resistance could be accounted for by a small set of anthropometric variables. The use of shoulder height and arm length rather than stature alone as a measure of the length of the conductor improves the accuracy of prediction marginally in adults [3]. However, there is a lack of similar data in children.

Theoretically, estimates of body composition using the whole-body bioelectrical impedance have been based on the equation $V = p \times S^2/R$, in which conductive volume (V) is assumed to represent total body volume or FFM, p is the specific resistivity of the conductor, stature (S) is taken as an estimate of the length of the conductor and R is a body impedance [2,5,11]. However, probably the stature is not a true conductor length when using the four-electrode wrist-to-ankle method of BIA. The true length of the conductor could be better represented by the acromial height and the arm length [6]. In our study, stature characterized only 1.9% ($p<0.05$) and 3.8% ($p<0.05$) of the total variance in boys and girls, respectively, while body mass characterized 18.4% and 17.4% of the total variance in boys and girls, respectively. The best predictor of body resistance was stature and body mass combined (21.7% and 20.7%, respectively), which was slightly higher than BMI (25.5% and 20.2%, respectively).

Results of the current study indicated that best predictors of body resistance were girth parameters which characterized about 30–50% of the total variance in prepubertal children. Surprisingly, not only small diameter limb girths, but gluteal in boys and waist in girls were added to the prediction model (Tables 4 and 5).

Interestingly, in both extreme subgroups selected by BMI (BMI<15 and BMI>19) the influence of girth parameters to body resistance was higher than in total group (see Tables 4 and 5). Surprisingly, the resistance was dependent on the segments which diameter was highest (gluteal, chest) of the body in very lean boys (BMI<15). Fuller and Elia [5] have indicated that only the thinner segments of the body provide the greatest resistance.

As in adults [2,11], length parameters only slightly influenced body resistance in children (see Tables 6 and 7). This is surprising as the body resistance depends on the conductor length. Potentially, the very small girths of the upper and lower body in children are higher predictors then the length of the limbs. It is very difficult to explane very high variability of the influence of length parameters of different subgroups. Sometimes the influence was very high as in boys with BMIs between 17–18 and 18–19 (Table 6). While the significant influence was absent in some subgroups of girls (Table 7).

The influence of skinfold thicknesses to the body resistance in the whole groups was low characterizing less than 10% of the total variance (Tables 2 and 3). This is due to the fact that body fat is a very bad electric conductor [2,11,12]. The influence of some skinfolds to the body resistance was surprising in different subgroups of boys and is very difficult to explane. The influence of breadth/length parameters to the body resistance was relatively high in the whole groups of boys and girls (Tables 8 and 9). The influence was highest in the thinnest groups of boys and girls by 34.6% and 23.4%, respectively.

In conclusion, traditional use of body stature as a single anthropometric measure used in the presentation of equations for body composition measurement is not acceptable. It is important to add girth and breadth/length parameters to stature in the prediction of body composition in preadolescent children with different body constitution.

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WHAT ARE THE EFFECTS OF CALCIUM INTAKE ON BONE HEALTH IN YOUNG MALES AND FEMALES — ANALYSIS OF DATA FROM THE AMSTERDAM GROWTH AND HEALTH LONGITUDINAL STUDY — (AGAHLS)

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ABSTRACT

The multiple longitudinal study design of the Amsterdam Growth and Health Study (AGAHLS) is presented as well as the data quality control with regard to the measurement of the calcium intake and the relation between calcium intake with lumbar bone mineral density (LMBD). In the AGAHLS, a group of 84 males and 98 females from three different birth cohorts was measured longitudinally from the mean age of 13 years until the mean age of 27 years. Over this period of 15 years, the calcium intake was assessed six times by a cross-check dietary history interview. A control population from identical birth cohorts was also included which was measured only once during the teenage period. Four aspects of data quality control were evaluated, i.e. cohort effects, time of measurements effects, test effects and drop-out effects. The results demonstrated that for calcium intake, no cohort, test or drop-out effects were found in males and females. Only one significant time of measurement effect was demonstrated in females at age 13 years. However this effect was quite small and only found in one age group.

In conclusion, the analysis of the longitudinal development of dietary calcium was not disturbed by cohort, time of measurement, test or drop-out effects. There was no significant relation of LMBD at age 27 years with calcium intake between 13 to 27 years in both males and females.

Key words: longitudinal study design, dietary intake, weight bearing physical activity

INTRODUCTION

There is growing interest in the potential contribution of calcium to bone health in young adults. Although several studies indicated that a high calcium intake is associated with higher bone mass values in (young) adulthood [2], this relationship is still not supported by strong evidence, partly because longitudinal prospective studies are lacking. The Amsterdam Growth and Health Longitudinal Study (AGAHLS), a multidisciplinary longitudinal investigation which measured growth, health and fitness from adolescence into adulthood over a 15-year period [5], created the unique opportunity to investigate the long-term effects of dietary calcium on the bone mineral density in males and females at the mean age of 27 years. Within the framework of this study, two other main points of interest relevant to the calcium-bone relation were examined: (a) the longitudinal development and tracking of calcium intake over time, and (b) the relative validity to recall the calcium intake from the distant past.

This paper describes the design and methods used to elucidate these three research questions within the framework of the AGAHLS. Furthermore, four possible disturbing factors (i.e. cohort effects, time of measurement effects, test or learning effects and drop-out effects) relevant to this longitudinal study were evaluated and discussed. At last the relation between calcium intake (measured on a longterm basis between 13 and 27 years) is studied on the bone mineral density of the lumbar spine, measured at the adult age of 27 years.

DESIGN OF THE AMSTERDAM GROWTH AND HEALTH LONGITUDINAL STUDY

In designing a longitudinal study three time parameters must be considered: (1) age of the subject, (2) birth cohort (group of subjects born in the same year), and (3) time of measurement (time at which the measurement is taken). One of the problems of most designs is that these three time parameters cannot be isolated. Observed differences over time in a longitudinal study may not be due only to ageing (age effect) but also to changes in the circumstances e.g. in the foodmarket (time of measurement effect). This implies that age effects and time of measurement effects are mixed up. Cohort effects play a disturbing role in cross-sectional studies because different groups are measured. To distinguish these disturbing effects, in the AGAHLS a 'multiple longitudinal design' was used, which means that repeated measurements were done in more than one cohort with overlapping ages (Figure 1). In this way the mean age effect can be distinguished from cohort and time of measurement effects [4].

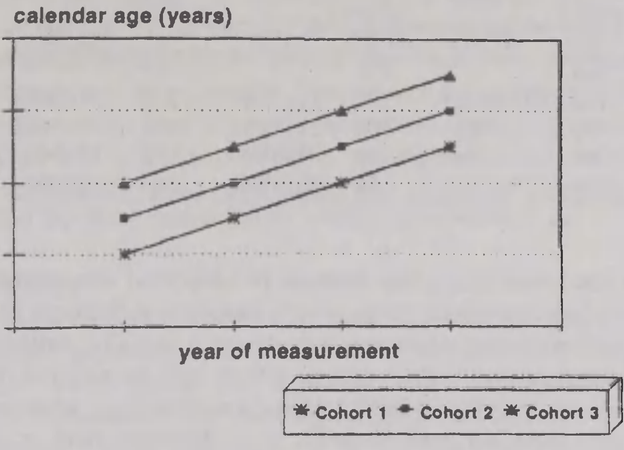

Figure 1. Principle of a multiple longitudinal design with repeated measurements in three different cohorts with overlapping ages.

The AGAHLS was carried out between 1977 and 1993 in a group of males and females from 13 to 29 years of age. The study started in 1977 with subjects from three birth cohorts (1962, 1963, 1964) of an Amsterdam high school. From that year onwards until 1980, these subjects were measured annually during four consecutive years from the mean age of 13 through the mean age of 16. The fifth measurement took place in 1985 at the mean age of 21, followed by a six and seventh assessment in 1991 and 1993 at the mean ages of 27 and 29 respectively.

The total number of participants who were measured longitudinally from age 13 until age 29 is presented in Table 1. Furthermore, the table shows the number of drop-outs over the 15 years of measurement. Over the total period of 15 years, the drop-out rate was 47% in males and 45% in females. If the subjects who drop out score significantly different for certain variables than the longitudinal subjects, this selective drop-out might diminish the generalizability of the results. Therefore, a drop-out effect can also play a disturbing role in longitudinal studies.

Table 1. Number of longitudinal subjects and drop-outs over the years of measurement.

	Males		Females		Total	
	Longi-tudinal	Drop-out	Longi-tudinal	Drop-out	Longi-tudinal	Drop-out
	n	n (%)	n	n(%)	n	n (%)
1977	148		159		307	
1980	102	46 (31%)	131	28 (18%)	233	74 (24%)
1985	93	9 (9%)	107	24 (18%)	200	33 (14%)
1991	84	9 (10%)	98	9 (8%)	182	18 (9%)
1993	78	6 (7%)	88	10 (10%)	166	16 (9%)

Another disturbing factor that emerges in a repeated measurement design is a test or learning effect. These effects introduce differences between repeated measurements, which are only due to a changing attitude towards the measurement itself. Such testing effects may be positive (e.g. when habituation or learning is important) or negative (e.g. when motivation decreases). Repeated measurements may therefore have a disturbing influence on the variable measured and diminish the external validity of the results. To analyse possible testing or learning effects the design of the AGAHLS included a control group with subjects from identical cohorts. The total control population consisted of 133 males and 159 females and was only measured during the first four years of the study. From this control group each year another quarter of the subjects was measured, which implies that independent samples were taken at each year of measurement instead of repeated measurements [4].

DATA COLLECTION

Kemper [5] gives an overview of all the methods used in the AGAHLS. In this paper only the measurement methods relevant to answer the three research questions will be described, i.e. measurements of dietary intake and bone mineral density as well as measurements of physical activity and body weight. These last two measurements are considered to be important confounding factors in the relation between calcium intake and bone mineral density in the lumbar spine.

Although the main goal of a longitudinal study is to take all measurements at all stages, this was not always possible. New methods were introduced and some other methods were deleted because they were not applicable, useful or feasible. The measurement of the bone mineral mass was included in 1991 when the subjects were 27 years old. The main reason for this was that new technology (dual X-ray absorptiometry) enabled us to perform this measurement on the population that was not available at the start of the study. The measurement of the dietary intake by a cross-check dietary history method was deleted in 1993 because no large dietary change was expected since the last measurement in 1991. At the same time a new food consumption method was introduced in 1993. This method was a quantitative dairy questionnaire and developed to estimate the calcium intake only from dairy products. The reasons why we included this dairy questionnaire will be described later on.

Anthropometry

Anthropometric measurements, carried out in each measurement period, were executed according to the guidelines of the International Biological Programme. Body weight was measured with a spring balance (van Vucht, the Netherlands) and standing height was measured with a Harpenden digital readout, wall-mounted or portable stadiometer (Holtain, UK; van Rietschoten & Houwens, the Netherlands). The body mass index was calculated as the weight divided by standing height squared.

Bone mineral mass

At the age of 27 years in all subjects, the bone mineral content (BMC) and area bone mineral density (BMD) of the lumbar region (L2-L4) of the spine were measured by dual X-ray absorptiometry (DXA) using the Norland XR-26. The scanning was performed in the Department of Nuclear Medicine, Academic Hospital of Vrije Universiteit, Amsterdam, while the subject was recumbent. A photomultiplier tube recorded transmission from a narrowly collimated X-ray source located under the scanning table. The whole procedure was finished within 10 to 15 minutes. The coefficient of variation of DXA for repeated measurements of the lumbar bone mineral density in human subjects at the department is 1.3% for short-term reproducibility (24 h) and 2.3% for long-term reproducibility (2–6 months).

Dietary intake

In adolescents and young adults it is very difficult to collect data about individual food habits because they are not always aware of their daily food and drink consumption. Therefore, a suitable method has to be chosen for collecting longitudinal data about the normal daily diet of these subjects. The most important requirements in choosing such a method were that (1) the technique should not interfere with the subject's dietary habits, (2) the data collected should be representative of the true intake, and (3) it should be applicable in field investigations with large groups of normal teenagers.

On the basis of a pilot study, it was decided to choose the cross-check dietary history interview for the determination of dietary habits [10]. A modification of the cross-check dietary history interview was used to ascertain the individual food intake of the subjects, with a reference period of one month [9]. The cross-check dietary history interview consisted of two parts. First, the subject was instructed to indicate mealtimes and type of meals on an average schoolday and weekendday. This information gives the interviewer an idea of the subject's pattern of eating, which would facilitate the subsequent part of the interview. The second part of the interview consisted of a structured check-list of series of food items covering the entire range of food and drinks, making allowances for teenagers. Subjects were questioned about foods eaten during regular meals as well as between meals. These data were collected separately for normal school days and for weekend days. The amounts were reported in household measures. Models were used to illustrate common portion sizes (glasses, bowls, spoons, etc.) and also imitations of such foods as potatoes, apples and other fruits were used. To estimate the amount of sugar in tea and coffee and the amount of butter on bread, small scales were used to weigh the amounts.

Since it was assumed that adolescents do not know everything about their food consumption and the preparation of food, during the first four measurements, a questionnaire was sent to their parents concerning details of several food items consumed by their children, e.g. skimmed or whole milk, kind and quantity of meat, and addition of butter or sauce to vegetables and potatoes.

For each individual, all amounts were converted into grams for the 5 weekdays and the 2 weekend days. The coding and calculation of the energy and nutrient intakes was based on the computerized Dutch food composition table [12]. The total interview took 60 to 90 minutes and was carried out during all measurement years, except the last measurement year in 1993.

Because of the growing interest in the potential role of calcium in the prevention of osteoporosis and because of the major importance in studies of osteoporosis to assess not only the current calcium intake but also the calcium intake in the past [3,11], the need was highlighted for a method of estimating dietary calcium intake that (a) is practical and efficient for epidemiological studies, and (b) accurately recalls the calcium intake in the distant past. Therefore we have developed a quantitative food frequency questionnaire to assess the calcium intake only from dairy products. This food frequency questionnaire is called a dairy questionnaire (DQ). It is a structured quantitative questionnaire with questions about the consumption of dairy products and mixed dishes based on dairy products, such as pancakes. In an interview, the respondent indicates the average size of servings and the frequency of intake of each food item, including working days and weekend days, with the reference time of one month. Amounts are listed in household measures and common portion sizes. To calculate the calcium intake, data are analyzed by the 1989/90 release of the Dutch Nutrient Database [12]. The validity and reproducibility of the DQ was determined and it was demonstrated that this questionnaire is reasonably accurate to assess the current calcium intake from dairy products [15].

In 1993 the dairy questionnaire was used to examine whether it was a valid instrument to recall the 1977 and 1985 calcium intake values. This implies that 29-year old subjects were asked to recall their calcium intake from 16 and 8 years ago, when they were 13 and 21 years old. Using data from the Amsterdam Growth and Health Study, it was possible to compare the retrospectively reported calcium intake with actual data collected at the ages of 13 and 21 years. In addition, in 1993 the DQ was used to measure the current calcium intake in order to examine whether the current calcium intake influenced the reporting of past calcium intake.

To assess the retrospectively reported calcium intake as well as the current calcium intake, the DQ was administered three times in succession in a prescribed order. In the first administration, participants reported their retrospective dairy consumption of a period of 16 years previously. The second administration referred to 8 years ago. These two administrations of the DQ began by placing the subject in the time period for which the diet was recalled. Therefore they were asked general questions about their places of living, family size, school or university or occupation, and leisure time activities. In the third administration, participants reported the current dairy intake, covering the preceding month. In all three administrations of the DQ the same list of food items were used. The total interview, including all 3 administrations, took about 60 minutes.

Physical activity

At each year of measurement, the habitual physical activity of all subjects was registered by an activity interview [13]. This standardized activity interview was based on a questionnaire developed for this study and covered the 3 months prior to the interview. To classify activities according to their energy expenditure independent of body size (i.e. body weight), the ratio of work metabolic rate to basal metabolic rate was used [7]. The interview was limited to activities with a minimal intensity level of approximately 4 times the basal metabolic rate (4 MET's), which is equivalent to walking at a speed of approximately 5 km/h. Below this level of intensity, physical activities will hardly contribute to a "reasonable" level of physical fitness [1]. The physical activity interview covered the following areas of habitual physical activity: (1) organized sports activities; (2) nonorganized sports and other leisure-time activities; (3) transportation to and from school, work, etc.; and (4) work-related activities. From the interview the average total weekly time in minutes was calculated. The scored activities were subsequently subdivided into three levels of intensity according to relative energy expenditure: (1) light (4-7 MET's), (2) medium-heavy (7–10 MET's), and (3) heavy (>10 MET's). For each of the three levels the average weekly time was calculated. In order to obtain an overall measure of the amount of physical activity, containing both time and intensity, for each individual, the total amount of weekly energy expenditure above the level of 4 MET's was calculated by multiplying the average weekly time (in minutes) spent per level of intensity of habitual physical activity by a fixed value for the relative expenditure at that level (5.5 MET's for the light activities, 8.5 MET's for the medium-heavy activities, and 11.5 MET's for the heavy activities). The scores of the three levels were added to obtain a total MET score. This score is called the weighted activity score [8]. In examining the effect of calcium intake on bone mass when the influence of physical activity was accounted for, only activities with a weight-bearing component were included. Weight-bearing activities (WBA) are thought to be important to the activity of the skeletal system. All activities as walking, running and stair-climbing were considered weight-bearing activities, while cycling, swimming, rowing, diving and canoeing were considered non-weight-bearing activities [15].

DATA QUALITY

The purpose of longitudinal studies is to investigate individual changes over time. This is only possible if the influence of disturbing factors is negligible. Four disturbing factors are important in longitudinal studies: cohort effects, time of measurement effects, test or learning effects and drop-out effects. In the AGAHLS, the multiple longitudinal design, together with the inclusion of a control group, makes it possible to examine these disturbing factors [4]. This was tested for the calcium intake data. Because of the design, time of measurement effects and test effects of calcium intake could be measured only during the first 4 years of measurement. The other two disturbing factors (cohort effects and drop-out effects) were based on the results of all calcium intake measurements, except the last one. The last measurement of the calcium intake in 1993 was not taken into account because this measurement was carried out with a different food consumption method compared to the earlier measurements.

Cohort effects

Possible cohort effects could be investigated by comparison of the longitudinal development of calcium intake between the three different cohorts. This was tested with MANOVA for repeated measurements. The MANOVA tested not only cohort effects but also the cohort*time interaction effects. No differences in the calcium intake between the three different cohorts (p=0.74 in males and p=0.46 in females) were revealed nor in the longitudinal development of the calcium intake between the different cohorts (p=0.14 and p=0.86 in males and females respectively) (Figures 2a and 2b).

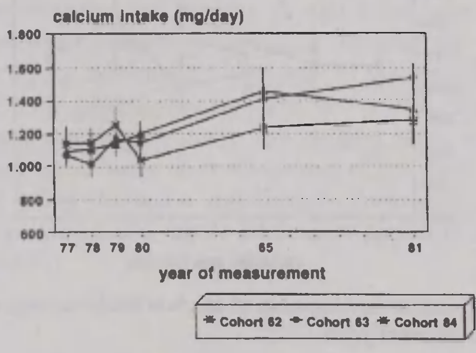

Figure 2a. Longitudinal development of calcium intake for three different cohorts in males.

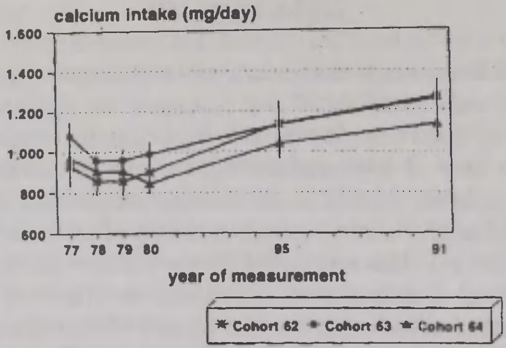

Figure 2b: Longitudinal development of calcium intake for three different cohorts in females.

Time of measurement effects

Comparison of calcium intake values among subjects of the same age, measured in different years, can show possible time of measurement effects. At age 13 and 16, we were able to compare two measurement years and at the ages 14 and 15 three measurement years. Differences were tested with ANOVA. The Figures 3a and 3b show the calcium intake of males and females of the same age measured at different years. In males no time of measurement effect was found, while in females a significant time of measurement effect (p=0.01) was demonstrated at the age of 13.

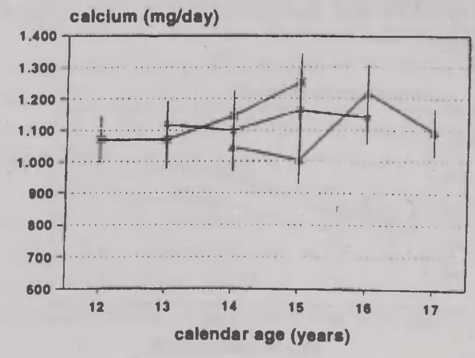

Figure 3a. Longitudinal development of calcium intake among males of the same age, measured in different years.

