DISSERTATIONES KINESIOLOGIAE UNIVERSITATIS TARTUENSIS

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MEELI SAAR

The relationships between anthropometry, physical activity and motor ability in 10–17-year-olds

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original papers, which will be referred to in the text by the Roman numerals (I–III):

I Saar M., Jürimäe T. The relationships between anthropometric parameters, physical activity and motor abilities in 10–17 years old Estonians. Journal of Human Movement Studies, 2004; 47, 1: 1–12

II Jürimäe T., Saar M. Self-perceived and actual indicators of motor abilities in children and adolescents. Perceptual and Motor Skills, 2003; 97: 862–866

III Saar M, Jürimäe T. Sports participation outside school is a main factor influencing total physical activity in children. Perceptual and Motor Skills, 2007; 105: 559–562

In all articles Meeli Saar has performed all measurements and statistical analyses individually. She has written the preliminary versions of all articles.

1. INTRODUCTION

Growth in children refers to measurable changes in body size, physique, and body composition – whereas biological maturation refers to progress toward the mature state (Beunen and Malina 1996). Growth focuses on size, and maturation focuses on the progress of attaining size (Beunen and Malina 1996; Faulkner 1996). According to Viru et al. (1999), the first critical period of biological maturation in regard to motor function is in infancy and early childhood, secondly at the age of 7 to 9, and the third critical period is during puberty.

In case of normal growth physical activity is an important development. Regular physical activity has important role in a child's health during childhood (Sallis and Patrick, 1994; Riddoch and Boreham, 1995; Dencker et al., 2006). Physical activity is indispensable for a healthy physical and cognitive development of children and young people. For growing into healthy adults, children and young people need physical activity. It is well known that a low level of physical activity in children is a risk factor of several diseases. The resulting prevalence of overweight and obesity, as well as the lack of physical activity has become a growing problem among children. If children and adolescents are not physically active, chances for later physical activity in adulthood are poor.

Organized physical activity outside school and participation in different competitions are the main factors due to which the physical activity level increases significantly in different ages and both sexes in children. Over the past decade, several organizations have recommended that children and youth participate in ≥60 minutes of physical activity each day (Biddle et al., 1998; US Department of Health and Human Services 2004). The ≥60 minutes can be accumulated throughout the day in school, during physical education and recess, during intramural sports, and in before-school and after-school programmes (Strong et al., 2005).

Normally children are more active than adults, but their activity levels decline as they move toward adolescence, and significant numbers of young people do not participate in recommended levels of physical activity (Pate et al., 2006). Physically active children are more fit than less active children and fitness can be increased by physical training (Baquet et al., 2003).

Motor abilities (physical fitness) can be thought of as an integrated measure of most of the body functions (musculo-skeletal, cardiorespiratory, etc.) involved in the daily physical activity. When physical fitness is tested, the functional status of all systems is actually being checked. This is the reason why physical fitness is nowadays considered one of the most important health markers, as well as a predictor of morbidity and mortality for cardiovascular diseases (Ortega et al., 2008). Basic motor skills in children (running, jumping, crawling, hopping, etc.) should be practiced regularly (Tokarski, 2005). Developmental level of several fundamental motor skills (throwing, jumping, running) is related with physical activity (Butcher and Eaton, 1989).

In the majority of daily tasks the child is primarily involved in short-term high – intensity exercise. However, most of the scientific literature is devoted to the study of maximal aerobic power. This situation is mainly due to the absence of an anaerobic "gold standard" comparable to the universally adopted maximal O_2 consumption criterion. Recent evidence confirm that aerobic performance has declined in children globally at the rate of – 0.46% p.a. since 1970 (Tomkinson and Olds, 2007). These changes are in stark contrast to those reported for children's anaerobic fitness test performance (Tomkinson and Olds, 2007).

Health-related physical fitness which is considered a significant health status (Bouchard and Shephard, 1994) is operationalized somewhat differently in field and laboratory testing. Normally, physically active persons are physically fit in a health-related sense and this relationship is causal (Livingstone, 1994). On the other hand the strength of this relationship in children and adolescents is moderate at best (Malina, 1995). Katzmarzyk et al. (1998) indicate a significant, but weak to moderate relationship between health-related physical fitness and physical activity in youth.