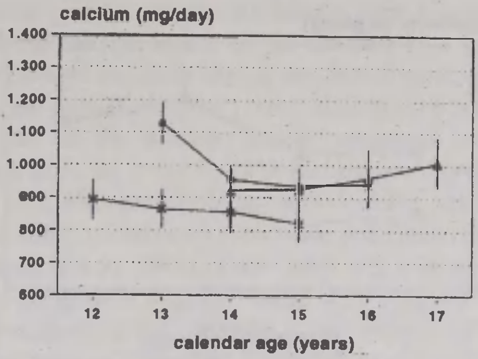

Figure 3b. Longitudinal development of calcium intake among females of the same age, measured in different years.

Test or learning effects

As mentioned before, in the first 4 years of measurement a control population was measured. Comparison of the independent measurements between this population and the repeated measurements of the longitudinal population could detect test or learning effects. Possible systematic divergence of the mean values between the longitudinal group and the control group during the first 4 years of the study was used as an indication for a test or learning effect and was tested with MANOVA for repeated measurements. If a test/learning effect occurs, a significant group*time interaction as well as a systematic divergence of the mean calcium intake values for both groups has to be observed. The Figures 4a and 4b show the calcium intake of the longitudinal group compared with the control group in males and females. A significant interaction between group and time was detected ($p=0.02$) in females but not in males ($p=0.20$). However no systematic divergence of the mean calcium intake values between both groups was revealed in females (Figure 4b). This suggests that there was no systematic test/learning effect in males neither females. Although there were no test/learning effects for calcium intake, the longitudinal group showed a significantly lower calcium intake than the control group through the whole adolescent period in males ($p=0.00$) and females ($p=0.01$).

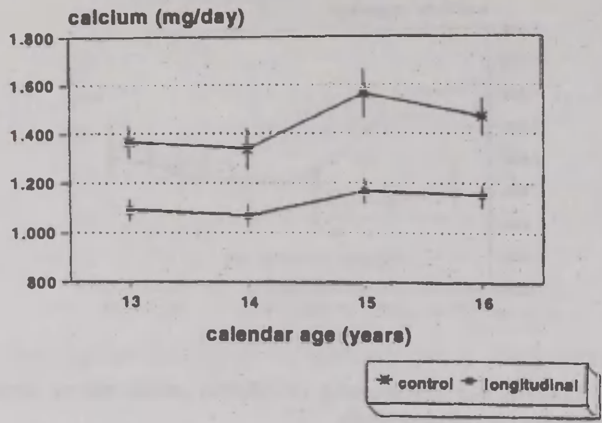

Figure 4a. Calcium intake of the longitudinal group compared with the control group in males.

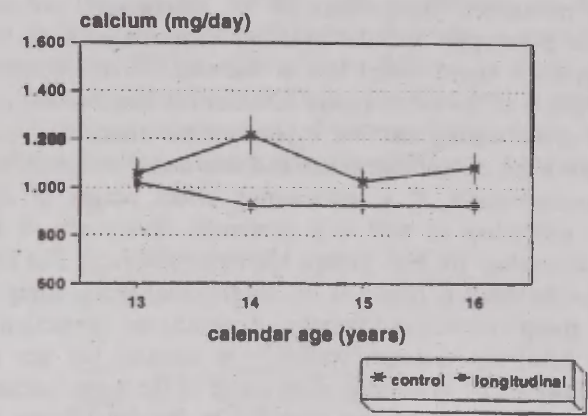

Figure 4b. Calcium intake of the longitudinal group compared with the control group in females.

Drop-out effects

Drop-out effects can influence longitudinal group results. In the case of selective drop-out, it is possible that subjects who dropped out during follow-up scored at an earlier measurement significantly different than the subjects who stayed in the study. Possible drop-out effects were tested in three measurement periods: (1) the adolescent period from 1977 to 1980 (comparison of the calcium intake of the measurement in 1977 between subjects who continued the study during the first 4 years and subjects who dropped out in that period), (2) the young adult period between 1980 and 1985 (comparison of the calcium intake measured in 1980 between subjects who stayed in the study in 1985 and subjects who dropped out in 1985), and (3) the adult period from 1985 to 1991 (comparison of the measurement of 1985 of subjects who were measured in 1991 and subjects who dropped out in 1991). These drop-out effects could be easily investigated using Student's t-test. Table 2 shows the calcium intake values of the longitudinal and dropout group during the three measurement periods in males and females. Furthermore, the p-values belonging to the estimated drop-out effects were demonstrated. No significant drop-out effects were found for calcium intake.

Table 2. Mean values and standard deviation (within parentheses) of the calcium intake of the longitudinal group and the drop-out group in males and females during three measurement periods and P values belonging to estimated drop-out effects.

Measurement period	Longitudinal group	Drop-out group	p
1977–1980			
Males	1074 (369)	1126 (510)	0.52
Females	1000 (412)	922 (443)	0.44
1980–1985			
Males	1153 (449)	1027 (523)	0.34
Females	910 (364)	891 (476)	0.82
1985–1991			
Males	1411 (595)	1361 (637)	0.77

Relation between longterm calcium intake and adult lumbar bone mass

In Figure 5a (males) and 5b (females) the lumbar BMD at age 27 is compared to the calcium intake during adolescence period (13–17 years), between 13 and 21 years of age, and over the total period of 15 years (13-27 years). In females with the relatively highest calcium intake (p>75) no significant higher lumbar BMD was found compared with the relatively lowest calcium intake (p<25). In the males this was only significant ($p<0.05$) during the adolescent period.

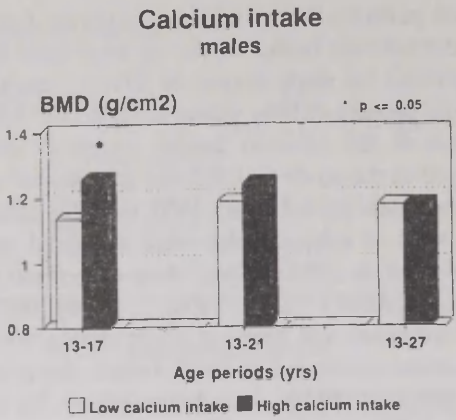

Figure 5a. The mean bone mineral density at the lumbar spine at age 27 in males with the relatively low (p<25) and high (>p75) calcium intake for the age periods 13–17, 13–21 and 13–27 years.

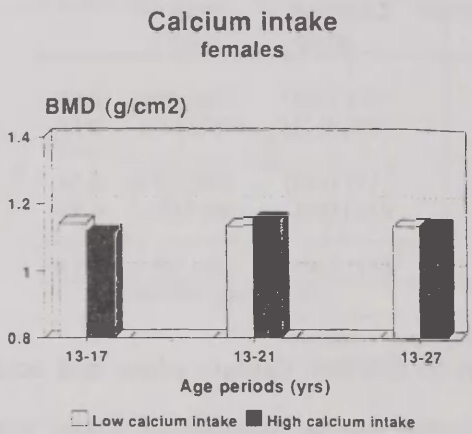

Figure 5b. The mean bone mineral density at the lumbar spine at age 27 in females with the relatively low (p<25) and high (>p75) calcium intake for the age periods 13–17, 13–21 and 13–27 years.

In a multiple regression analysis we used BMC at age 27 years as outcome variable and incorporated body height (HT), body weight (WT), calcium intake (CAI) and weight bearing activities (WBA) as predictor variables.

In Table 3a (males) and Table 3b (females) the results are summarized: In both sexes HT, WT and in males also WBA are important predictors for lumbar BMC, but not for CAI.

Table 3a. Final models for predictions of BMC in males at age 27 years by CAI, WBA, WT and HT for three different age periods.

Age period (year)	Variables	Regression coefficient ß	Explained variance R2
13–17	WBA	1.16[b]	
	HT	3.84[c]	0.22
13–21	WBA	1.10[b]	
	WT	5.80[b]	0.29
13–27	WBA	1.07[c]	
	WT	5.96[b]	0.27

[b] $p < 0.001$
[c] $p < 0.01$

Table 3b. Final models for predictions of BMC in males at age 27 years by CAI, WBA, WT and HT for three different age periods.

Age period (year)	Variables	Regression coefficient ß	Explained variance R2
13-17	HT	6.38[b]	0.23
13-21	WT	2.89[d]	
	HT	5.35[b]	0.32
13-27	WT	3.32[c]	
	HT	5.04[b]	0.33

[b] $p < 0.001$
[c] $p < 0.01$
[d] $p < 0.05$

DISCUSSION

For calcium intake, no cohort, test/learning and drop-out effects were found in males and females. However, one significant time of measurement effect was demonstrated in females at the age of 13. Because this effect was quite small and only found in one age group, the conclusion is drawn that the analysis of the longitudinal development of calcium intake, was not disturbed by cohort, test/learning, drop-out or time of measurement effects in males and females.

Although no test/learning effect was observed for calcium intake, the longitudinal group had a lower calcium intake during the whole adolescent period than the control group, particularly in males but also in females. This is probably because the longitudinal group was selected from an urban area (Amsterdam), while the control group came from a rural area. Another possible explanation is that the level of occupation, education and income is higher in the control group than in the longitudinal group [6]. This means that extrapolation of the results to all segments of the population is not possible.

The relation between calcium intake during the 15 year follow-up with bone mineral mass in the lumbar spine at age 27 year revealed no significant effects. Only in the males the calcium intake during the adolescent period the boys with a relatively high calcium intake had significantly ($p<0.05$) higher lumbar BMD (see Figure 5a).

But also this effect was not anymore significant when the calcium intake was taken over the total period of 15 years as predictor variable. The best predictors for lumbar BMC appeared to be height, weight and WBA, but not CAI. The absence of an effect of calcium can be explained by the relatively high CAI in both males and females in the Netherlands [17] from milk and cheese.

ACKNOWLEDGEMENTS

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BLOOD AND MUSCLE LACTATE CONCENTRATIONS AND ANAEROBIC ENERGY RELEASE DURING INTENSE BICYCLING

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ABSTRACT

It is not known to what extent the blood lactate concentration reflects the anaerobic energy release and lactate production in muscle during intense exercise. Therefore the blood lactate concentration and the anaerobic energy release, taken as the accumulated O_2 deficit, were determined during intense bicycling to exhaustion and for rides stopped before exhaustion. The lactate concentration in the knee extensor muscle was also measured after some rides. For a given anaerobic energy release the blood lactate concentration was higher after exhausting than after non-exhausting bicycling, and the peak value appeared later in the recovery after the exhausting rides. The peak blood lactate concentration differed systematically for a given muscle lactate concentration. In particular, a short, exhausting sprint at very high power led to a higher concentration in blood ($P = 0.01$) but a lower concentration in muscle ($P < 0.05$) compared with the values for 1 min nonexhausting bicycling at a lower power. These data suggest that the blood lactate concentration may not be a good measure of the anaerobic energy release and lactate production in muscle during shortlasting, high-intensity bicycling.

Key words: anaerobic energy release, blood, exercise, lactate, skeletal muscle

INTRODUCTION

High intensity exercise depends on energy not only from aerobic but also from anaerobic processes. The main anaerobic source of energy is breakdown of glycogen to lactate in the working muscles. Part of the lactate produced is released to the blood where it is easy to measure. However, there is incomplete information to what extent the blood lactate concentration reflects the anaerobic energy release and lactate production in muscle. We have for example shown that the relationship between the accumulated O_2 deficit and the peak blood lactate concentration differs between exhausting and nonexhausting treadmill running and between subjects [17]. The relationship between the muscle and blood lactate concentration after different types of bicycling has not been studied in much detail.

At least two preconditions must be fulfilled if the blood lactate concentration shall be a reliable measure of the anaerobic energy release during exercise. A constant and preferentially large fraction of all lactate produced should be released to the blood, and the distribution volume should be constant and thus not vary between experiments and subjects. These preconditions do not seem to be fulfilled since the extracellular distribution volume increases by time [10, 21]. In addition the amount of lactate released from the leg to the blood during bicycling is <10% of all produced [12, 21]. We have recently found that the extracellular distribution volume of lactate released from the working leg may vary considerably and be larger after nonexhausting than after exhausting exercise [21]. These findings suggest that the blood lactate concentration may not reflect the anaerobic energy release accurately, particularly if exhausting and nonexhausting exercises are compared.

To examine the relationship between the anaerobic energy release and the blood lactate concentration further we let subjects bicycle at different powers to exhaustion. Some subjects carried out 2 min bicycling to exhaustion, a condition leading to a maximal anaerobic energy release [18–20, 30]. Since the anaerobic energy release during short sprints of very high intensity is much less [15, 18], we also included short sprints at a very high power. In all experiments the anaerobic energy release, taken as the accumulated O_2 deficit, and the peak blood lactate concentration were established. The muscle lactate concentration was also measured in some experiments. In further studies we let subjects bicycle but stop before exhaustion. We hypothesized that for a given anaerobic energy release or a given muscle lactate concentration the peak blood lactate concentration may differ between exhausting and nonexhausting exercise.

METHODS

Subjects

Altogether 38 healthy and moderately trained men 25 ± 4 yr old (mean ± SD), 1.82 ± 0.07 m tall and with a body mass of 77 ± 8 kg served as subjects in one or more of the experiments described below. Their maximal O_2 uptake was 40 ± 3 μmol s^{-1} kg^{-1} (53 ± 4 ml_{STPD} kg^{-1} min^{-1}), and the fraction of type 1 fibers in their knee extensor muscle was 0.50 ± 0.11 (n = 33). The subjects were thoroughly informed about the purpose of the experiments and its practical details before they gave their written consent to participate. The experiments were approved by the Ethics Committee of the Institute or by the Ethics Committee of Health Region 1 in Norway.

Procedures

All exercise was done on an electrically braked Krogh-type bicycle ergometer [11] at either a pedaling frequency of 1.5 or 2 Hz. The frequency was continuously shown to the subjects on an analog instrument. Thus only negligible deviations between the preset and the actual power was found in all experiments [19, 20]. The ergometer was equipped with a work meter counting the flywheel's revolutions and thus also including the run-off after each exercise. Flat pedals with no straps were used, and thus work was done only during the downward push.

Pretests. During the last weeks before the experiments first the maximal O_2 uptake was established. Most of the experiments described below were exhausting bicycling at constant power lasting either 10–15 s, 30 s, 1 min, or ≈2 min. Therefore the highest power each subject could keep for the duration in question was also established. Third, individual relationships between the power and the O_2 uptake were established for each subject. The O_2 uptake was measured at 8–10 min of exercise at constant power below the maximal O_2 uptake. The anaerobic contribution is negligible during those conditions, and the measured O_2 uptake thus equals the O_2 demand or the ATP turnover rate expressed in O_2 units [18]. This procedure was carried out at least ten times (17 ± 8 times; mean ± SD) for each subject at powers between 30 and 90% of his maximal O_2 uptake, and thus linear relationships between the power and the O_2 demand were obtained for each subject [13, 18, 19]. The regression parameters from the pretests are summarized in Table 1.

Table 1. Summary of the data on the regression parameters established for each subject.

Experimental condition, pedaling rate (Hz)	Y-intercept (μmol kg^{-1}s^{-1})	Slope (μmol J^{-1})	Error of the slope (μmol J^{-1})	Error of regression (μmol kg^{-1} s^{-1})	Correlation coefficient	n
1.5	5.6±0.9	8.3±0.3	0.24±0.09	0.72±0.21	0.994±0.005	31
2.0	12.0±1.7	7.7±0.5	0.23±0.05	0.58±0.16	0.996±0.002	8

The data are mean ± SD. *n* is the number of subjects. Data on the regression parameters for two subjects in the experiments on bicycling at 2.0 Hz were lost because of technical problems with the O_2 analyzer. One subject served in both the experiments at 1.5 and at 2.0 Hz bicycling.

Experiments

On the day of the experiment the subject arrived at the laboratory at least 3 h after the last meal. He warmed up for 10 min at 50% of his maximal O_2 uptake. He thereafter exercised at the preset, constant power to exhaustion or for the preset duration (nonexhausting rides; see further details below). Exhaustion is here defined as inability to keep the preset power despite high motivation and encouragement. In all experiments expired air was collected in Douglas bags continuously throughout the experiment to measure the O_2 uptake. Before the ride and 0, 1, 3, 6, 9, 12, 15, 20, 30, 45, and 60 min after, 25 µl of arterialized capillary blood was sampled from a prewarmed finger and precipitated in 500 µl of 0.4 mol L^{-1} perchloric acid (PCA) for later measurement of the blood lactate concentration [16].

In some experiments we wanted to exhaust the subjects in less than 15 s. Pretests showed that at a pedaling rate of 1.5 Hz some of our subjects could bicycle for 30 s even when using the maximal breaking resistance our bicycle ergometer could deliver. Therefore bicycling at 2 Hz (120 rpm) was used to exhaust the subjects in less than 15 s (n = 8). For a comparison with exercises at 1.5 Hz these eight subjects also carried out an exhausting bout lasting ≈30 s, and these data do not differ from those obtained during 30 s bicycling at 1.5 Hz to exhaustion. Otherwise all experiments were carried out at 1.5 Hz (90 rpm). The 38 subjects did altogether 15 exhausting rides of ≈30 s duration, 12 exhausting rides lasting ≈1 min, and 31 exhausting rides lasting ≈2 min. On separate days 15 of the subjects repeated exercise at an intensity leading to exhaustion in 2 min, but in these additional experiments they stopped after exactly

25, 50, and 75% of the duration of the ≈2 min exhausting ride, that is after ≈30, 60, and 90 s (nonexhausting exercises).

Muscle biopsy experiments. Local anesthesia (10 g L^{-1} Xylocain, Astra, Södertälje, Sweden) was injected subcutaneously and in the muscle fascia before incisions were made in the skin and muscle fascia over the lateral portion of the knee extensor muscle. Two preexercise biopsies were taken after the 10 min warming-up. The bicycling was then carried out as explained above. Two muscle biopsies were taken about 10 and 30 s, respectively, after the bicycling while the subject was still sitting on the bike, and the biopsy was then frozen within 2 s in freon-22 cooled to its freezing point with liquid N_2. Muscle biopsies were taken for 2 min bicycling to exhaustion (n = 8), for the same eight subjects after 1 min nonexhausting bicycling at the same power that exhausted the subjects in 2 min, and for the 10–15 s bicycle sprints at 2 Hz (n = 8 other subjects).

Measurements and analyses

The maximal O_2 uptake was determined by the leveling off criterion [27] using a discontinuous protocol of stepwise increases of the bicycle power, measuring the O_2 uptake during the last 30 s of a 3 min exercise bout at constant power. Fractions of O_2 and CO_2 were measured on a Scholander [26] gas analyzer or on an automatic system (O_2: S3A/I O_2 analyzer, Applied Electrochemistry, Pittsburgh, PA, USA; CO_2 on a CD-3A CO_2-analyzer from Applied Electrochemistry or a CO_2-analyzer from Simrad Optronics, Oslo, Norway). The expired volume was measured in a wet spirometer.

The blood lactate concentration was measured by enzymatic photofluorometry according to Passoneau and Lowry [24] with an analytical error of 0.1–0.3 mmol L^{-1} blood as further described elsewhere [16]. All samples from each subject were measured on the same day, thus minimizing the effect of possible day-to-day variations.

The frozen muscle biopsies were dissected free from visible fat and connective tissue, divided into pieces of less than 10 mg and weighed at –23°C on a Cahn gram electrobalance (Cahn, Instruments, Paramount, CA, USA) to the nearest 0.01 mg. Each muscle piece was thereafter transferred to a tube containing frozen (–70°C) 3 mol L^{-1} perchloric acid (PCA). The tubes were thereafter held at 4°C for 5 min while the PCA melted, penetrated the muscle tissue, and extracted the metabolites. After 5 min centrifugation at 4°C and 20 km s^{-2} (2000 g) the supernatant was transferred to tubes containing frozen (–70°C) 2 mmol L^{-1} $KHCO_3$. The solution was melted and mixed at 0°C, and the neutralized extract obtained was kept frozen at –80°C until it was analyzed by enzymatic photofluorometry for lactate and phosphocreatine [24]. The muscle protein concentration was measured as described elsewhere [19].

Calculations and statistics

The O_2 demand was estimated by linear extrapolation of the relationships between the power and the steady state O_2 uptake established individually during the pretests, and the accumulated O_2 demand was taken as the O_2 demand times the exercise duration. The accumulated O_2 uptake is the O_2 uptake integrated over the whole exercise period. The accumulated O_2 deficit was taken as the difference between the accumulated O_2 demand and the accumulated O_2 uptake as explained in more detail elsewhere [18]; the imprecision in the accumulated O_2 deficit is ≈4% [13, 14].

Since muscle during exercise may take up fluid that dilutes the metabolites, the muscle lactate concentration after exercise was corrected for this dilution, assuming that the muscle protein content was constant [20].

Statistics. The data are given as mean ± SEM. Tests of statistical significance were carried out by *t*-tests using Bonferroni-correction for repeated comparisons and by regression analyses [29].

RESULTS

The subjects were able to bicycle at a constant power of 5.2 ± 0.1 W kg^{-1} body mass for 136 ± 6 s to exhaustion. To exhaust the subjects in shorter time the power had to be increased, and bicycling leading to exhaustion in less than 15 s was carried out at 13.0 ± 0.3 W kg^{-1} (Table 2). Fifteen subjects repeated the exercise at 5.4 ± 0.1 W kg^{-1} (the power exhausting these subjects in ≈2 min), but in these experiments they stopped after ≈30, 60, and 90 s (exactly 25, 50, and 75% of the duration leading to exhaustion).

Table 2. Summary of the main data from the exhausting bicycling.

Experiment	Exercise duration (s)	Power (W kg^{-1} body mass)	Accumulated O_2 deficit (mmol kg^{-1} body mass)	Peak cLa_{bl} (mmol L^{-1})	*n*
10–15 s	12.8 ± 1.2	13.0 ± 0.3	1.28 ± 0.17	8.5 ± 0.5	8
30 s (2.0 Hz)	31.6 ± 3.2	9.46 ± 0.33	1.91 ± 0.16	11.7 ± 0.5	8
30 s (1.5 Hz)	34.4 ± 1.5	9.03 ±0.21	1.93 ± 0.07	10.1 ± 0.7	7
1 min	68 ± 3	6.53 ± 0.23	2.16 ± 0.05	12.7 ± 0.6	10
2–3 min	135 ± 7	5.22 ± 0.11	2.37 ± 0.06	13.8 ± 0.5	27

The data are from bicycling at constant power to exhaustion. The 10–15 s bicycling was carried out at 2 Hz, the 30 s bicycling at either 2 or 1.5 Hz (no statistically significant difference in any data), and the 1 min and 2–3 min bicyclings were carried out at 1.5 Hz. The accumulated O_2 deficit is a measure of the total anaerobic energy release during the exhausting ride; peak cLa_{bl} is the peak postexercise blood lactate concentration measured from capillary blood taken from the tip of a prewarmed finger; *n* is the number of subjects in each group. The data are mean ± SEM.

During all exercises the blood lactate concentration rose, and the value continued to rise for some minutes into the recovery period (Figure 1A). After exhausting bicycling the blood lactate concentration rose or remained nearly constant for 3–10 min into the recovery period; for the example in Figure 1A the highest value was seen 6 min after the end of the exercise. When the bicycling was stopped before exhaustion, the peak value was seen earlier in the recovery period. For the example in Figure 1A the highest blood lactate concentration appeared 3 min after the end of the exercise, and 9 min into the recovery the value was 20% less than the peak and less than half of the corresponding value after the 2 min bicycling to exhaustion. Later in the recovery period the value after the nonexhausting bout was 15–35% of the corresponding value after the 2 min exhausting bicycling.

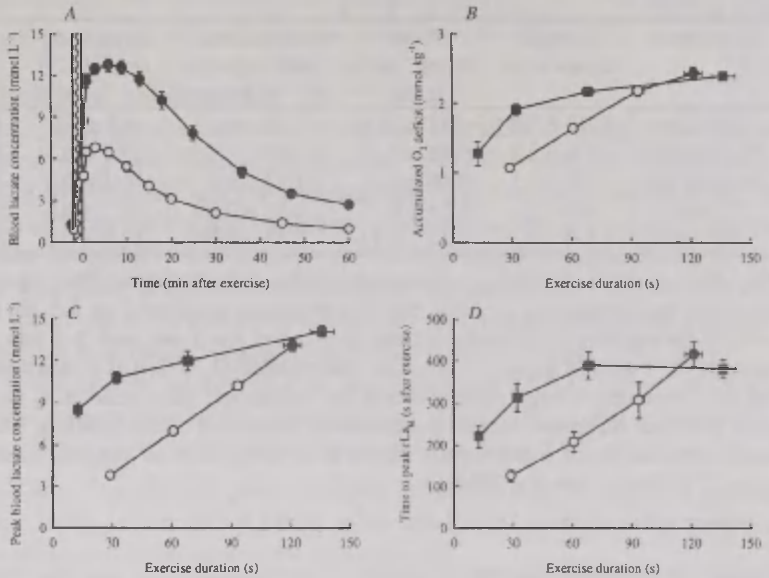

Figure 1. *A*, capillary blood lactate concentration during and after 2 min bicycling to exhaustion (•) and for 1 min bicycling at the same power (nonexhausting, ○) taken from a prewarmed finger. The hatched bar marks the bicycling. The data are mean ± SEM of 15 subjects. *B*, accumulated O_2 deficit versus exercise duration for bicycling at different powers to exhaustion (■) and at a power that exhausted the subjects in ≈2 min (•) but was stopped after ≈30, 60, and 90 s (exactly 25, 50, and 75% of the duration of the ≈2-min ride; ○). The data are mean ± SEM of 8–27 subjects. *C*, peak postexercise blood lactate concentration versus the exercise duration for the same studies as in *B*. *D*, time from the end of the exercise to the peak blood lactate concentration was found versus the exercise duration. The data are from the same studies as in *B* and *C*. Error bars not shown are hidden by the symbols.

For exercise lasting 1 min or less the accumulated O_2-deficit was less after nonexhausting than after the exhausting rides of the same duration ($P < 0.001$; Figure 1B). The peak blood lactate concentration was less after exercise stopped before exhaustion than after exhausting exercise of the same duration ($P < 0.001$; Figure 1C), and that difference was in relative terms larger than the difference for the accumulated O_2 deficits ($P < 0.01$). For example, for the 30 s rides the accumulated O_2 deficit of the nonexhausting rides was 56% of the corresponding value of the exhausting rides, while the blood lactate concentration after the nonexhausting rides rose by only 28% of what it did after the exhausting rides. For the rides at 5.4 W kg^{-1} the peak blood lactate concentration rose linearly by the exercise duration. The peak blood lactate concentration appeared earlier into the recovery period for the two nonexhausting rides lasting 1 min or less ($P < 0.001$; Figure 1D; Table 2).

For a given anaerobic energy release (taken as the accumulated O_2 deficit), the peak postexercise blood lactate concentration was less after the nonexhausting than after the exhausting bouts ($P < 0.01$; Figure 2).

Table 3 Summary of the main data from the nonexhausting bicycling.

Experiment	Exercise duration (s)	Accumulated O_2 deficit (mmol kg^{-1} body mass)	Peak cLa_{bl} (mmol L^{-1})	Time to peak (s after exercise)	*n*
0.5 min	29.0 ± 1.3	1.07 ± 0.05	3.8 ± 0.3	126 ± 14	14
1 min	60.8 ± 2.2	1.63 ± 0.06	7.0 ± 0.3	208 ± 25	15
1.5 min	93.6 ± 2.6	2.17 ± 0.08	10.2 ± 0.3	307 ± 43	10
2 min	121.2 ± 4.4	2.41 ± 0.09	13.1 ± 0.4	416 ± 30	15

The data are from bicycling at a constant power of 5.43 ± 0.10 W kg^{-1} (mean ± SEM) at a pedaling rate of 1.5 Hz that was carried out for ≈2 min to exhaustion or was stopped after ≈0.5, 1, 1.5 min (nonexhausting rides, exactly 25, 50, and 75% of the duration of the 2-min exhausting ride). The accumulated O_2 deficit is a measure of the total anaerobic energy release during the rides. The peak cLa_{bl} is the peak postexercise blood lactate concentration measured from capillary blood taken from the tip of a prewarmed finger. The time to peak is the time from the end of the exercise to the peak blood lactate concentration was seen. *n* is the number of subjects in each group. One subject did not carry out the 30 s ride, and five subjects did not carry out the 90 s ride.

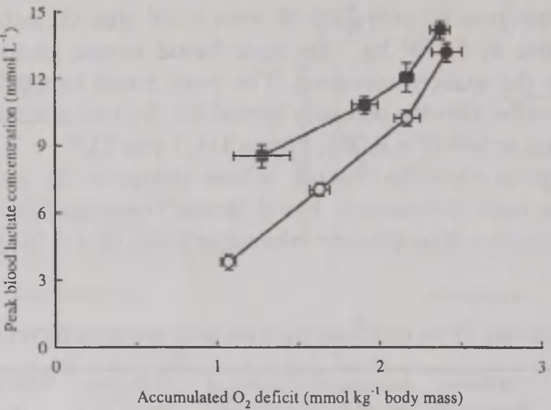

Figure 2. Peak postexercise blood lactate concentration versus the accumulated O_2 deficit. The data are from exhausting bicycling at different powers and durations (■) and at a power that exhausted the subjects in 2 min (●) but was stopped after 30, 60, and 90 s (○). The data are mean ± SEM of 8–27 subjects.

Anaerobic energy release and muscle and blood lactate concentrations

The muscle lactate concentration was measured in biopsies taken after bicycling at 13 W kg^{-1} for 10–15 s to exhaustion, and after bicycling at 5.4 W kg^{-1} body mass for 1 min (nonexhausting) and for 2 min to exhaustion. While 1 min bicycling at 5.4 W kg^{-1} led to a higher muscle lactate concentration than the 10–15 s bicycle sprints did ($P < 0.05$), the peak blood lactate concentration was higher after the sprints than after the 1 min nonexhausting bicycling ($P = 0.01$; Figure 3). After the 10–15 s bicycle sprint the numeric value of the peak blood lactate concentration (in mmol L^{-1} whole blood) was 76% of the numeric value of the muscle lactate concentration (in mmol kg^{-1} wet muscle mass) at exhaustion. For bicycling at 5.4 W kg^{-1} body mass the numeric value of the peak blood lactate concentration was 50% of the numeric value of the muscle lactate concentration both for the 1 min nonexhausting and the 2 min exhausting rides, taken the same way as above. There was on the other hand a much closer match between the muscle lactate concentration and the accumulated O_2 deficit (Figure 3).

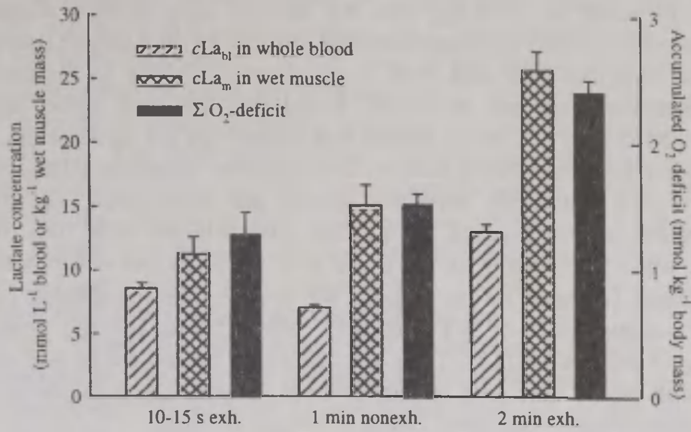

Figure 3. Peak postexercise blood lactate concentration in capillary blood (cLa_{bl}, in mmol L^{-1} whole blood), increase in muscle lactate concentration (cLa_m, in mmol kg^{-1} wet muscle mass), and accumulated O_2 deficit (ΣO_2-deficit, right Y-axis) for bicycling at 13 W kg^{-1} body mass for 10–15 s to exhaustion, and for bicycling at 5.4 W kg^{-1} for 1 min (nonexhausting) and for 2 min to exhaustion. The data are mean ± SEM of 8 subjects.

Since also breakdown of phosphocreatine adds to the anaerobic energy release and thus is part of the accumulated O_2 deficit, the muscle phosphocreatine concentration was also measured. The value fell by 7.1 ± 0.8 (10 s sprints), 9.4 ± 1.0 (1 min nonexhausting rides), and 9.3 ± 0.7 mmol kg^{-1} wet muscle mass (2 min exhausting bicycling). This means that there was no further breakdown of phosphocreatine during the last minute of the 2 min ride.

DISCUSSION

The main results in this study was first that for a given anaerobic energy release the peak blood lactate concentration was higher after an exhausting than after a nonexhausting bout of bicycling. The peak blood lactate concentration appeared later after the exhausting than after the nonexhausting rides. Finally, the lactate concentrations in blood differed systematically between different experimental condition even when the muscle lactate concentrations were similar.

Comparisons with other studies

For the bicycling at 5.4 W kg^{-1} that was stopped after different durations the peak blood lactate concentration rose linearly by the exercise duration, and this is in line with data from a corresponding study by Hermansen [7]. Moreover, Hirvonen et al. [8] found that the peak blood lactate concentration after 40–100 m sprints rose linearly by the distance run. We found quite high peak blood lactate concentrations of around 10 mmol L^{-1} after 10–30 s exhausting bicycling. Osnes and Hermansen [23] found peak values of 16–20 mmol L^{-1} in elite track athletes after 100–200 m sprints, while Hirvonen et al. [8] found peak blood lactate concentrations of ≈8 mmol L^{-1} after 100 m sprints. We have earlier found peak blood lactate concentrations of 9–17 mmol L^{-1} after 15 s to 2–4 min treadmill running to exhaustion [17]. Thus, our measured values are in fair agreement with others data, and others have found even higher blood lactate concentrations after very short bursts of intense exercise.

We have earlier shown that for treadmill running the blood lactate concentration is lower and appears earlier after a nonexhausting than after an exhausting run, even when the anaerobic energy releases are the same. The present study confirms our former findings and shows that conclusions drawn for treadmill running [17] hold for bicycling too.

Blood and muscle lactate concentration and the accumulated O_2 deficit

The blood lactate concentration was in this study not closely related to the concentration in muscle. That finding agrees with former studies [1, 3–6, 8, 9, 20, 22, 25, 28, 30]. Some studies report a ratio of 0.5–0.7 between the numeric value of the peak blood lactate concentration in mmol L^{-1} blood and the numeric value of the muscle lactate concentration in mmol kg^{-1} wet muscle mass [1, 9, 20, 22, 28, 30], while others report a ratio of 1.0–1.4 [6, 8, 22]. Ratios less than 0.5 have also been found [3, 4, 20]. Two reports give a quite wide range of ratios even within the same study, depending on the experimental condition used [6, 22]. Thus, it is well established that the blood lactate concentration is at best only a very rough measure of the concentration in the working muscles. What is new in our study is that the ratio between the concentrations in muscle and blood differed systematically between short bicycle sprints and bicycling at lower power and of longer durations.

There was a quite close relationship between the accumulated O_2 deficit and the muscle lactate concentration, in particular if not only the lactate production but also the phosphocreatine breakdown is taken into consideration. The anaerobic energy ATP-production in the muscle, taken from the measured lactate production and phosphocreatine breakdown, and the accumulated O_2 deficit during the 1 min nonexhausting ride were 67% and 68%, respectively, of the value of the 2 min ride to exhaustion. This relationship between the accumulated O_2 deficit and the anaerobic ATP-production in muscle during bicycling is in line with former studies [15, 20, 30]. The peak blood lactate concentration after the bicyclings differed systematically between experimental conditions with the same accumulated O_2 deficit or muscle lactate concentration. In particular, the blood lactate concentration was higher but the muscle lactate concentration was less after 10–15 s bicycling at 13 W kg^{-1} body mass to exhaustion than after 1 min nonexhausting bicycling at 5.4 W kg^{-1}. In line with this Osnes and Hermansen [23] found very high blood lactate concentrations after 100 and 200 m sprints on track athletes, but they did not measure the concentration in muscle. We show in a parallel paper that the distribution volume of lactate released from the leg may differ between exhausting and nonexhausting exercise [21]. Thus, the high lactate concentration after sprints may suggest that lactate released after exhausting sprints is distributed in a very small extracellular volume.

We measured the muscle lactate concentration from biopsies taken from the knee extensor muscle. That muscle is only one of several important muscles for bicycling, and it could be argued that the lactate concentration in this muscle may not reflect that in other working muscles. However, there was in this study as well as in others [15, 20, 30] a close agreement between the accumulated O_2 deficit and the lactate concentration in the knee extensors after exercise. Thus, it is likely that variations in the lactate concentration in the knee extensors during bicycling reflects that in other working muscles too.

When we have compared the O_2 consumption and the accumulated O_2 deficit to the ATP-production in working muscles, we have taken 1 mol of O_2 used to oxidize glycogen equal to 6.5 mol of ATP produced, a ratio that can be found even in undergraduate textbooks of biochemistry. Our data have nevertheless been heavily criticized [2] since Bangsbo et al. apparently obtained an apparently excellent agreement (only a 0.44% reported mismatch) between the anaerobic ATP-production in the knee extensor and the accumulated O_2 deficit across the working leg. However, while Bangsbo et al. [3] claim to have used an ATP/O_2-ratio of 5.0 (according to the footing of Table 2 of [3]), they actually used a ratio of only 4.61 (calculated from their accumulated O_2 deficit of 460 ml O_2 kg^{-1} muscle = 20.5 mmol O_2 kg^{-1} and the reported ATP-production of 94.7 mmol ATP kg^{-1} muscle given in their Table 2; see also the last paragraph of page 555 in [3]). If an ATP/O_2-ratio of 6.5 is used, a mismatch of more than 40% between the accumulated O_2 deficit and anaerobic ATP-production is seen in their study. Bangsbo [2] has highlighted two outliers in our former study [20] and suggested that the approach we have used is unreliable. Interestingly, the systematic error in the mean values in the study by Bangsbo et al. [3] is as large as the extreme deviations in our former study [20]. Further shortcomings in the knee extensor model used by Bangsbo et al. [3] are discussed elsewhere [13–15]. The poor match referred to above leads us to question whether the knee extensor model can be used for studies on the accumulated O_2 deficit.

Possible explanation for why the blood lactate concentration does not reflect the lactate production accurately

The peak blood lactate concentration was seen earlier after the nonexhausting than after the exhausting rides. One possible interpretation of this is that less lactate was released and for a shorter period of time after the nonexhausting bouts. However, measurements of the leg's release of lactate after exhausting and nonexhausting bicycling have shown that there is a continued release of lactate for ≈20 min after exercise, that is well after the peak value is found [21]. It appears that the blood lactate concentration falls because of an increasing extracellular distribution volume, and lactate appears to be distributed in a larger extracellular volume after nonexhausting than after exhausting exercise. It is well known that blood is redistributed to the exercising muscles during exercise. It may be that this situation persists also in the recovery after exercise, and perhaps so to a larger extent after exhausting exercise than after exercise stopped before exhaustion.

CONCLUSIONS

The peak postexercise blood lactate concentration differed systematically between exhausting and nonexhausting exercises even when the muscle lactate concentration or the anaerobic energy release were the same. There was on the other hand a close agreement with the anaerobic energy release in the knee extensor muscle and the accumulated O_2 deficit.

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TRACKING OF MOTOR ABILITIES, PHYSICAL ACTIVITY, AND ELEMENTARY MOTOR SKILLS DURING TRANSITION FROM PRESCHOOL TO SCHOOL

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ABSTRACT

The purpose of the present study was to examine the tracking of physical activity, motor abilities and elementary motor skills during two years, in a period of transition from preschool to school. In total, 294 Estonian children who were 6-year old at the beginning of the study were studied (161 boys and 133 girls). Children were measured four times — in the last year at the preschool and first year at the school both in autumn and spring. Children's physical activity was registered using the questionnaire of Harro. Following motor ability tests from the Eurofit test battery were used: Flamingo balance (30 s), handgrip strength, sit-and-reach, plate tapping, standing broad jump, bent arm hang, sit-ups, 10 × 5 m shuttle run. The endurance 3-min shuttle-run test has been validated in our previous research, which is based on the test of Kaneko and Fuchimoto. Sprint running, long jump and overhead throwing were performed in field conditions as an indicator of motor skill development and videotaping was used. The basic motor abilities during two years tracked mostly on the moderate level. There were no differences between boys and girls during preschool and school. Tracking of the physical activity and basic motor skills were not significant as a rule.

Key words: physical activity, motor ability, motor skills, tracking, children

INTRODUCTION

The health benefits of regular physical activity and physical fitness among adults are well established [21]. Less well understood are the health benefits associated with physical activity and physical fitness among children [23]. There is a growing recognition that childhood experiences (i.e. preschool) play a significant role in the future physical activity habits of adolescents and adults [8].

Tracking is the maintenance of the relative position in a group over time [1]. Tracking for physical fitness, physical activity, movement skills, and sport performance has been studied in diverse areas such as an epidemiology of physical activity [13] or as sport sciences [16]. Several researchers, such as Espanschade [7], Clarke [3], Rarick and Small [24], and Maia et al. [15] have added methodological and substantive insights to the present understanding of tracking. Autocorrelations across the age groups are usually assessed by Pearson or Spearman. If the values of the autocorrelations reach a cut-off point 0.50, it is especially assumed that the trait in question should be considered as a stable characteristic [2] or by Malina [16] correlations < 0.30 are considered low and those between 0.30 and 0.60 are moderate. Finally, the closer the time spans between measurements, the higher the correlation.

There is an evidence that physical activity in variable between studies, the results suggest low to moderate short term tracking of activity in the transition from early to middle childhood [22, 27]. There are only very few data about the tracking of motor abilities during childhood. Marshall et al. [17] indicated that in youth ages 9 to 12 sit-and-reach test and pull-up test tracked at high level. However, one mile running and sit-up test tracked moderately in boys. For girls, sit-and-reach test and pull-up test tracked highly while one mile run and sit-up test tracked moderately [17].

The purpose of the present study was to examine the tracking of physical activity, motor abilities and elementary motor skills during transition from preschool to school during two years.

MATERIAL AND METHODS

In total, 294 Estonian children who were 6-year old at the beginning of the study were studied (161 boys and 133 girls). Children were measured four times — in the last year at the preschool and first year at the school both in autumn (September–October) and spring (April–May). Children participated both in preschool and school in 2–3 compulsory physical education classes per week, which were conducted by a teacher of physical education. Parents of the children gave their written permission for the testing and confirmed that child was free from any medical condition that would preclude from participation.

Height and body mass of the children were measured by Martin metal anthropometer (±0.1 cm) and medical scales (±0.05 kg), respectively. BMI (kg/m^2) was calculated. Children's physical activity was registered using the questionnaire of Harro [11]. This questionnaire has been validated in 4–8-year-old Estonian children. Parents and teachers according to the daily physical activities of the children filled in questionnaires. Parent reported about the duration of several indoor and outdoor activities in minutes during the children awake time at home. Another questionnaire was given to the teacher to fix the time of children's activities at the preschool or school in order to assess the mode and duration of various physical activities. Following motor ability tests from Eurofit [6] test battery were used: Flamingo balance (30 s), handgrip strength of the dominant hand (Lafayette hand dynamometer, USA), sit-and-reach, plate tapping, standing broad jump, bent arm hang, sit-ups, and 10 × 5 m shuttle-run. The endurance 3-min shuttle run test has been validated in our previous research [19], which is based on the test of Kaneko and Fuchimoto [12]. All fitness tests were conducted at the kindergarten or school in the morning and separate stations were set up for each measurement.

Sprint running, long jump and overhead throwing were performed in field conditions as an indicator of motor skill development. Three trials for each child were recorded with a Panasonic video camera located to the left of the child. The qualitative evaluation of running, jumping and throwing performance was done by visual observation of the videotapes. Three specialists of motor development served as observers. Each had previous training with the evaluation of total body developmental sequences to assess the fundamental motor skills [16]. Scores for each child on each trial could range from 1–4 corresponding to stages 1 through 4.

Standard statistical methods were used to calculate mean ($\bar{X}$) and standard deviation (±SD). Statistical comparisons between boys and girls were made using independent t-tests. Because all data were not normally distributed, Spearman rank order correlation coefficients were used to examine tracking of physical activity, motor ability and motor skill parameters across four time periods: baseline and 6, 12 and 18 months. All time points were calculated with the baseline measure. Additionally, tracking coefficients were calculated on wintertime both in preschool and school and on summertime between preschool and school (between 2^{nd}

and 3rd measurements). All measured children participated in all four measurement periods. Analyses were conducted separately for boys and girls. Statistical significance was set at $p < 0.05$.

RESULTS

Mean anthropometrical parameters of boys and girls are presented in Tables 1 and 2. Body height and weight increased significantly during the experiment. There were less significant changes in BMI values.

Table 1. Mean results of different motor abilities, motor skills and physical activity in boys ($\bar{X}\pm SD$; n=161).

	Preschool		School	
	Sept–Oct 1	April–May 2	Sept–Oct 3	April–May 4
Height (cm)	121.5±5.7^{DG}	123.6±6.0^{JM}	126.5±6.0^{S}	129.1±6.0
Mass (kg)	22.6±3.8^{DG}	24.0±4.0^{KM}	25.8±4.4	27.0±4.9
BMI (kg/m^2)	15.2±1.4^{EM}	15.6±1.7	16.0±1.7	16.1±1.9
MOTOR ABILITY				
Standing broad jump (cm)	110.9±15.0^{CFI}	124.3±18.7^{J}	129.6±13.0^{S}	132.1±13.7
Sit-ups (x)	12.0±4.3^{GC}	13.6±3.2^{J}	13.9±4.0^{P}	15.4±3.3
Sit- and -reach (cm)	21.3±5.4^{DGC}	21.1±5.3^{LM}	18.2±5.7^{P}	16.8±6.2
Balance (x)	8.1±3.9^{DG}	6.7±3.8^{LM}	4.9±2.8	4.7±2.9
Bent arm hang (s)	10.6±5.9	11.6±7.1^{L}	12.1±8.3	11.6±8.3
Handgrip strength (kg)	8.9±4.2^{ADG}	11.7±2.0^{L}	12.2±2.9^{S}	12.8±2.5
Plate tapping (s)	23.7±2.0^{ADG}	17.4±3.0^{MJ}	16.3±2.7^{P}	14.7±2.3
10X5 m (s)	21.2±4.3	24.2±2.3^{J}	22.4±2.0^{S}	21.2±2.2
Endurance shuttle run (m)	410.8±10.4	410.9±35.4	401.8±28.2^{S}	416.2±33.0
MOTOR SKILLS				
Run	3.13±0.63	3.12±0.59	3.42±0.59^{S}	3.33±0.58
Jump	2.69±0.71^{ADG}	3.23±0.59	3.17±0.70^{S}	3.23±0.69
Throw	2.91±0.86	3.11±0.75	3.15±0.64^{S}	3.08±0.64
PHYSICAL ACTIVITY				
Indoor passive (min)	198.9±144.6	143.7±130.5^{O}	388.4±249.5^{S}	467.0±103.9
Indoor active (min)	50.5±45.7	37.9±35.9	66.7±59.9	197.5±166.9
Outdoor passive (min)	103.1±82.3	56.1±66.9	77.7±53.0	229.0±290.4
Outdoor active (min)	47.0±30.9	42.1±48.6	61.6±79.9	68.4±49.1
Indoor passive weekend (min)	293.5±231.8	146.1±214.4^{O}	275.0±219.7^{S}	409.9±349.1
Indoor active weekend (min)	56.1±88.2	23.3±46.5	58.6±88.1^{S}	68.1±79.5
Outdoor passive weekend (min)	116.7±114.4^{E}	70.2±117.1	52.1±91.0^{S}	205.3±184.2
Outdoor active weekend (min)	51.4±69.2^{C}	44.0±84.2^{O}	59.9±81.5^{S}	182.6±223.8

$p<0.05$ 1 vs 2 = C; 1 vs 3 = F; 1 vs 4 = I; 2 vs 3 = L; 2 vs 4 = O; 3 vs 4 = S
$p<0.001$ 1 vs 2 = A; 1 vs 3 = D; 1 vs 4 = G; 2 vs 3 = J; 2 vs 4 = M, 3 vs 4 = P

Table 2. Mean results of different motor abilities, motor skills and physical activity in girls ($\bar{X}$±SD; n=133).

	Preschool		School	
	Sept–Oct 1	April–May 2	Sept–Oct 3	April–May 4
Height (cm)	120.7 ± 5.1^{CDG}	122.8 ± 5.3^{JM}	125.7 ± 5.1^{P}	128.5±5.2
Mass (kg)	21.9 ± 2.8^{CDG}	23.4 ± 3.2^{LM}	24.8 ± 3.4^{P}	25.9±4.0
BMI (kg/m^2)	15.1±1.3	15.5±1.6	15.6±1.7	15.5±2.4
MOTOR ABILITY				
Standing broad jump (cm)	101.9 ± 14.5^{ADG}	116.0±11.6	114.6±14.0	117.9±11.5
Sit-ups (x)	10.7 ± 3.2^{CFG}	13.1±4.3	12.6±2.6	13.6±2.7
Sit- and -reach (cm)	21.6 ± 5.0^{I}	22.9 ± 5.1^{LM}	20.6±5.1	18.8±5.1
Balance (x)	5.7 ± 2.9^{DG}	5.1 ± 2.4^{JM}	3.6±1.8	2.8±2.1
Bent arm hang (s)	12.4 ± 14.8^{FI}	9.1±5.4	8.5±6.4	8.0±4.9
Handgrip strength (kg)	8.3 ± 4.7^{CDG}	9.9 ± 2.8^{O}	10.6±2.2	11.7±2.0
Plate tapping (s)	20.7 ± 3.7^{ADG}	16.7 ± 2.4^{M}	16.3 ± 2.8^{P}	14.5±2.0
10X5 m (s)	24.1 ± 1.8^{AG}	22.7±1.9	23.4 ± 1.9^{P}	21.9±2.2
Endurance shuttle run (m)	391.4 ± 48.0^{CI}	406.4±31.6	401.4±23.4	406.2±26.0
MOTOR SKILLS				
Run	2.99 ± 0.49^{I}	3.19 ± 0.43^{J}	3.24±0.52	3.60±1.92
Jump	2.49 ± 0.66^{CDG}	2.89 ± 0.46^{MJ}	3.02 ± 0.57^{S}	3.45±1.28
Throw	2.25 ± 0.61^{O}	2.54 ± 0.48^{MJ}	2.62 ± 0.62^{P}	3.40±1.98
PHYSICAL ACTIVITY				
Indoor passive (min)	230.6 ± 182.7^{F}	212.2±109.3	315.0 ± 197.3^{S}	460.5±315.2
Indoor active (min)	53.8 ± 51^{F}	56.4±36.0	46.3±36.6	205.6±448.6
Outdoor passive (min)	103.3±59.4	78.1±47.9	40.1 ± 40.5^{S}	417.0±475.8
Outdoor active (min)	35.8±29.5	43.5±33.5	31.8 ± 35.2^{S}	48.4±49.6
Indoor passive weekend (min)	291.9 ± 259.4^{F}	340.0 ± 158.8^{L}	250.6 ± 247.0^{S}	457.2±402.7
Indoor active weekend (min)	48.6 ± 76.6^{F}	64.2 ± 48.2^{L}	39.6 ± 59.8^{S}	82.0±104.4
Outdoor passive weekend (min)	101.1 ± 124.6^{I}	177.4 ± 121.6^{L}	69.9±79.7	260.5±243.7
Outdoor active weekend (min)	34.4 ± 61.1^{I}	113.8 ± 83.0^{KM}	31.6 ± 64.8^{S}	138.9±167.9

$p<0.05$ 1 vs 2 = C; 1 vs 3 = F; 1 vs 4 = I; 2 vs 3 = L; 2 vs 4 = O; 3 vs 4 = S
$p<0.001$ 1 vs 2 = A; 1 vs 3 = D; 1 vs 4 = G; 2 vs 3 = J; 2 vs 4 = M. 3 vs 4 = P

Mean motor ability tests results are presented in Tables 1 and 2. In boys, only on standing broad jump the results were increased every half years. Surprisingly, the results of the sit-and-reach test decreased. There were less significant changes in the other used tests in boys (Table 1). In girls, the results of plate tapping were better from the initial results in every half years. There were less changes during the summer holidays. Only the sit-and-reach and Flamingo balance test results decreased.

There were more significant changes in the motor skills in boys compared with girls during two years (Tables 1 and 2). However, the mean results were better in boys than girls at the beginning of the experiment. Contrary, at the end of experiment, the results were slightly ($p>0.05$) better in girls. From the different parameters of physical activity, there were more significant changes in girls compared with boys during two years (Tables 1 and 2).

In most cases, the motor ability tests results were significantly better in boys compared with girls (Table 3). There were not significant differences in the plate tapping and endurance shuttle-run (except Sept-Oct in preschool). Of the motor skills, there are more significant differences between boys and girls in the throwing skill (Table 3). Of the different physical activity parameters, the differences between sexes are more on the spring and on autumn (in school).

Table 3. Differences in motor abilities, motor skills and physical activities between boys and girls.

	Preschool		School	
	Sept–Oct.	April–May	Sept–Oct.	April–May
MOTOR ABILITY				
Standing broad jump	0.001	0.001	0.001	0.001
Sit-ups	0.05	NS	NS	0.01
Sit- and -reach	NS	0.05	0.05	0.01
Balance	0.001	0.05	0.001	0.001
Bent arm hang	NS	0.05	0.001	0.001
Handgrip strength	NS	0.001	0.001	0.001
Plate tapping	NS	NS	NS	NS
10×5 m	0.001	NS	0.001	0.05
Endurance shuttle run	0.001	NS	NS	NS
MOTOR SKILLS				
Run	0.05	0.05	NS	NS
Jump	NS	0.001	NS	NS
Throw	0.001	0.001	0.001	NS
PHYSICAL ACTIVITY				
Indoor passive	NS	0.001	0.05	NS
Indoor active	NS	0.001	0.001	NS
Outdoor passive	NS	0.05	0.001	0.001
Outdoor active	NS	NS	0.001	NS
Indoor passive weekend	NS	0.001	NS	NS
Indoor active weekend	NS	0.05	NS	NS
Outdoor passive weekend	NS	0.001	NS	0.001
Outdoor active weekend	NS	0.001	0.01	NS

NS — not significant

Interperiod Spearman correlation coefficients of different motor abilities, motor skills and physical activity are presented in Table 4. From the motor abilities, standing broad jump, sit-ups (except after 18 months in girls), sit-and-reach test, Flamingo balance results tracked significantly. The tracking of running, jumping and throwing skills were not significant (except in throwing in boys after 6 months). As a rule, there were not any significant tracking coefficients in the different physical activity parameters (Table 4).

Table 4. Spearman correlation coefficients of motor ability, motor skills and physical activities of boys and girls (in brackets) at three assessment points with baseline.

	After 6 month		After 12 month		After 18 month	
MOTOR ABILITY						
Standing broad jump	0.40**	(0.50**)	0.26*	(0.34**)	0.36**	(0.49**)
Sit-ups	0.37**	(0.48**)	0.47**	(0.49**)	0.38**	(0.14)
Sit- and -reach	0.50**	(0.58**)	0.55**	(0.44**)	0.65**	(0.44**)
Balance	0.46**	(0.46**)	0.48**	(0.34**)	0.44**	(0.49**)
Bent arm hang	0.43**	(0.03)	0.18	(0.04)	0.35**	(0.07)
Handgrip strength	0.36**	(0.25*)	0.28*	(0.20)	0.27*	(0.06)
Plate tapping	0.09	(0.53**)	0.08	(0.49**)	0.06	(0.46**)
10×5 m	0.13	(0.47**)	0.24*	(0.24*)	0.05	(0.03)
Endurance shuttle run	0.38**	(0.22*)	0.19	(0.03)	0.18	(0.25*)
MOTOR SKILLS						
Run	0.14	(0.17)	0.02	(0.19)	0.04	(0.03)
Jump	0.04	(0.18)	0.02	(0.13)	0.01	(0.05)
Throw	0.22*	(0.14)	0.09	(0.10)	0.11	(0.07)
PHYSICAL ACTIVITY						
Indoor passive	0.04	(0.16)	0.09	(0.18)	0.08	(0.22*)
Indoor active	0.13	(0.14)	0.02	(0.20)	0.03	(0.19)
Outdoor passive	0.01	(0.03)	0.05	(0.12)	0.04	(0.07)
Outdoor active	0.10	(0.12)	0.11	(0.01)	0.19	(0.05)
Indoor passive weekend	0.09	(0.21)	0.02	(0.20)	0.07	(0.07)
Indoor active weekend	0.03	(0.03)	0.07	(0.31*)	0.11	(0.13)
Outdoor passive weekend	0.33**	(0.08)	0.13	(0.22*)	0.02	(0.43**)
Outdoor active weekend	0.14	(0.06)	0.02	(0.10)	0.04	(0.40**)

*p<0.05; ** p<0.01

Spearman correlation coefficients of the motor abilities, motor skills and physical activities during winter in preschool and school, and during summer holidays are presented in Table 5. Motor abilities are tracking in the moderate level in both preschool and school, and about the same level during summer holidays. Motor skills are tracking moderately and especially low is the tracking of different physical activity parameters (except winter in school).

Table 5. Spearman correlation coefficients during wintertime in preschool and school and during summer between preschool and school in boys and girls.

	Winter				Summer	
	Preschool		School			
MOTOR ABILITY	Boys	Girls	Boys	Girls	Boys	Girls
Standing broad jump	0.40**	0.50**	0.28**	0.36**	0.45**	0.44**
Sit-ups	0.37**	0.48**	0.57**	0.51**	0.46**	0.44**
Sit- and -reach	0.50**	0.58**	0.63**	0.58**	0.60**	0.65**
Balance	0.46**	0.46**	0.55**	0.28**	0.51**	0.26**
Bent arm hang	0.43**	0.03	0.53**	0.37**	0.41**	0.35**
Handgrip strength	0.36**	0.25*	0.31**	0.36**	0.22*	0.69**
Plate tapping	0.09	0.53**	0.69**	0.41**	0.71**	0.49**
10X5 m	0.13	0.47**	0.19	0.10	0.33**	0.17
Endurance shuttle run	0.38**	0.22*	0.31**	0.05	0.15	0.04
MOTOR SKILLS						
Run	0.14	0.17	0.61**	0.01	0.14	0.72**
Jump	0.04	0.18	0.51**	0.04	0.15	0.64**
Throw	0.22**	0.14	0.61**	0.11	0.01	0.73**
PHYSICAL ACTIVITY						
Indoor passive	0.04	0.16	0.33**	0.38**	0.10	0.02
Indoor active	0.13	0.14	0.24*	0.49**	0.01	0.07
Outdoor passive	0.01	0.03	0.16	0.47**	0.11	0.01
Outdoor active	0.10	0.12	0.25*	0.51**	0.05	0.08
Indoor passive weekend	0.09	0.21*	0.54**	0.33**	0.10	0.26**
Indoor active weekend	0.03	0.03	0.45**	0.34**	0.04	0.20*
Outdoor passive weekend	0.33**	0.08	0.39**	0.26**	0.12	0.32**
Outdoor active weekend	0.14	0.06	0.37**	0.31**	0.08	0.40**

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

DISCUSSION

In our study, different physical activity parameters in school days or weekend days did not track significantly in preschool and school (Table 4). Our results were similar with Sallis et al. [27] study in very young children (4.4 yrs). Previous studies in children that used objective measures of physical activity reported correlations over brief intervals of 0.10

[26], 0.66 [4], and 0.81 [5] in the short time experiments. Contrasts are even more striking when longer-term correlations are considered. Pate et al. [20] reported tracking correlations around 0.60 over one and 2 years; and Mechelen et al. [18] reported a correlation of 0.51 in older children over 4 years and 0.19 over 9 years. One explanation for the difference in tracking correlations between the present study and other studies may be that very different methods with different time intervals have been studied. Secondly, we studied a critical period of children, specifically the transition from preschool to school where physical activity rapidly decreases and consequent result is weight gain.

Most of the used motor ability tests tracked significantly but only on the moderate level using Malina's scale [16]. The tracking coefficients were similar in boys and girls and there was not any rapid decrease during the increasing the time between measurements. However, in some tests, such as plate tapping in boys, endurance shuttle-run and 10×5 m shuttle-run in girls, the tracking coefficients were not significant as a rule. Moderate tracking coefficients in the well-known motor ability tests results during the longer time intervals have also found in other studies [14,25]. Similarly to other studies, we can conclude that the different motor abilities tracked during two years significantly but on the moderate level as a maximum.

Compared with physical activity and motor ability, there are less data available about the tracking of motor skills in children. In our study, the preliminary scores of running, jumping and throwing in both boys and girls were relatively high (Tables 1 and 2). However, the scores were slightly higher in boys compared to girls ($p>0.05$). Probably, the relatively high level of basic motor skills development in our children is the main reason why tracking coefficients were relatively low and in most cases statistically not significant. It is well known that most children have the potential to be mechanically efficient and coordinated in the fundamental motor skills by the time they are 5 to 7 years old [8]. On the other side, the development of basic motor skills is considered by many as a key objective of physical education programs [9], because it increases the options for participation in games, sports and other physical activities. In summary, the basic motor abilities during two years tracked mostly on the moderate level. There were not any differences between boys and girls during preschool and school. Tracking of the physical activity and basic motor skills were not significant as a rule.

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INJURIES AT THE KONICA ASIAN JUDO CHAMPIONSHIPS

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ABSTRACT

The purpose of this study was to assess the injury profile in Asian elite judo athletes (judoka). Subjects were male (n=100) and female (n=84) elite judoka participating in the Konica 1997 Asian Judo Championships in Metro Manila, Philippines. Injury data were collected with simple check-off forms that describe the athlete, type, location and mechanism of injury. The Mann-Whitney U test was used to determine the difference in total injury rate between males and females. The women recorded a higher injury rate (41.28/1,000 athlete-exposures) than the men (25.18/1,000 athlete-exposures) ($p<0.001$). The major injury type was the abrasion (13.76/1,000 athlete-exposures) in the women. The body part most often injured in the women was the toes (9.17/1,000 athlete-exposures) and in the men, the wrist (10.79/1,000 athlete-exposures). The major injury mechanism in the women was groundwork (13.76/1,000 athlete-exposures) and in the men, executing a throw (7.19/1,000 athlete-exposures).

Key words: judo injuries, Asian, injury rates, time-loss injuries

INTRODUCTION

There is a dearth of prospective research on judo injuries. Most of the information available comes from case series and case reports. For instance, case reports on judo injuries include studies on trauma to the head and neck [e.g., 5, 9, 10], upper extremities [12, 14], trunk [8, 20] and lower extremities [e.g., 4, 6]. However, inherent methodological problems associated with case series and case reports preclude any conclusions regarding injury rates and groups at higher risk of injury [23, 24].

Only a few prospective studies on judo injuries have been conducted with some of them more than three decades ago. For instance, in possibly the oldest prospective study on judo injuries, Sturm [21] recorded a total injury rate of 17.42/1,000 athlete-exposures for male judoka [judo athletes]. One athlete-exposure (A-E) refers to one individual competing in one bout where he/she is exposed to the possibility of being injured. Since there are always two athletes competing in a judo match, there are two A-E per bout. In Sturm's study [21] abrasions (3.72/1,000 A-E) were the most often occurring injury type followed by the nose bleed (3.25/1,000 A-E). In a follow-up study, Witak and Sturm [25] subsequently reported a total injury rate of 18.00/1,000 A-E, again for male judoka. Of these injuries, 37% were to the upper extremities followed by 25% to the head. In both studies, the injury rates refer to injuries sustained during competition.

In the largest prospective study on judo injuries to date, Barrault et al. [2] found a total injury rate of 122.63/1,000 A-E for the combined sample of young and adult males, and a rate of 130.60/1,000 A-E for their female counterparts. No separate injury rate was reported for the young and adult judoka within each gender. More than ten years later, Pieter and De Crée [15] recorded a total injury rate of 51.3/1,000 A-E and 125.0/1,000 A-E for the men and women, respectively. The difference was statistically significant. In a follow-up study, James and Pieter [11] reported a total injury rate of 48.54/1,000 A-E for the males, which was statistically significantly higher than that found for the females (34.25/1,000 A-E).

Severity of injuries is expressed by the time lost from training, study or work. For instance, Witak and Sturm [25] reported that 28% of all injuries in judo led to time-loss. Barrault et al. [2] found time-loss injury rates of 9.80/1,000 A-E for the combined sample of young and adult male judoka and of 8.21/1,000 A-E for their female colleagues. A study conducted in the Ivory Coast revealed a time-loss injury rate of 3.97/1,000 A-E for a combined sample of young and adult judoka [7]. No other prospective studies could be located dealing with time-loss injuries in judo.

Although studies have been carried out in Japan as reviewed by Azuma [1] and in the USA [e.g., 19], none of them used a prospective design. In addition, no prospective studies using Asian subjects could be found. Therefore, the aim of the present study was assess the injury profile of elite Asian male and female judoka during competition.

MATERIAL AND METHODS

Subjects were 100 male and 84 female elite judoka participating in the Konica 1997 Asian Judo Championships in Metro Manila, Philippines. A simple check-off injury data collection form was used, developed by the first author, that was a modification of one utilised in previous research on judo injuries [15]. This form included demographic data as well as information on injury type, body part injured, injury situation (what the player injured was doing at the time of injury) and mechanism (the actual cause of the injury). An injury was defined as any circumstance for which assistance was sought from the medical personnel. In addition, time-loss injuries as part of the total reported injuries were recorded. Time-loss injuries are defined as those that will keep the athlete from completing the present bout and/or subsequent bouts and from participating in judo for a minimum of one day thereafter. A form was completed for every injury thus reported. All diagnoses were done by the tournament physicians within the constraints of the site of the tournament setting.

Exposure data for calculating injury rates were gathered from records of bouts actually fought. Injury rates were calculated from matches fought using the basic rate formula: [# injuries / # athlete-exposures] x 1,000 = # injuries per 1,000 athlete-exposures (A-E).

To determine the difference in injury rates between men and women, the Mann-Whitney U test was used. The level of significance was set at $\alpha = 0.05$.

RESULTS

Table 1 shows the injury rates for both men and women. The women recorded a higher injury rate than the men ($p < 0.001$).

Table 1. Injury rates in Asian male and female elite judo athletes (judoka).

	Men	Women
Number of athletes	100	84
Number of athlete-exposures (A–E)	278	218
Number of injuries	7	9
Injury rates:		
– per 100 athletes	7.00	10.71
– per 1,000 A–E	25.18	41.28

Table 2 shows the injury rates for each body part injured. The type of injury sustained, injury situation and mechanism are depicted in Tables 3–5.

Table 2. Distribution of judo injuries by body part per 1,000 athlete-exposures*.

Men			Women		
Body Part	Number	Rate	Body Part	Number	Rate
Head	1	3.60	Nose	1	4.59
Mouth	1	3.60	Clavicle	1	4.59
Wrist	3	10.79	Acromio-clavicular joint	1	4.59
Knee	2	7.19	Shoulder	1	4.59
			Hand	1	4.59
			Foot	1	4.59
			Toes(s)	2	9.17
			Other	1	4.59
Total	7	25.18	Total	9	41.28

* Body parts not listed in this Table were not involved in any recorded injury

Table 3. Distribution of judo injuries by injury type per 1,000 athlete-exposures*.

Men			Women		
Injury Type	Number	Rate	Injury type	Number	Rate
Abrasion	1	3.60	Abrasion	3	13.76
Contusion	1	3.60	Epistaxis	1	4.59
Laceration	1	3.60	Fracture	2	9.17
Ligament-complete tear	1	3.60	Separation	1	4.59
Sprain	1	3.60	Strain	1	4.59
Strain	1	3.60	Other	1	4.59
Other	1	3.60			
Total	7	25.18	Total	9	41.28

* Injury types not listed in this table were not involved in any recorded injury

Table 4. Distribution of judo injuries by situation per 1,000 athlete-exposures.

Men			Women		
Situation	No.	Rate	Situation	No.	Rate
Attacking with throw	3	10.79	Ground work	4	18.35
– Body drop forward throw	*1*	*3.60*	Being thrown	2	9.17
– Unknown	2	*7.19*	*– Inner leg sweep*	*1*	*4.59*
Being thrown	2	7.19	*– Shoulder throw*	*1*	*4.59*
– Major outer leg sweep	*1*	*3.60*	Grappling	1	4.59
– Unknown	*1*	*3.60*	Other	1	4.59
Ground work	1	3.60	Unknown	1	4.59
Other	1	3.60			
Total	7	25.18	Total	9	41.28

Table 5. Distribution of judo injuries by mechanism per 1,000 athlete-exposures.

Men			Women		
Mechanism	No.	Rate	Mechanism	No.	Rate
Performing a throw	3	10.79	Ground work	4	18.35
– Body drop forward throw	*1*	*3.60*	Receiving throw	2	9.17
– Unknown	2	*7.19*	*– Inner leg sweep*	*1*	*4.59*
Receiving throw	1	3.60	*– Shoulder throw*	*1*	*4.59*
– Unknown	*1*	*3.60*	Impact with surface	1	4.59
Impact with surface	1	3.60	Other	1	4.59
Ground work	1	3.60	Unknown	1	4.59
Other	1	3.60			
Total	7	25.18	Total	9	41.28

The total time-loss injury rate for the men was 3.60/1,000 A-E and for the women, 9.17/1,000 A-E. The body part injured in the men was the knee and the type of injury, a complete tear of the lateral collateral ligament. The injury situation was *osoto gari* (major outer reaping) with the mechanism being receiving the *osoto gari*. The women sustained fractures to the hand and clavicle. The injury situations were ground work for the injury to the hand, and the shoulder throw for the fracture to the clavicle. The mechanisms were ground work and impact with surface, respectively. These injuries led to time lost of more than 21 days.

DISCUSSION

The total injury rates for the Asian males and females are lower than or comparable to those found in other prospective studies on judo injuries [11, 15]. Table 6 shows comparative data on injury rates for judo. Some of these studies [2, 21, 25] involved more tournaments than others [11, 15], which has repercussions for the resultant injury rates: the more tournaments covered, the lower the injury rate will become. Barrault et al.'s [2] subjects comprised both young and adult judoka, as alluded to above. Since the last prospective study using more than 17,000 judoka was published some 18 years ago [2], more research is needed with a much larger sample size than that used in the most recent studies on judo injuries before any definitive conclusions may be drawn.

Table 6. Comparative injury rates in judo and other martial arts per 1,000 athlete-exposures.

Sport/Study	Men	Women
Judo [this study]	25.18	41.28
Judo [21]*	17.42	n.a.
Judo [25]	18.00	n.a.
Judo [2]**	122.63	130.60
Judo [7]**	115.08	n.a.
Judo [15]	51.28	125.00
Judo [11]	48.54	34.25

* Except for our own studies, all injury rates are estimations based on information provided by the authors

** Includes both young and adult athletes

Although the sample was too small to arrive at any definitive inferences, the Asian judoka in the present study incurred most of the injuries to the upper extremities (injury rate: 10.79/1,000 A-E for the men and 18.35/1,000 A-E for the women) (see Table 2), which may be expected based on the nature of the sport. Witak and Sturm [25] found 37% of all reported injuries to the upper extremities, while Barrault et al. [2] recorded 44.3% of all reported injuries to this body region for their combined sample of young and adult male and female judoka. More recent studies show the injury rate to the upper extremities to be 19.84/1,000 A-E as opposed to the lower extremities with 15.87/1,000 A-E [7]. Pieter and De Crée [15] found injury rates of 12.8/1,000 A-E for the upper extremities and 25.6/1,000 A-E for the trunk, with no injuries reported for the lower extremities in the men. In the women, all injuries occurred to the upper extremities (125.0/1,000 A-E). James and Pieter [11], finally, reported the same injury rate for the upper and lower extremities (6.2/1,000 A-E each) in the men, which was lower than that for the head and neck (19.42/1,000 A-E). In the women, the head and neck and the upper extremities showed the same injury rate (13.70/1,000 A-E each).

The abrasion in the women in the present study was the most often occurring injury type. Sturm [21] also found the abrasion to be the most frequently occurring type of injury. On the other hand, Dah and Djessou [7] reported the contusion as the most often occurring type of injury (15.87/1,000 A-E), while no one injury occurred more often than another in Pieter and De Crée's [15] study. James and Pieter [11] found the strain (14.56/1,000 A-E) to rank first in the men, while the women recorded the contusion and hyperextension as the most often occurring injury (13.70/1,000 A-E each). This pattern is contrary to that found in other contact martial arts, such as karate and taekwondo where the contusion occurs most frequently [22, 26].

The injury situation and mechanism reflect the competition rules and the sport-specific techniques used. In the present study, attacking with a throw and performing a throw were the major injury situation and mechanism, respectively, in the men. In the women, the main situation and mechanism involved ground work (see Tables 4 and 5). Witak and Sturm [25] found 42% of all injuries to be the result of ground work. Pieter and De Crée [15] reported being thrown (men; 25.64/1,000 A-E) and attacking with a throw (women; 125.0/1,000 A-E) to be the main injury situations. Although no one injury mechanism was dominant in the men, performing a throw was the major mechanism (125.0/1,000 A-E) in the women. James and Pieter [11] found attacking with a throw and being thrown (14.56/1,000 A-E each) as the major injury situations in the men, and the arm lock (13.70/1,000 A-E) in the women. The main injury mechanisms in the men were performing a throw and impact with surface (14.56/1,000 A-E each), while no one mechanism occurred most often in the women. In a case series study, Koiwai [13] reported throwing techniques as most frequently (81.43%) leading to injuries in judo. The injuries were a combination of those incurred in practice and competition.

Table 7 shows comparative data on time-loss injuries in judo and other martial arts based on prospective studies. The same considerations mentioned above regarding the number of tournaments covered in each study should be applied. The higher time-loss injury rate for the women in the present study may be related to the small sample size. Research on injuries in other martial arts with larger sample sizes has shown a higher time-loss injury rate in men [e.g., 16, 18]. Based on the results of this study, it may be concluded that judo competitions lead to fewer serious injuries. However, it was also found that a large proportion of injuries in martial arts are not reported, including such injuries as fractures and cerebral concussions [3]. In other words, the rates reported in this study, both for the general and the time-loss injuries, should be considered minimum rates.

Table 7. Comparative time-loss injury rates per 1,000 athlete-exposures in judo.

Sport/Study	Men	Women
Judo [this study]	3.60	9.17
Judo [25]*	5.00	n.a.
Judo [2]**	9.80	8.21
Judo [7]**	3.97	–
Karate [7] (with padding)	1.98	n.a.
Karate [W. Pieter, Unpublished data] (with padding)	11.32	2.44
Taekwondo [16]	22.90	9.68
Taekwondo [17]	27.13	8.77
Taekwondo [26]	23.58	13.51

* Except for our own studies, all injury rates are estimations based on information provided by the authors

** Includes both young and adult athletes

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FAT DISTRIBUTION AS A FUNCTION OF OBESITY IN YOUNG FILIPINOS

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ABSTRACT

The purpose of this study was to assess fat distribution in young Filipinos using the conicity index, waist-hip ratio (WHR) and subscapular-triceps ratio (STR). Subjects were freshmen recruited from a private university in the Philippines (183 males and 206 females between 17–18 years). In addition to stature, body mass tricipital and subscapular skinfolds were taken as well as waist and hip girths. The conicity index was calculated according to Valdez et al. The males and females were divided into three obesity sub-groups as suggested by Dowse et al. The conicity index of the lean males (1.15 ± 0.08) was lower than that of their obese counterparts (1.24 ± 0.11) ($p < 0.001$). That of the obese males was higher than that of the lean (1.15 ± 0.12) ($p < 0.001$), normal (1.15 ± 0.08) ($p < 0.001$) and obese females (1.15 ± 0.12) ($p = 0.008$). The men had more truncal (1.11 ± 0.31 versus 0.93 ± 0.26) as well as abdominal fat (0.86 ± 0.11 versus 0.79 ± 0.10) than the women. The lean group (WHR: 0.79 ± 0.08) had less abdominal fat than their normal (0.84 ± 0.14) ($p < 0.001$) and obese colleagues (0.89 ± 0.10) ($p < 0.001$). It is disconcerting that the fat distribution of the young Filipinos was comparable to that of older subjects, some of whom were diagnosed with type 2 (non-insulin-dependent) diabetes mellitus and glucose intolerance.

Key words: Filipino youth, conicity index, waist-hip ratio, subscapular-triceps ratio

INTRODUCTION

Obesity, defined as having a body mass index (BMI) of > 30 kg/m^2 [27], was found to be related to cardiovascular risk factors, such as hypertension and diabetes mellitus [18, 27]. Overweight and obesity are prevalent among children in such non-western countries as United Arab Emirates (UAE) [1] and was reported in adults as having increased as a result of modernity in Papua New Guinea [10], Mauritius [9] and Palau [12].

Central obesity (fat around the trunk and abdominal areas) has been associated with glucose intolerance and insulin resistance [15]. Fat distribution has been found to be a predictor of cardiovascular diseases (CVD) in European men and women [13, 14] as well as in South Asians [15] and Micronesian Nauruans [11]. One of the indices to represent fat distribution is the waist-hip ratio (WHR), which was used in the aforementioned studies.

A relatively new index to express abdominal obesity is the conicity index (C index) [25]. This index relates someone's waist circumference to that of a cylinder using that person's height and weight, while using a constant for body density [16]. Using the C index, Gishen et al. [7] found young (19–20 years of age) female South Asians of the Indian sub-continent to have a higher C index than their European (i.e., UK) counter-parts, as did the South Asian males in the top tertiles of body mass and BMI. The authors concluded that the higher incidence of CVD and diabetes in older South Asians living in the UK may have its origins at younger ages.

Hardly any data are available on fat distribution in young Filipino males and females. Pieter and Bercades [20] found young (17–18 years) Filipino males, regardless of obesity level, to have more truncal fat (subscapular-triceps ratio = 1.19) than their female counterparts (STR = 0.94), while they also had more abdominal fat as measured by the WHR (0.88 versus 0.84). Collapsed over Sex, the obese group (WHR = 0.92) had more abdominal fat than their normal (WHR = 0.86) and lean colleagues (WHR = 0.84). No studies are available using the conicity index in Filipinos. The purpose of the current investigation, therefore, was to assess fat distribution in young Filipinos using the C index, waist-hip ratio (WHR) and subscapular-triceps ratio (STR).

MATERIAL AND METHODS

Subjects (183 males, 17.99 ± 1.37 years, 170.93 ± 6.78 cm, 63.35 ± 16.05 kg and 206 females, 17.78 ± 0.84 years, 157.21 ± 6.38 cm, 51.07 ± 9.34 kg) were freshmen recruited from a private university in the Philippines. The anthropometric measurements taken consisted of stature, body mass and skinfold thicknesses from the triceps and subscapula. Standing height was measured with a wall-mounted wooden stadiometer to the nearest 0.5 cm. Body weight was assessed with a calibrated electronic digital scale to the nearest 0.01 kg. A Slimguide skinfold caliper was used to measure the skinfold thicknesses. All skinfolds were taken according to the specifications provided by Ross and Marfell-Jones [22]. Girths were taken according to Dowse et al. [4] at the waist (the minimum circumference between the xiphisternum and umbilicus) and hip (maximum circumference around the buttocks). All measurements were taken three times and the median used for statistical analysis.

The conicity index was calculated according to Valdez et al. [25], where C index = waist circumference/$[0.109\sqrt{W/H}]$ with waist girth (W) and height (H) in meters and body mass in kilograms. The waist-hip ratio was calculated as the quotient of waist and hip girths, while the subscapular-triceps ratio was calculated as the quotient of the subscapular and triceps skinfold thicknesses. Both males and females were divided into three obesity sub-groups according to BMI as suggested by Dowse et al. [4].

A two-way (Sex*Obesity) MANOVA was used to determine the differences between gender and obesity level in age, height, weight, C index, WHR and STR. In case of an interaction, simple effects analysis was carried out to identify the exact location of the differences. Tukey HSD post-hoc analysis was used when Obesity main effects were found. All analyses were done with a significance level of 0.05.

RESULTS

There was a multivariate Sex by Obesity interaction ($p = 0.004$). Subsequent univariate analysis revealed an interaction for body mass ($p = 0.016$) and conicity ($p = 0.017$). Simple effects analysis showed that the lean males weighed less than the normal males, the obese males and the obese females, but more than the lean females ($p < 0.001$ for each comparison; see Table 1). The normal males weighed less than the obese males, but more than the lean and normal females ($p < 0.001$ each). The obese males weighed more than all female obesity groups ($p < 0.001$ each). The lean females weighed less than the normal and obese females. Finally, the normal females weighed less than their obese colleagues ($p < 0.001$ each).

Table 1. Descriptive statistics for body mass and conicity by sex and obesity group ($\bar{X}$±SD).

Group	Body mass (kg)	Conicity
Lean males (n=70)	54.02 ± 5.26	1.15 ± 0.08
Normal males (n=51)	66.64 ± 5.23	1.18 ± 0.15
Obese males (n=69)	84.14 ± 14.19	1.24 ± 0.11
Lean females (n=176)	46.95 ± 4.99	1.15 ± 0.12
Normal females (n=57)	55.93 ± 5.08	1.15 ± 0.08
Obese females (n=22)	71.50 ± 11.58	1.15 ± 0.12

The C index of the lean males was lower than that of their obese counterparts ($p < 0.001$). That of the obese males was higher than that of the lean ($p < 0.001$), normal ($p < 0.001$) and obese females ($p = 0.008$).

A multivariate sex main effect was also found ($p < 0.001$), which was confirmed by the univariate follow-up analysis for height, STR and WHR ($p < 0.001$ for each). The males were taller than the females, had more truncal (1.11 ± 0.31 versus 0.93 ± 0.26) as well as abdominal fat (0.86 ± 0.11 versus 0.79 ± 0.10).

Collapsed over sex, there was a multivariate difference among obesity groups ($p < 0.001$). Follow-up univariate analysis revealed an Obesity main effect for STR and WHR ($p < 0.001$ each). Subsequent Tukey HSD post-hoc analyses showed the lean group (0.92 ± 0.27) to have less truncal fat than the normal group (1.03 ± 0.27) as expressed by the STR ($p = 0.002$). Both the lean and normal groups had less truncal fat than the obese group (1.19 ± 0.31) ($p < 0.001$ each).

In terms of the WHR, the lean group (0.79 ± 0.08) had less abdominal fat than their normal counterparts (0.84 ± 0.14) ($p < 0.001$) as well as their obese colleagues (0.89 ± 0.10) ($p < 0.001$). The normal group also had less central fat than the obese counterparts ($p = 0.003$).

DISCUSSION

Table 2 depicts comparative data for the C index. The subjects investigated by Gishen et al. [7] were 19 years of age, similar to the age of the Filipinos. The South Asian males in the BMI top tertile recorded a C index of 1.23 [7], which is comparable to that of the obese Filipinos. The BMI of the South Asians in the top tertile is also comparable to that of the Filipinos: 27.2 kg/m^2 [7] versus 28.5 kg/m^2. The female South Asians in the top BMI tertile, with a BMI of 26.1 kg/m^2, had a C index of 1.17 [7], which is comparable to those of the female Filipinos in all obesity groups. Interestingly, the BMI for the lean Filipino females was 18.9 kg/m^2 and those for the normal and obese groups, 23.0 kg/m^2 and 28.4 kg/m^2, respectively. Values for the UK sample in Gishen et al.'s [7] study were 25.8 kg/m^2 in the top tertile for males and 25.5 kg/m^2 for females with corresponding conicities of 1.19 and 1.07, respectively. The American Indian males were 50 years old and the women, 48, while the ages for the Italians were 42 and 44 years, respectively [25]. It is disconcerting that the C indices of the young Filipinos were comparable to those of older subjects. Future research should include both young and older Filipinos as fat distribution is suggested to change with age[5].

Table 2. Comparative conicity values of Filipinos and those of other groups.

Group	Males	Females
Lean Filipino (this study)	1.15	1.15
Normal Filipino (this study)	1.18	1.15
Obese Filipino (this study)	1.24	1.15
South Asians [7]	1.19	1.11
British [7]	1.17	1.07
American Indian [25]	1.30	1.25
Italian [25]	1.29	1.24

The WHR has been used more often in studying fat distribution. The results from the current study support the findings of Pieter and Bercades [20], who also reported the WHR to differ between obesity levels, with the lean group recording a ratio of 0.84, the normal group, 0.86 and the obese counterparts, 0.92. Comparative values are displayed in Table 3.

It is of concern that compared to much older adults who were diagnosed with type 2 (non-insulin-dependent) diabetes mellitus (NIDDM) and glucose intolerance, the young Filipinos, especially those in the obese groups, had similar waist-hip ratios. Central fat was also found in Filipino national elite athletes [21], which is even more worrisome, as physical inactivity has been reported to be an independent risk factor for NIDDM [4, 19, 24]. In a previous study it was revealed that most adolescent Filipinos investigated were inactive, especially in the obese groups [3]. However, it was also reported that an intervention program was successful in increasing voluntary physical activity of Filipino youth [2]. It is suggested to include dietary modifications in addition to increasing physical activity for the subjects of the current study. Central or hypertrophic obesity is believed to be more susceptible to interventions with the aim to reduce fat as opposed to gluteal-femoral or hyperplastic obesity [26]. In other words, the effect of increased physical activity will be more apparent in those with a high WHR.

Table 3. Comparative waist-hip ratios in non-Caucasian groups.

	Males		Females	
Group	Age (yrs)	Ratio	Age (yrs)	Ratio
Lean Filipino (this study)	17.9	0.81	17.8	0.78
Normal Filipino (this study)	18.0	0.86	17.8	0.82
Obese Filipino (this study)	18.1	0.90	18.0	0.85
Samoans [6]	42.3	0.96	42.7	0.92
Pakistani [23]	51	1.00	48	1.00
Mauritians [19]				
– Hindu Indians	43.0	0.92	42.9	0.84
– Muslim Indians	42.7	0.91	43.5	0.86
– Creole	42.7	0.89	43.2	0.84
– Chinese	45.1	0.89	44.2	0.81
Mauritians [4]				
– Hindu Indians	42.2	0.89	42.5	0.81
– Muslim Indians	41.0	0.89	41.7	0.82
– Creole	44.0	0.88	45.3	0.82
– Chinese	48.5	0.89	46.9	0.80

The subscapular-to-triceps ratio was found to be higher in South Asians with normal glucose tolerance as opposed to whites (combined ratio of male and female South Asians: 1.36 versus 1.17 for their white counterparts) [17]. When collapsed over gender, the obese Filipinos recorded an STR of 1.19, which is much lower than that of the South Asians in Nagi et al.'s study [17]. Normoglycemic Nauruan men with a BMI of 33 kg/m^2 had an STR of 1.5 [11], which is much higher than that of the obese

Filipino men in the current study with a BMI of 28.5 kg/m^2 and an STR of 1.2. Haffner et al. [8] suggested that both WHR and STR are predictive of NIDDM. In women, both independently contributed to predicting NIDDM and HDL-C, while in men, they predicted serum triglycerides. In the present study, there was no interaction for the WHR and STR.

However, collapsed over gender, both ratios increased with increasing level of general obesity. This puts the obese group at a higher risk for CVD and a prime candidate for an intervention program, which is also true for the men, since they had more truncal and abdominal fat than the women.

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MOTOR PERFORMANCE OF LOWER EXTREMITIES IN 5-YEAR-OLD CHILDREN

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ABSTRACT

The aim of this study was to examine the motor performance of lower extremities in 5-year-old normal and speech-disordered (SD) children. A group of normal children (3 girls and 6 boys) was compared with a group of SD children (also 3 girls and 6 boys), and a group of normal girls (n=13) was compared with a group of boys (n=16). Bilateral (BL) and unilateral (UL) maximal isometric strength of the leg extensor muscles was measured by specially designed electromechanical dynamometer. Vertical jump from the standing position with preliminary counter-movement (CMJ) was tested on the force platform. The results indicated that BL maximal isometric strength was greater in normal than SD children, and in boys greater than in girls. Normal children had greater UL maximal isometric strength of the left and right leg compared with SD children. Boys had greater UL maximal isometric strength of the left leg than girls. BL strength deficit was greater in girls than boys. Normal children demonstrated greater vertical jumping height in CMJ as compared to SD children. No significant differences in vertical jumping height between the boys and girls were observed. It was concluded that the isometric force-generating capacity of the leg extensor muscles and jumping performance is considerably greater in 5-year-old normal children as compared to SD children.

Key words: 5-year-old children, leg extensor muscles, isometric strength, jumping performance, speech disorders

INTRODUCTION

Motor development in children, defined as a progress in motor performance, is influenced by growth and maturation as well as environmental factors, including habitual physical activity [4]. Muscle strength and power (explosive strength) of lower extremities are important characteristics of motor performance, which changes throughout the years of growth and maturation. Ability to recruit motor units and to coordinate the activity of agonist-antagonistic muscle groups under maximal voluntary muscle action are responsible for force-generating capacity of the muscles in prepubertal children. These mechanisms are closely related with maturation of nervous system, which includes myelinisation of the axons of spinal motoneurons [3, 7, 8].

Gender differences in muscle strength in prepubertal children have been contraversially reported. Some authors observed throughout the puberty moderately greater isometric and explosive muscle strength in boys compared with girls [10, 17, 18]. Other authors have not established any significant gender differences in muscle strength characteristics before puberty [3, 21]. Little attention has been paid to the examination of the gender differences in maximal and explosive strength characteristics in preschool children. No information is available about bilateral strength deficit in children, which has been reported in adult muscles [9, 15].

It has been observed that gross-motor and fine-motor skills in speech-disordered (SD) 4- to 9-year-old children are less developed than in Lage- and gender-matched normal children [2, 12, 16, 22]. However, the relationship between motor development and speech disorders in preschool children is poorly understood.

The purpose of this study was to compare the motor performance characteristics of lower extremities in 5-year-old normal and SD children, and normal girls and boys. More specifically, we examined maximal voluntary isometric strength of the leg extensor muscles and dynamographic characteristics of vertical jumping as indicators of explosive strength of the leg extensors.

MATERIAL AND METHODS

Subjects

Twenty nine 5-year-old children (13 girls and 16 boys) participated in this study. A group of normal children (girls and boys together) was compared with a group of SD children, and a group of normal girls was compared with a group of boys. Articulatory speech disorders were diagnosed by a phoniatrician. The physical characteristics of the measured groups are presented in Table 1. Informed parental consent was obtained prior to the children's participation in the experiment. The study carried the approval of the University Ethics Committee.

Table 1. The physical characteristics of the subjects. Mean± SEM.

Groups	n	Age (yrs)	Height (cm)	Body mass (kg)	Body mass index ($kg \cdot m^{-2}$)
Normal children (3 girls and 6 boys)	9	5.1±0.2	115.6±1.4	20.3±0.4	15.3±0.4
Speech-disordered children (3 girls and 6 boys)	9	5.4±0.2	116.2±1.5	21.0±0.4	15.5±0.4
Girls	13	5.3±0.2	115.5±1.3	21.3±0.3	15.9±0.5
Boys	16	5.3±0.2	115.0±1.2	20.3±0.4	15.3±0.4

Twenty-four to 48 hours before data collection the subjects were given instructions and the strength testing procedures and vertical jump tests were demonstrated. This was followed by a practice session to familiarize the subjects with the procedures.

Apparatus and Experimental Procedure

Maximal isometric strength of the knee extensor muscles was measured during unilateral (UL) and bilateral (BL) contractions. The subjects were seated on a specially designed dynamometric chair in a horizontal frame with knee and hip angles equal to 110° and 120°, respectively [17]. The body position of the subjects was secured by two Velcro belts placed over the chest and hip. The feet were placed on a footplate mounted on a steel bar held in ball-bearings on the frame. The isometric force production of the leg extensor muscles was recorded by standard strain-gauge transducer connected with footplate. The electrical signals from the strain-gauge transducer were digitized online (sampling frequency 1 kHz) using a personal computer. During testing the subjects were instructed to push the footplate as forcefully as possible for 2–3 s in three cases: (1) UL contraction of the right leg, (2) UL contraction of the left leg and (3) BL contraction in random order. Three trials were performed for each case and the greatest strength value was taken as the maximal isometric strength. Verbal encouragement to motivate producing maximal effort was given throughout each trial. A rest period of 2 min was allowed between the trials. During UL exertions the contralateral leg was allowed to rest. Bilateral strength deficit was calculated by the formula [9]:

$$\text{BL strength deficit} = 100\,[\text{BL} / (\text{UL}_{\text{Right}} + \text{UL}_{\text{Left}})] - 100\ (\%),$$

where BL — bilateral maximal isometric strength; UL_{Right} — unilateral maximal isometric strength of the right leg and UL_{Left} — unilateral maximal isometric strength of the left leg.

The vertical jumping tests were performed on force platform (PD-3A, VISTI, Russia) with the dimensions of 0.75x0.75 m and natural frequency of 150 Hz. Maximal counter-movement jump (CMJ) started from upright standing position immediately after a fast preparatory counter-movement that stretches the leg extensor muscles (eccentric contraction). This was followed by an explosive maximal extension in the opposite direction (concentric contraction). The subjects were instructed to jump with their hands on the hips to eliminate the influence of the arm swing impulse. Prior to the testing the subjects performed several preliminary trials. The following characteristics were recorded by a vertical force-time curve for each jump:

(1) Jumping height by the height of rise of the body centre of gravity:

$$H = g\, t_f^2 / 8,$$

where g is acceleration of gravity (9.81 m/s^2) and t_f flight time.

(2) Peak vertical ground reaction force ($VGRF_{peak}$).

Each subject performed three maximal jumps and the attempt with highest jumping height was used for further analysis. A rest period of 2 min was allowed between the jumps.

Data Analysis

Data are means and standard errors of the mean (±SEM). One-way analysis of variance (ANOVA) following by Tukey post hoc comparisons were used to test for differences between groups of children and for each leg. A level of $p<0.05$ was selected to indicate statistical significance.

RESULTS

The results indicated that boys had significantly greater UL maximal isometric strength of the left leg than girls (Figure 1A). However, no significant differences in UL maximal isometric strength of the right leg were observed between boys and girls. Normal children had significantly greater UL maximal isometric strength of the left and right leg as compared to SD children. BL maximal isometric strength was significantly greater in normal than SD children, and in boys greater than in girls (Figure 1B). BL strength deficit was significantly greater in girls than in boys (Figure 1C). No BL strength deficit was observed in SD chidren. Normal children demonstrated significantly greater vertical jumping height in counter-movement jump as compared to SD children (Figure 2A). No significant differences in vertical jumping height between the boys and girls were observed. Peak vertical ground reaction force during take-off in CMJ did not differ significantly between the measured groups (Figure 2B).

DISCUSSION

This study demonstrated that the force-generating capacity of the leg extensor muscles during UL and BL maximal isometric voluntary contraction is in 5-year-old normal children much greater than in age- and gender-matched SD children. Several central (neural) and peripheral (muscular) factors can determine the differences in muscle voluntary force-generating capacity. No significant differences in body mass and other anthropometric characteristics were found between the measured groups of children. The lower force-generation capacity of lower extremities in SD children seems to be limited by the ability to activate agonist muscles and/or to control antagonistic muscles during maximal voluntary effort. One possible factor may be less developed central processing mechanisms during voluntary effort in children with speech disorders. The neural control of muscles in children is closely related with the maturation of the nervous system. It has been suggested that the expression of muscle strength is dependent on the myelination of the motor nerves, which is not completed until sexual maturity [3, 7, 8]. Thus, the lower voluntary force-generating capacity of the leg extensor muscles in SD children compared with normal children is, possibly, related with differences in the development of motor control mechanisms.

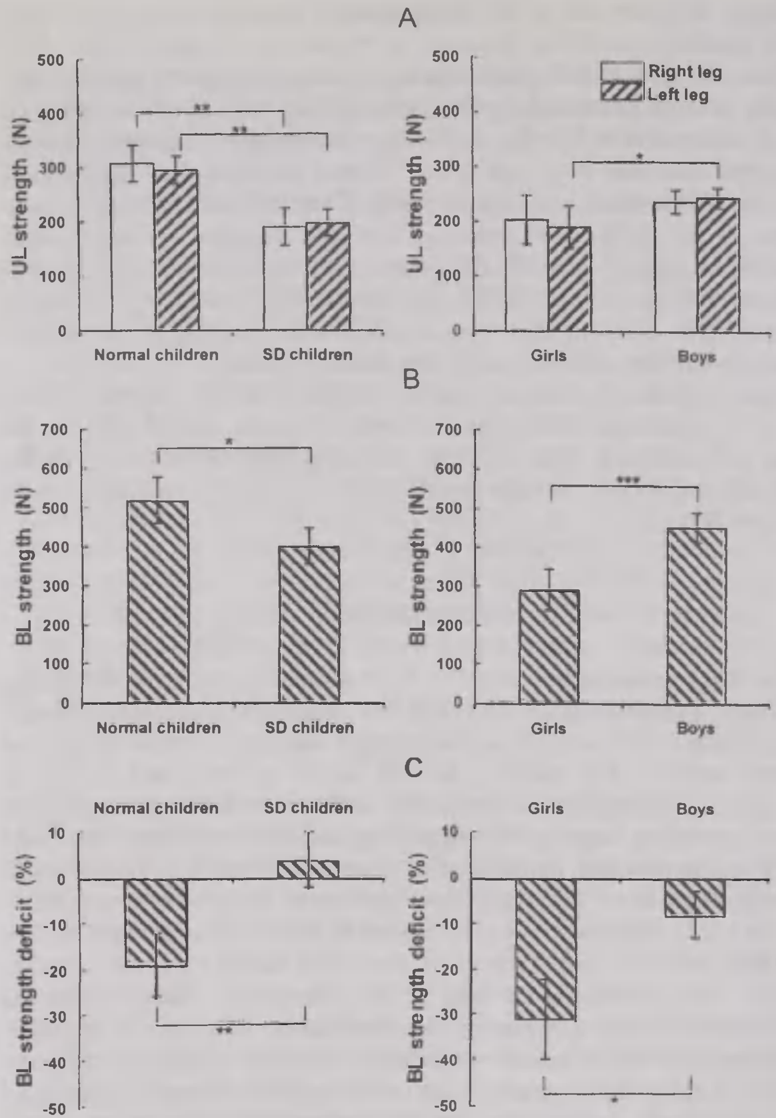

Figure 1. Mean (±SEM) unilateral (UL) maximal isometric strength **A,** bilateral (BL) maximal isometric strength **B** and bilateral strength deficit **C** of the leg extensor muscles in 5-year-old normal and speech-disordered (SD) children. * p<0.05; ** p<0.01; *** p<0.001

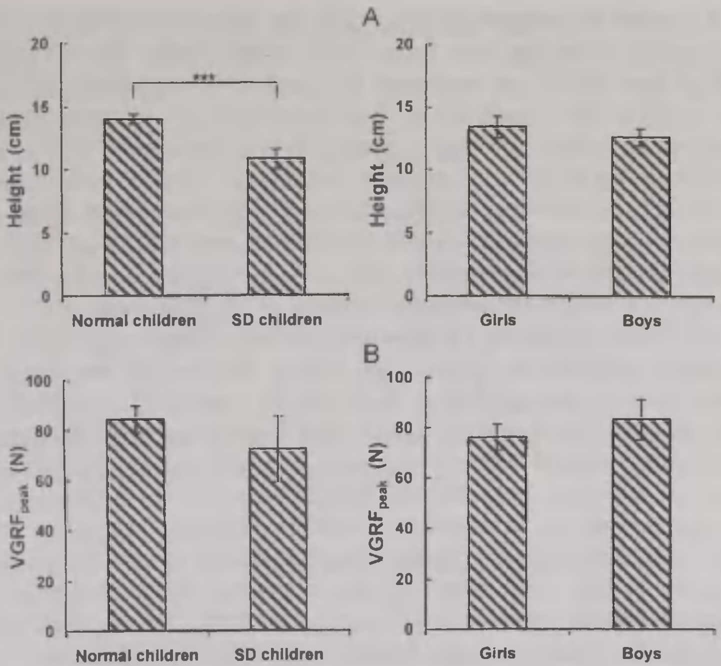

Figure 2. Mean (±SEM) jumping height **A** and peak take-off vertical ground reaction force ($VGRF_{peak}$) **B** in counter-movement jump in 5-year-old normal and speech-disordered (SD) children. *** $p<0.001$

This study indicated a markedly greater maximal isometric strength of the leg extensor muscles during BL contraction as well UL contraction for left leg in boys compared with age-matched girls. This is in agreement with preliminary studies [10, 17], indicating that over prepubertal period the boys have moderately greater muscle strength than girls. However, other authors [3, 21] have not observed significant gender differences in muscle strength characteristics before puberty. No significant gender differences in body mass and anthropometric characteristics have been found in the present study. The gender differences in force-generation capacity of lower extremities may be related to higher ability to recruit the motoneurones of agonist muscles during maximal voluntary effort in boys compared to girls and/or differences in muscle contractile properties. It has been observed that preschool boys have a greater number of muscle fibres in their muscles than age-matched girls [6, 8].

A marked BL strength deficit of the leg extensor muscles in 5-year-old normal children has been found in the present study. The mean values of BL deficit in girls and boys were 31% and 19%, respectively ($p<0.05$). Less information is available on lower extremity BL strength deficit in prepubertal children. However, several investigators have observed BL strength deficit of the leg extensor muscles in healthy adult subjects. Taniguchi [23] published that BL strength deficit ranged from 7% to 19% in male students. Secher et al. [20] reported BL strength deficit of 20% in untrained, 14% in weight-lifters and 24% in cyclists. The BL strength deficit described in the study of Schantz et al. [19] were 14% in the untrained male group and 8% in heavy-resistance trained male group.

Neural mechanisms rather than muscle morphology are the likely cause of the BL strength deficit. To determine whether BL strength deficit is due to neural mechanisms, Howard and Enoka [9] studied three groups of differently trained subjects (untrained, cyclists, and weightlifters). The results of this study indicated that interlimb interactions during maximal BL contractions are mediated by neural mechanisms. The nature of the neural mechanism must ultimately involve altered motor unit discharge frequency and/or recruitment during maximum BL contraction. The unilateral muscle contraction is mainly controlled by the contralateral cerebral hemisphere and the bilateral contraction is considered to be generated by the simultaneous activation of both hemispheres. However, the mechanisms of BL strength deficit themselves have been discussed and are still unclear. Therefore, one explanation for the BL strength deficit is that it could be neural interaction between the two hemispheres connected by comissural nerve fibres [13, 15]. It has been shown that BL strength deficit was associated with reduced movement-related cortical potentials caused by a mechanism of interhemispheric inhibition [5, 14].

A significantly greater BL strength deficit of the leg extensor muscles in girls compared with boys can be explained by the lower ability to coordinate muscles of the right and left side during bilateral maximal voluntary contraction in girls. No significant BL strength deficit has been observed in SD children. One possible explanation of this phenomenon is a lower ability to recruit motor units under maximal UL isometric voluntary contraction in SD children.

Vertical jumps can be used as a model to study explosive force-generating capacity of the lower extremities. The results of this study showed a markedly lower height of CMJ in SD children as compared to normal children. Vertical jumping is a multijoint movement and requires the intra- and intermuscular coordination, which describes the ability of muscles engaged in a movement, i.e. the ability of agonists, antagonists and synergists to co-operate in performing the task [1, 11]. The less developed motor coordination in SD children compared with normal children has been shown by several investigators [2, 16, 22]. The ability of the leg extensor muscles to develop force rapidly has prounonced influence on vertical jumping performance [1]. Our results indicated a markedly lower voluntary force-generating capacity of the lower extremities in SD children as compared to normal children.

It was concluded that the isometric maximal voluntary force-generating capacity of the leg extensor muscles and vertical jumping performance is considerably higher in normal children as compared to same-age SD children. These differences in motor performance of the lower extremities between the measured groups are not related to body size characteristics. The lower motor performance characteristics in SD children compared with normal children seem to be related to differences in the development of the motor control mechanisms.

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MODELING AND VISUAL PERCEPTION OF THE MOVEMENTS

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SUMMARY

Visual demonstrations or modeling have been used extensively as an instructional technique for a variety of skills. In fact social psychologists have long acknowledged modeling "to be one of the most powerful means of transmitting values, attitudes and patterns of thought and behaviors" [8]. In general, the theoretical explanations for the modeling process have corresponded with the psychological orientations of the era and have moved from instinctual interpretations [111] though classical conditioning [51], reinforcement [84], and more recently cognitive interpretations [6, 7, 8, 105]. The primary theoretical basis for observational learning in the last two decades has been derived from Bandura's progressive reformulations of mediational-contiguity theory [6], social learning theory [7] and more recently the social cognitive analysis of modeling [8].

Modeling can be defined as the cognitive, affective, and behavioral changes that result from observing others while models are individuals whose behavior, verbalizations, and nonverbal expressions are attended to by observers and serve as cues for subsequent behavior [101]. Traditionally, modeling has served three functions in affecting the perceptions and behaviors of observers [7, 8, 81]. First, observational learning effects represent the acquisition of new skills and behaviors by the observer, as exemplified by the use of visual demonstrations across millions of practical teaching situations. A second function of modeling concerns response facilitation, or eliciting already learned behaviors in observers. The third function of modeling is described as its inhibition/disinhibition effects on behavior. This function focuses on reducing avoidance behaviors through effects on observers' psychological responses such as self-confidence, motivation, and anxiety [131]. These psychological effects of modeling have been studied extensively and reported in the clinical, health, and educational psychology literature [35, 46, 81, 101, 109, 112]. The tree

functions of modeling account for developmental, learning, and social psychological changes in observers, and thus the topic of modeling extends knowledges from the areas of motor learning and control, motor development, and sport psychology [128].

A primary consideration in modeling is the impact of the observer on what is perceived in the demonstration and how this information is rehearsed. A second element that has received only limited attention in the motor behavior literature is movement perception which focuses on the perception of human motion. This is argued as an important aspect of modeling since observers must perceive the motions they are later required [81]. Recent developments in the perceptual psychology domain have attempted to reach a better understanding of what information cues are detected in demonstrations and how such cues aid in skill reproduction. On the other hand, arguments for increasing the ecological validity of the research paradigms are increasingly familiar in the motor control and learning field [108, 133, 134]. The main purpose of the current article is to review current research that examines issues related to the modeling and visual perception of the movements from theoretical as well as from the empirical point of view. The paper is divided into three main parts: (a) theoretical perspectives of modeling; (b) developmental factors related with the modeling; and (c) visual perception of movements.

Key words: modeling, observational learning, motor skills, visual perception

1. THEORETICAL PERSPECTIVES OF MODELING

The majority of observational learning research has been conducted in the last three decades. It would be a misconception, however, to think that modeling process has been ignored by psychologists in the past, for the study of imitation has a history dating back to the early works of Tarde [111] and McDougall [82]. These investigators suggested that modeling was a basic instinct, as it was characteristic of the social philosophical nature of the field as this time. Later, modeling was reinterpreted as a function of associative or instrumental conditioning [51, 54, 84] or from a developmental perspective [47, 91]. Of these theories, however, only the work of Miller and Dollard [84] was founded on a systematic data base. Yet little modeling and motor skill research was generated to test Miller and Dollard [84] predictions and the modeling-motor behavior relationship remained empirically unexplored.

The first systematic, long-term research program examining the relationship between modeling and motor skill acquisition was funded by Sheffield and his associates [105]. Based upon the findings of empirical research, Sheffield developed what may be called symbolic representational theory. In adopting a cognitive orientation he maintained that what is learned from a demonstration is a sequence of perceptual and symbolic responses. This perceptual behavior was thought to mediate overt performance through providing a blueprint by which to guide skill reproduction. Basically, Sheffield's symbolic representational theory postulates that observers symbolically code perceptual responses to sensory stimuli. This perceptual blueprint is thought to cue skill reproduction through matching overt behavior with the perceptual memory of the action. Despite this important early work by Sheffield, little theoretically-based applied research has been conducted on the modeling of motor tasks. Therefore, many important questions pertaining to modeling of motor tasks for effective learning remain unanswered.

Most of the researches examining the relations between modeling and motor skill acquisition during recent two decades have been based on Bandura's [7] social learning theory of modeling. According to Bandura, people must learn new response patterns either by direct experience or observation. Most human behavior falls into latter category and is learned observationally through modeling. Bandura proposed the necessary ingredients for achieving a desired response following a demonstration. This theoretical formulation advocates an informational-processing perspective in that the observer cognitively transforms or processes the modeled information and subsequently uses it to guide future behavior. The perception-action relationship is indirect, mediated by the verbal or visual coding of the features displayed in the demonstration. This sequence of events from demonstration to cognitive representation of action reveals several vulnerable stages in the modeling process. For the modeling process to be effective, the observer must retain an accurate cognitive representation as well as the appropriate behavioral response.

Scully and Newell [104] proposed an interesting alternative to Bandura's social-cognitive oriented theory of modeling. The salient information picked up from demonstrations, according to these authors, is that of the relative motion patterns. It is thought that in novel tasks, i.e., tasks in which a novel relative motion must be coordinated, demonstrations will be effective in providing the important cues, even if this information does not yield immediately the production of the appropriate set of relative motions. However, in motor tasks, where the movement patterns are already established, the information regarding the common motion to be picked up from a demonstration may not be as directly relevant to the observer's performance because of individual differences in optimization and hence, absolute motion.

1.1. Research implications

Many facts of modeling have been investigated in an attempt to provide empirical support for various aspects of Bandura's theoretical approach and to further understand the relationship between demonstrations and motor skill acquisition. Burwitz [19] conducted a series of experiments in which he found modeling to be effective in certain motor task situations and neutral or even detrimental in others. Using undergraduate students Burwitz found demonstrations beneficial to performance on the Bachman Ladder task, but not differences were found between the demonstration group and the control group for the pursuit-rotor task. Burwitz concluded that the correct strategy must be visible to the performer for demonstrations to be beneficial to future performance. Burwitz did not elaborate, however, the basis on which strategy is operationalized in this situation. Burwitz [19] found in a follow-up experiment that another major factor influencing the effectiveness of a demonstration was the performer's ability to perform activity. The task used was the shoot-the-moon game in which high scores can be obtained only by using the correct strategy. Although the demonstration presumably made this strategy visible, those who watched the demonstration had the lowest average score. Furthermore, no difference was found between a filmed demonstration by experts and live demonstrations even though the latter manipulations did not always lead to a perfect score. Burwitz [19] concluded that correct modeling was limited by the inherent task difficulty and that there are at least two prerequisite conditions for successful utilization of demonstrations in motor skill learning. These conditions are perception of the strategy or technique and the ability, innate or acquired, of the observer to imitate the demonstrated action.

Further testing of the assumption that observing a model facilitates motor performance through providing additional information was conducted by Martens et al. [77]. In the first three experiments male adult subjects were taught a ball roll-up task after viewing a film of a model either performing the task correctly, incorrectly or in a progressive learning sequence. In the control condition subjects did not view any filmed demonstration. The results indicated a significantly better performance by both groups of subjects viewing the films compared to the control group, but only over the initial 10 trials.

The second experiment attempted to determine why the modeling only facilitated early task performance. The same subjects and conditions were used with the addition of a second film shown to all subjects. The results of the model's performance in this film were not shown until after the subjects estimated the outcome of the demonstrated trials. Again results indicated that better initial estimates of performance were exhibited by both the correct model and the learning sequence model groups compared to the control group. Martens et al. [77] proposed that observation of a model provided task relevant information to assist in the development of a response.

These early investigations by Burwitz [19] and by Martens et al. [77] are both theoretically based and systematic in their approach. The findings are important in that they demonstrate that modeling procedures are an objective means of conveying pertinent information to observers in order that they learn motor skills more efficaciously. The findings also provide some support for Sheffield's early contentions that modeling effects are to a large extent dependent upon the nature of the task being used.

1.2. Cognitive elements

The influence of cognitive processing during motor skill acquisition has been central to much of the recent research efforts in the motor domain. Early theoretical views of motor learning suggested that the motor commands and the sensory feedback that resulted from the movement were all that needed to be stored in memory for learning to occur [2]. By this view, thinking was not too important for purposes of motor learning. More recent views stress the role of cognition in motor skills [14, 15, 73, 74, 99]. In general, cognition refers to a collective group of thought processes. The golfer without a clear shot to the green tries to remember how to hit a controlled fade. The hockey goalie tries to predict the direction of a shot by searching for perceptual clues that provide advance information.

Bandura [8] has proposed that observation provides a performer with the opportunity to develop a cognitive representation of a task sufficient to direct the initial efforts to execute a response. However, what exactly is learned by viewing a demonstration? Previously referred study by Martens et al. [77] clearly demonstrated that modeling affected the strategies adopted by subjects, which in turn affected the level of their performance. Other experiments have produced findings in support this notion [16, 19]. In the cognitive domain, numerous studies have shown that the use of appropriate strategies (i.e., "cognitive or behavioral activities that are under the deliberate control of the subjects") can enhance performance [34, 100, 106]. Strategy-use requires that individuals use cognitive resources to achieve a goal in certain task environments [71]. In the motor learning domain, research also demonstrated that when an appropriate strategy is taught to subjects and they are requested to use it, motor performance usually improves. This effect has been demonstrated with labeling [135], rehearsal [129], contextual interference [15, 67, 70] and organization [43].

A major characteristic of most of these studies is that cognitive strategies are studied in isolation, and little attention is paid to how the learner might use them together to reach goal [16]. A number of self-regulation theorists [8, 17, 138] have studied the actions learners spontaneously use to promote their own learning in the absence of external agents. These theorists are frequently interested in the use of self-regulated learning strategies, which Zimmerman [138] defines as the learners' "actions and processes directed at acquiring information or skill that involve agency, purpose, and instrumentality perceptions" (p. 329). The cognitive literature [34, 95, 96, 100, 106] clearly show that the learner is an active processor of information who can make numerous decisions and use strategies in a variety of ways to regulate his or her own learning.

Most self-regulation theorists postulate that cognitive processes are hierarhically organized [8, 20]. A higher level often called meta-level or executive-level [17, 71, 85], is responsible for strategy orchestration/ deployment, as well as the amount of time allocated to the use of particular strategies [8, 25]. In contrast, the function of the lower level is to execute the available strategies. Using an information-feedback loop, the meta-level can continually monitor the actions of the lower level [85]. Subsuquently this feedback can be used for error detection purposes and, hence, be used to control the use of lower level strategies [16].

A popular hypothesis among motor learning theorists is that movement information can be stored and rehearsed in the form of visual image [70, 76, 98, 108]. Although to date, researchers have not experimentally tested a direct link between mental imagery and modeling, innuendos have been made that the processes governing these factors may be similar [23, 29, 48, 52, 53]. In modeling, you observe someone perform, encode and rehearse this information, and then reproduce a response. In imagery, you typically think about what you are to perform, encode and rehearse this information, and then reproduce a response. Studies have shown that mental imagery is more effective in improving cognitive as opposed to motor task components [23, 39, 136] and a meta-analysis of the research [29] has supported this general notion. If modeling can be viewed as a form of covert rehearsal that primarily influences performance because task components are symbolically coded and if these representations provide the internal standard upon which reproduction is based, then the parallels between modeling and mental imagery may not be that distant [80, 81].

Housner [52, 53] has provided some data that indicate the relationship between imagery and motor modeling. It was his contention that imaginal coding strategies are similar to imagery and therefore people identified as having high ability to image should benefit more from modeling than people who have low imaging ability. Free recall as well as serial recall of performance was assessed, and imagery ability as found to affect only free recall [53]. The author discussed these findings by relying on the work of Paivio [87] and suggested that visual imagery may be important for recognition or free-recall situations whereas verbal processes may be more important for tasks that require temporal ordering of items.

As stated by Bandura's theory [7, 8], modeling experiences are maintained in memory through the mediation of symbols. The evidence suggest that the beneficial effect of rehearsal strategies depends on (a) meaningfulness of the stimulus in the case of verbal and numeric associations, and (b) extent of experience with the stimulus in imaginal rehearsal [9, 10, 29]. Consequently, if observing motor skill results in some cognitive representation of the skill then it would be possible to rehearse that skill through a mental process without motorically performing the skill. It may be that at highly skilled performance levels, the observation process itself is a mental rehearsal of the action. However, most often imaginal rehearsal is thought to occur without the presence of the stimulus event [81]. The individual is thought to reinstate the entire movement by "thinking" of it or "mentally practicing". Various theories have been proposed to explain how this process is possible by defining the way that information is stored in memory [14].

One of such theories states that the mental representation is in the form of propositions or a propositional network [62, 92]. That is, memory codes are in an abstract form that contains relationships among concepts [14]. Lang [62] suggest that the content of propositions includes the logical relationship among concepts. When an image has formed the visual information, motor activity, and emotions associated with the image are reinstated. Thus, imaginal rehearsal of a motor skill would include the entire elaboration of the associated propositional network [81]. On the other hand, the dual code theory states that information is represented in memory in the form of verbal codes or visual codes. The verbal codes are thought to store information which is auditory in nature while the visual codes are considered to represent spatial relationships. Basic to this notion is the assumption that memory systems are connected directly to the auditory and sensory modalities. Both Paivio [87, 88] and Finke [30, 31], among others, are proponents of this theoretical standpoint. Finke [31] has written that there appear to be some common neural mechanisms between imagery and visual perception. As a result of several conducted experiments, Finke [31] concluded, "when a person decides to create a mental image of a particular object, the kind of image that can be fashioned depends on the knowledge the person has about the object, such as size, color and shape. Then once the image is formed it can begin to function in some respects like the object itself, bringing about the activation of certain types of neural mechanisms at lower levels in the visual system". These statements, when putted in a motor learning context, suggest that to more elaborate the cognitive representation (through experience and observational learning) the more effective the imaginal rehearsal would be. On the basis of a meta-analysis, Feltz and Landers [29] concluded that the effects of imaginal rehearsal depend on the type of motor task. It might be that the content of highly cognitive tasks is more visually oriented and therefore results in greater mental elaboration than tasks primarily motor in nature. Thus, cognitive imaginal rehearsal requires fewer practice trials to be beneficial [81]. Since it has not been shown that there are individual differences in observational learning ability, perhaps those persons who are high vivid visual imagers might benefit on a greater extent from observing a visual model that would those individuals who are classified as predominantly kinesthetic imagers [80, 81]. This line of research could possible link the characteristics of imagery to the study of individual differences in observational learning and provide deeper theoretical understanding of the associations among visual perception, action perception, and observational learning [80].

1.3. Model characteristics

While it is recognized that a host of social, psychological, and developmental issues may impact the modeling process [8, 80], one issue that received renewed attention recently in the literature is model characteristics. Within Bandura's theory [6] model characteristics were originally hypothesized to influence the attentional phase of observational learning. It was presumed that observers would differentially focus their attention to relevant cues dependent on model characteristics. Model characteristics could include such factors as age [11], similarity [79], status [78], or skill level [61]. Two central issues related to skill level have been addressed in the literature. Whether the model is skilled or unskilled has produced contradictory findings [78, 127]. A basic assumption regarding the modeling process is that because the observer is attempting to reproduce the behavior of the model, the imitation of efficient strategies of correct model would best aid observer [70]. There also exists the generally held belief that observers symbolically represent the model's performance by creating a perceptual code. This cognitive representation is developed through repeated demonstrations and serves as referent against which comparisons are later made [80].

Sheffield [105] provided a theoretical rationale for the use of expert models. He argued that a perceptual "blueprint" of the modeled action would be represented in the memory of an observer. This blueprint was thought to serve as a perceptual referent against which the perception of concurrent action could be compared and corrected. Indeed, most of the empirical investigations that provide support for the benefits of observational motor learning have used skilled models [80, 81]. Although the theoretical predictions and the empirical evidence point to the preferability of observing skilled models, evidence indicates that beginners can derive learning benefits even from observing unskilled demonstrators [74]. Although most of this research is recent, it was anticipated many years ago by Twitmyer [120]. He compared two groups of subjects who learned to trace a pencil maze while blindfolded. Subjects in one group (the learning models), practiced the task in two different days. Subjects in a second group (the observers) watched and recorded the results of the learning models during this time. These observers then performed the task in a third day. Since the learning models performed without previous observation of a model, their results were used as control data. The performance of the observers was better than the models' performance in the very first trial, and remained better throughout the learning session. Although Twitmyer may have done first study using unskilled models in an observation experiment, a study by Adams [3] has sparked the recent research efforts. Similar to the Twitmeyer method, a model practiced in the presence of an observer, after which the observer practiced the task. In Adam's study, the model practiced a movement timing task for 50 trials and observed under one of two conditions. The two groups of observers differed in terms of the augmented feedback provided while observing: one group received the movement time augmented feedback that was delivered to the model, whereas the other group did not receive this additional information. Adams [3] found that the observers performed better that the models, with the best performance achieved by the observers who also received the models' augmented feedback.

While studies comparing the value of expert versus learning models in acquiring sport skills have begun [61, 127], research evidence is showing that, at a minimum, observing a learning model will be no less effective than observing an expert model. In some circumstances, it may even be more effective. The skill level of the model has an impact on the observer's cognitive effort to learn from the motor behavior that was demonstrated. An expert model provides a precise representation of how a skilled action would be performed. However, a learning model engages the observer more actively in the problem-solving processes that characterize learning [3].

2. DEVELOPMENTAL FACTORS OF MODELING

Although Bandura's [7] theory has been the basis for modeling research in the field of motor behavior, developmental issues regarding the modeling process were not addressed until a recent modification of social learning theory [8]. In a effort to explain developmental issues related to the modeling process, Yando et al. [137] formulated a two-factor theory of imitation. Their consolidation of other modeling theories [7, 91] was based on an extensive study of 4 to 13- year-old children. They found that age period from 4 to 7 years is a transitional stage in which a variety of related neurophysiological changes occur, resulting in increasingly more cognitive, perceptual, and motor organization. For example, evidence shows that the child's motor system comes under verbal system control during these years [33, 72] and that the predominance of visual systems in early years gradually gives way to symbolic and verbal representation at more advanced stages of development [18]. In addition, Patrick and Richman [90] found that by age three years, children are influenced by both the motor and verbal aspects of modeling, suggesting that we must examine both the motor behaviors of models as well as how they verbally describe their behaviors when considering developmental issues.

According to the Yando's two-factor theory of modeling, the first factor addresses the observer's cognitive-developmental level and specifically relates to his or her ability to reproduce modeled behavior. The second factor encompasses the observer's intrinsic and extrinsic motivational system. The cognitive-developmental factor controls the observer's imitative skill, whereas the motivational factor controls the amount of imitation produced. This theory is an outgrowth of many modeling theories and places a strong emphasis on developmental factors (i.e., attention span, memory capacity, coding capabilities and physical abilities). Both attention and retention capabilities are significantly different between children and adults. Age related differences in information processing have been supported by empirical studies [41, 126]. For example, children are slower at processing information and thus require more time to comprehend visual stimuli. In addition, they are unable to selectively attend to movement characteristics until about 12 years of age [41]. Children younger than seven tend to over-exclude visual cues and may detect only a portion of the task relevant information, for example attending only to the stance but not to the body transfer when observing a baseball batter. In contrast, children seven to 11 years of age tend to over-include visual cues, for example noticing the batter's brand of shoes as well as the correct position for batting. Furthermore, younger children have a limited memory capacity and less sophisticated retention strategies [41]. When older children and adults spontaneously invoke strategies such as verbal rehearsal and labeling to help remember, younger children will only adopt such strategies when prompted [131].

A more comprehensive studies on cognitive and memory development have been provided by Thomas et al. [113, 114] and Gallagher et al. [38, 39, 40, 41, 42]. They have demonstrated age differences in information processing capabilities, particularly selective attention, visual processing speed, and control processes such as labeling, rehearsal, and organization. For example, attention to appropriate movement characteristics proceeds from overexclusiveness in which a limited number of cues is utilized (up to ages 5–6) to overinclusiveness in which both relevant and irrelevant task stimuli are assimilated (between about 6 and 11–12 years) and finally to selective attention (over 11–12 years) [40]. Control processes also differentiate the younger from older child. Children less than 7 or 8 years of age do not tend to label or name modeled cues without prompting, or engage in spontaneous rehearsal to help remember movements. Finally, younger children do not have the cognitive abilities to effectively organize and chunk information as with grouping or recording strategies [113]. French and Thomas [37] suggest that the ability to use memory strategies contributes to the development of a knowledge base which, in turn, can enhance decision making, motor control, and actual execution of motor skills and strategies.

Several studies have examined developmental or age-related differences in modeling based primary on Yando et al. [137] theory as a theoretical framework. Feltz [28] studied the differences between children and adults as well as number of demonstrations on a balance task and found that both form and outcome scores differentiated the age groups. In addition, when subjects were asked to describe the demonstration which they saw, children were able to describe only one component of form correctly, as compared to the three components identified by the adults. Feltz concluded that children's performance was probably lower because of attentional and/or retentional deficits, and that model who verbalized skill components may have facilitated both cognitive and execution capabilities.

Weiss [128] specifically tested the cognitive-developmental hypothesis of Yando et al. [137] two-factor modeling theory. Weiss assigned children of two age groups (4 to 6 and 7 to 12 years) to a silent model (visual demonstration only) or verbal model (visual verbal explanation), with the task being a six-part motor skill obstacle course. Children were also asked or not asked to use verbal self-instruction to guide their motor performance through the skill sequence. Results revealed that older children performed equally well with either a verbal or silent model, and this was significantly better than the no model groups. The younger children, however, performed significantly better with a verbal model than silent or no model groups. Thus, the verbal cues provided with the model demonstration appeared to facilitate the younger children's performance, perhaps by focusing their attention to task-relevant cues or helping them remember the order of the skills. Weiss [128] suggested that the older children in her experiment benefited from either model because their cognitive-developmental level implied an ability to spontaneously rehearse the visual information, even in the absence of overt verbalizations by the model.

In a subsequent study, Weiss and Klint [130] further investigated the role of modeling and verbal rehearsal on motor skill performance. The task was six-part motor skill sequence consisting of components to be recalled. Children comprising two age groups (5 to 7 and 8 to 10 years) were assigned to one of four instructional groups (verbal model only, verbal model plus verbal rehearsal, verbal rehearsal only, and no model/ no rehearsal). Quantitative results indicated that the verbal rehearsal only and model plus rehearsal groups performed significantly better than the verbal model and control groups, regardless of age. However, qualitative analyses indicated that although the verbal model plus rehearsal and verbal rehearsal only groups were best for either age group, the two groups of children went about remembering the motor sequence in markedly different ways. Additional support for verbal models was reported by McCullagh [80]. These researchers concluded that presentation of a visual model benefited children's quality or form of performance, whereas the verbal explanations enhanced children's sequencing of skills. The effect of modeling on children's motor skill acquisition and retention was examined in a study conducted by Weiss et al. [129]. Results revealed that older children performed equally well under any of the modeling conditions during performance and learning. However, younger children's performance as well as learning was enhanced when they were provided with a verbal model and verbal rehearsal.

A recent study by Wiese-Bjornstal and Weiss [132] illustrates an evaluation of the outcome and process distinction as well as the recall and recognition distinction. It sheds light on the skill acquisition process via modeling and practice in young girls. It was one of the first modeling studies to exemplify a complex sport skill task and evaluate the matching of form to that of model. Objective kinematic assessments of performance form as well as outcome were obtained in 7-to 9-year-old girls. The results supported the hypothesis regarding the effect of modeling and practice on children's performance of a complex sport skill. Strong support was obtained for the hypothesis that, with increased observation of the model and increased practice trials, subjects better recognized correct form and perform more like the model. Both kinematic and descriptive form variables reflected significant trends across time and conditions toward performing more like the model. In addition, children exhibited better cognitive recognition of correct form as a function of increased exposure to the visual model.

The results of these developmental modeling investigations suggest that effective modeling strategies may depend on the cognitive-developmental level of the learner and the goal of the task. A "show and tell" model provides children both visual and verbal cues which has been found especially effective in facilitating attention and retention of skill components [128, 129]. In addition, research has consistently supported the notion that children would be prompted to employ rehearsal strategies and given adequate time to do so [58, 129]. Furthermore, children's attentional abilities, memory capacity, and use of rehearsed strategies must be accounted for when demonstrating motor skills. Finally, psychological responses such as self-efficacy, motivation, and anxiety are known to have dramatic effects on motor skill performance. This calls for employing modeling strategies such as model/observer similarity, coping versus mastery models, participant modeling, and model verbalization.

3. VISUAL PERCEPTION OF MOVEMENTS

3.1. Theoretical views of visual perception

A vision is the most heavily relied on sensory modality for environmental information and appears to be intimately related to the motor system, examination of how vision relates to action perception may aid in understanding observational learning. Two major theoretical positions have dominated research work in visual perception. The traditional computational (or indirect) perception theories and the ecological (or direct perception) theories differ in terms of their conception of the organization of the visual system and how it functions in order to provide veridical information about the world.

Marr [75], one of the leading contemporary theorists in the computational theory of vision, has suggested that there are at least three levels of explanation (and analysis) which must address a consolidated theory of vision. At the most conceptual level (the computational level) an integrated theory of vision must be able to specify the task the visual system must complete, including description of the raw informational sources available to support the task. At the next (algorithmic) level, Marr has argued that theorists with a belief in indirect perception must attempt to determine how the information available in the retinal image can be processed to meet the computational needs of the task. It is at this level that specific algorithms, processing mechanisms, and representations are needed to solve the computational task have to be discovered and tested. At the implementational level the concern must be with allow the algorithms to function [75]. Research operating from this indirect perception framework has tended to focus primarily at the algorithmic and implementational levels attempting to understand how systems like feature detectors operate in 'normal' vision and attempting to develop machine analogues to human vision [1].

The direct perception view of vision is grounded in Gibson's [44, 45] ecological optics and is thus also frequently referred as the ecological perspective. The basic premise underlying the Gibsonian view is that the retinal image is not the starting point for seeing; rather the information needed to guide the observer's actions is available in the structure of the light present at a point of observation. Direct perception theorists argue that the structure of the optic array (and the optic flow field generated by relative motion between the observer and objects within the environment) lawfully specifies inter alia the layout of the surrounding surfaces, the observer's motion relative to those surfaces, and the nature of events occuring within the surrounds [45]. The direct perception perspective, therefore, views the perceptual information available at a point of observation not as static and impoverished but rather as dynamic, rich, and complete [1]. In contrast to the views of computational theorists such as Marr [75], the direct perception approach, therefore, only recognizes effectively two levels of vision- an ecological level (roughly equivalent to Marr's computational level) and a physiological (implementational) level, with the research focus being actively at the first level [94].

Research from within the direct perception perspective focuses upon the search for invariants within the optic flow field capable of specifying the essential information to guide action- spatio-temporal invariants to specify direction, speed, and force, and to identify objects and events and the affordances they present for action. Such a focus encourages the use of natural experiments, where the maintenance of the functional links between perception and action is of paramount importance [68]. Therefore, an important consideration in assessing the relative importance of empirical research evidence must relate to the ecological validity of the experiment, i.e. the extent to which the experiments maintains normal rather than altered viewing conditions [1].

Theory of action perception articulated by Turvey [117] and Kugler et al. [60] supported an ecological viewpoint whereby action is examined in its natural context. "Adaptation to an environment is synonymous with the evolution of special biological and behavioral features that are compatible with special features of the environment" [36]. Thus, an organism exhibits skilled motor behavior as it adapts to the environment in which the movement occurs and which determines its behavior. The movements becomes the property of a physically constrained system [103]. However, for the movement to be coordinated in the environment there must be reciprocity between the action and perception [81]. From this theoretical view, action is thought to be executed through the control or groups of muscles referred to as "coordinative structures" [13, 115, 116]. These muscle groups function together as a unit and are sensitive to constraints in the environment, and individual commands to specific muscles are not a conceivable mode of functioning. Given the number of possible combinations of specific muscle groups, it would be impossible for the system to respond as efficiently and effectively as it would if all parameters had to be specified by the biological system [59]. The solution to this "degrees of freedom" problem, find their origin in the earlier work of Bernstein [13], is to conceptualize the system as functioning through coordinative structures [119]. Thus, the concept of action perception posits that visual perception of environmental constraints during biological motion results in alterations of the coordinative structures [32, 118, 119].

3.2. Research implications

The early research in motion perception involved examples of mechanical objects moving in space. Much of the subsequent research on the perception of biological motion is based on principles of mechanical motion perception [104]. In general, early research on mechanical motion highlights an intriguing paradox in event perception, that is, the apparent simplicity in perceiving even complex motion patterns [26, 93]. A minimum principle is thought to account for the functioning of the perceptual system, "other things being equal, that perceptual response to a stimulus will be obtained which requires the least amount of information to specify" [50]. This perceptual phenomenon of grouping physically separate stimuli made it necessary to clearly distinguish between the types of motion apparent in motion perception [104]. An acceptable principle originating from this early research is that absolute motion (the motion of any individual element in a configuration) is rarely, if ever, perceived. It is also agreed that absolute motion is a combination of common and relative motion (the motion of individual elements of the configuration relative to each other) [21, 22]. The perceptual system apparently determines the event by utilizing a minimum principle on common or relative motions [104].

In contrary to mechanical motion, Johansson [55, 56] used the term biological motion to distinguish human movement patterns from the motion of more rigid inanimate objects previously utilized in visual motion perception. Johansson [57] has shown (using the point-light technique which provides relative motion information in the absence of structural cues) that observers can differentiate a human walk from a wooden puppet walk. But how are observers able to do this? According to Cutting and Proffitt [21] events such as walking have an underlying structure regardless of the surface contours. It is the perception of invariance in the underlying structure of the event which gives rise to the ability to distinguish accurately the two forms of walking. Both topographic invariants and dynamic invariants provide the essential characteristics of structural relation in time. Cutting and Proffitt [21] defines topographic invariants as "structural properties in space that hold over the course of the event", and dynamic invariants as "rules that govern the nature of change over the course of the event".

The extant literature demonstrates that technical components of human movement are readily identifiable from point-light kinematic displays. However, little is known about the perception of other aspects of biological motion often presumed to enhance impressions of an observed performance. In this topic, some very interesting works have been done by Scully [102, 103]. Using the point-light technique Scully [102] has shown that observers can perceive and thus judge both technical execution and aesthetic qualities in balance beam routines almost as well as they do from the natural performance. Evidently the kinematics of transformational information provided in the point-light display were sufficient to evaluate performance of a known skill. In a followed series of experiments, Scully [102] attempted to determine in a sport skill context if the topological properties of the relative motion patterns are invariant and if the scaling of these relative motion patterns can be noted. Relative motion in this context was considered to be the displacement patterns of the limbs, while absolute motion was defined as the speed of the total movement. To test these concepts Scully used the overarm throw and the overarm bowl because the two patterns of movement are similar and yet distinct. Observers were asked to classify seven relative motion patterns comprised of one real action pattern of each skill, two abstraction patterns of each skill, and an ambiguous pattern. These seven relative patterns were presented at five speeds ranging from very slow to very fast. Observers viewing the point-light displays were able to classify correctly the real movement patterns 100% of the time and the abstractions of the bowl or throw 92–97% of the time. They were able to do this regardless of the speed of the movement presentation. Author concluded that topological or kinematic characteristics were perceived as invariant even though the absolute motion varied.

In experiment 2 the speed of point-light displays were varied. Three point-light speeds were used. For the real action patterns, there was no perception problem at all three speeds. However, observers perceived the abstraction patterns differently. These studies seem to link together the notion of the relationship between direct action and perception and lead to a greater understanding of what in the demonstration may be essential in observational learning. Since it was the relative motion pattern which was critical, it led to the conclusion that static demonstrations (still pictures) provide little information regarding coordination of the pattern [104].

3.3. Visual regulation of action in sport

The idea that regularities in the optic flow field can constrain movement behavior was amply demonstrated in early experiments of balancing in children and adults [65]. The dominance of vision when performing motor skills was clearly demonstrated in a classic experiment by Lee and

Aronson [64]. In a purpose-built room, with a fixed floor and moveable walls, considerable postural sway was induced in subjects by moving the walls slowly forwards and backwards. Subjects were compensating appropriately for what they perceived as forward or backward ego-motion signified by the changes in the visual flow field. The "moving room" experiment demonstrates the special priority we assign to vision on our daily activities. In that experiment, when the proprioceptive and visual systems provided conflicting information to the central nervous system, people gave attention to vision while ignoring proprioception [74]. During sport performance, it is impossible to avoid optic information. Light reflects from the take-off board at the end of a long jump runway, and from a volleyball in flight towards a backcourt defender. The earlier referred findings from Lee et al. [68, 69] and Lee and Aronson [64] suggest how regularities in the ambient optic structure may serve as a powerful source of information for co-ordinating and controlling the actions of sport performers. Perhaps the best developed of the optic invariants to which athletes may become attuned with experience is "tau" [63]. Tau (t_c) proposed as an optic variable which may be used to specify directly the time-to-contact of impending collision of an animal with an object or surface in the environment. It is defined as the inverse of the relative rate of dilation of an approaching object's image on the retinal plane of the observer [63].

The importance of time-to-contact information in the visual regulation of movements has been demonstrated in performing different motor skills [1]. Lee et al. [66], in a widely cited work on three female long jumpers, demonstrated that the flight times of the final few strides of the jumpers as they approached to the take-off board were directly modulated is response to t_c with the board. Lee et al. [66] hypothesized that this gait regulation was achieved through control of a single gait parameter, the vertical impulse applied during the stance phase. Hay and Koth [49] replicated the Lee et al. [66] experiment with 14 elite male and 14 elite female long jumpers and again observed the presence of visually-based adjustments in foot placement late in the athletes' approaches to the board although no postulations were made as to the precise nature of the visual control parameter. In addition, Meeuwsen and Magill [83] observed similar marked increases in the variability of foot placement in the final two strides (compared to earlier strides) for female gymnasts running up to perform a straight-body handspring vault. The control of foot placement again appeared to be modulated in response to t_c by altering the duration of the flight phase of gait through adjusting vertical impulse.

It is interesting to note that the use of visual t_c to regulate gait does not depend on the expertise of the person. Although the participants in the Lee et al. [66] study were highly skilled, novice long jumpers also have demonstrated similar stride-length adjustments consistent with the influence of t_c [12]. An analogous situation to that involved in adjusting gait to achieve a specific footfall position for take-off in any jumping activity occurs when normal running gait must be adjusted (to avoid stepping on loose stones and other obstacles) when running over uneven terrain. Warren et al. [125] showed that, in a treadmill version of this task, runners could adjust their step length to find appropriate footfall targets through simply adjusting vertical impulse and that the visual information needed for the accurate modulation of this gait parameter was the difference in t_c between two upcoming footfall targets. To examine gait adaptations further Patla et al. [89] had subjects voluntarily adjust their step length in response to visual cues presented at various times during the gait cycle. Direct recording of ground reaction forces indicated that step length modulation in response to t_c was achieved through alteration in both vertical and horizontal impulse. Although the precise nature and magnitude of the horizontal impulse adjustment during gait adaptation is the point of some contention [89, 124], and may well vary according to whether treadmill or overground locomotion is examined, the importance of t_c as the visual information source for gait adjustment has not been challenged.

The role played by the optical variable t_c in catching an object is much-debated issue in motor learning and control literature. This is actually a very complex skill since the optimal area for receiving the ball at the hand is very small- just above the palm and at the base of the knuckles [4]. Once the hand is oriented in the correct line of flight, a major problem is the timing of the crasp action. Closing the fingers too early results in the ball hitting the knuckles, too late and the ball may rebound out of the palm. The margin of error for catching a ball travelling at a speed 10 ms^{-1} has been calculated to be around 32 ms [4]. In a series of experiments, Savelsbergh et al. [97, 98] attempted to determine the effects of manipulating the optic structure on key kinematic variables of the grasp phase in one-hand catching. It was expected that the relative retinal expansion velocity of three types of ball would not differ due to their distinct sizes. In order to test this assumption, the authors used a small ball (diameter 5.5 cm), a large ball (diameter 7.5 cm) and a deflating ball condition to examine the kinematics of of the grasp during one-hand crasping. It has shown that the differing characteristics of each ball results in different kinematic profiles for the grasp action. Analysis of the data on the mean hand aperture at the onset of the crasping action for all three balls appears to show that the deflating balloon and large ball were treated similarly by the subjects. As the ball deflated during flight, and it came to resemble the smaller rather than larger ball, the kinematic profile of the catching hand changed accordingly. T_c only provides temporal information during interceptive actions. One interpretation of these data suggest that the order parameters underlying the grasp action may be coupled to control parameter information provided by the dynamics of the specific retinal image of each approaching ball. In addition, Wallace et al. [123] showed that t_c acts as the sole action trigger at a specific time-to-contact only when the object approaches the person directly, on a collision course with the eye. When the object is not on this type of trajectory, as when a person catches a ball off to the side or close to the ground, that person uses t_c along with other visual information to help him or her estimate time-to-contact. The person then must develop an appropriate movement strategy to successfully catch the object.

In a series of experiments, Elliott et al. [27] examined the effects of periodic visual occlusion on ball catching. Subjects were required to catch a ball with one hand while having their vision intermittently occluded by special goggles that could make the lenses either transparent or opaque. Results showed that the critical total view time was only 100 msec of the 1000-msec ball flight. More interestingly, participants were able to catch balls successfully when they intermittently saw brief snapshots (20 msec) of the ball every 80 msec during its flight. These results are remarkably similar to those reported for people walking on a balance beam and walking across a horizontal ladder whose vision was occluded intermittently [5]. Recently, arguments for increasing the ecological validity of research on visual perception of motor skills are suggested [86, 107, 108, 110, 134]. Abernethy [1] argues that simplistic or contrived laboratory tasks may negate the expert's advantage by (a) removing from the task the experimental basis for the expert's advantage, (b) introducing potential floor or ceiling effects in the measurement process, and (c) causing experts to function differently either by denying them access to information they would normally use, or by causing them to use different information to solve a particular problem. During recent years, some experimental and "ecologically valid" studies were conducted [108, 121, 122] examining the visual search during sports performance. With the continued advancement of technology, researchers have been afforded the opportunity to reduce the discrepancy between laboratory testing and the real-world environment. Thus, the production of more ecologically valid experimental tasks and more sophisticated instrumentation have advanced research possibilities which, in turn, enabled to analyze the visual search patterns in real sporting environment [108].

4. CONCLUSION

Modeling or observational learning has not received prolonged and systematic study in motor behavior and sport. Although Bandura's theories have generated a great deal of interest among social psychologists, surprisingly little theoretical research has been conducted examining the acquisition and retention of motor or sport skills. However, during recent two decades, several studies have been conducted to provide emprical support for various aspects of Banduras's theoretical approach to modeling. Several investigators are strongly advocated an interdisciplinary strategy incorporating both ideas and methods from motor learning, biomechanics, social psychology and other fields related to cognitive science in studying issues in motor learning. An enhanced understanding of the processes by which motor skills are learned can gained by studying complex motor responses in realistic settings and by examining whether cognitive processes involved in the learning and performance of simple motor skill under controlled in laboratory conditions were the same for complex motor skills under more naturalistic settings. Thus, arguments for increasing the ecological validity of the research are increasingly familiar in the sport and exercise psychology. An attempt to integrate theoretical and empirical research findings from divergent subdisciplines although a difficult task for future research, would help explain more of the variance in modeling of the motor skills.

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