There are few studies about the relationship of physical activity and the level of motor abilities, e.g., endurance, speed, strength, coordination, etc. in young people. Freedson and Rowland (1992) mentioned that the best strategy for improving the health of children and adolescents thorough exercise may be creating a lifestyle pattern of regular physical activity that will carry over adult years rather than promoting childhood physical fitness.

Anthropometric parameters (length, breadths, circumference, skinfold thickness) together with motor ability and physical activity measures, provide more information on the development process of children. Finally, to understand better the relationships between growth (anthropometry), physical activity, motor ability and perceived motor ability in children, the complex investigations are recommended.

2. REVIEW OF LITERATURE

2.1. Growth of children

The term "growth" has been used in all developmental processes. Attention has to be paid to the variation in body height and body mass of children at a chronological age. The main purpose of anthropometry is to assess and monitor growth (Acheson, 1966; Hauspie et al., 2004). Growth refers to an increase in the size of the body or any of its parts. Growth does not cease when maturity is attained but continues throughout life as in almost organs and tissues there is a recurring cycle of growth. Individual parts of the body do not necessarily grow at the same rate and therefore the relative size and body mass of tissues and organs change through the life cycle (Armstrong and Welsman, 1997).

The tempo of growth is the relative rate of maturation and children may be identified as "early maturing" or "later maturing" compared with population norms (Tanner, 1962). The chronological age i.e., the timing at which a maturational event occurs relative to some population norm, is a measure of the rate of maturational progress, e.g. the age of menarche.

The weight-for-stature charts consider body weight distributions relative to specific stature. Age is not used when applying the charts, this approach assumes that the relationship of weight as function of stature is the same throughout the age range considered. The children who are usually short or tall for their age are evaluated without bias. The age-specific weight-for-stature slopes systematically increase during this period but the practical effects of this violated assumption are small (Roche, 1992). Weight-for-length and weight-for-stature are useful because weight is relatively more labile and sensitive to short-term effect of nutrition and infection than length or stature. Data for ratios of two measurements are related in as much as they summarize the relationship between two dimensions. They are usually presented relative to age. For example body mass index (BMI), whitch describes the ratio of mass (kg): body height $(m)^2$. BMI is the preferred anthropometric weight-stature indicator for children and adolescents describing overweight and obesity (Becque et al., 1988; Himes and Dietz, 1994). BMI is good for everyone at all ages. Chest circumference for nutrition assessment (Malina, 1991), waist: hip (and other trunk versus extremity ratios) for fat distribution (Bouchard and Johnson, 1988) and sitting height: stature for endocrine evaluations (Styne, 2001) are recommended to use.

The purpose of different anthropometrical measurements is to assess and monitor children's growth. Growth in height and body mass have been extensively used as indicator of health and nutritional status of children (Tillmann et al., 2002). In contrast, a more detailed data on growth, such as different lengths, breaths and skinfold thicknesses are not well documented

(Norton et al., 1996). It has to be considered that body mass and skinfold thicknesses are more environmentally dependent, while different length and breadths variables of the skeleton are more genetically determined (Arnold, 1969; Norton et al., 1996; Carter et al., 1997). However, the growth pattern of a child is the result of a continuous interaction between the child's genes and environment.

Before puberty the variation in boys and girls on the anthropometrical parameters is relatively small, the girls having more adipose tissue than boys (Siervogel et al., 1991; Jürimäe and Jürimäe, 2001). The puberty starts earlier in girls than boys, and is expressed in a quick increase in different anthropometrical parameters. Children's growth in height is especially quick during the first year, when it can be 30 cm (Roemmich and Rogel, 1995; Rolland-Cachera, 1995). Not all parts of the body experience the adolescent growth spurt at the same time (Satake et al., 1994; Barba et al., 2006). For example, different regions of the skeleton reach the peak rate of growth during adolescence at different ages (Satake et al., 1994).

All young people follow the same pattern of somatic growth from infancy through adolescence, but it is characterized by individual variation, both between and within sexes, in the timing and magnitude of changes. For a short period girls are often taller and heavier than boys and tend to experience the onset of puberty about two years in advance of boys. At puberty differences in body shape become apparent between the sexes and boys experience marked increases in muscle mass (Armstrong and Welsman, 1997).

Anthropometric measurements (ISAK, 2001) have been used in different ways to study the growth of children:

1. Directly (e.g. skinfolds, circumferences, breadths, diameters) (Rolland-Cachera, 1995);
2. Indices (e.g. body mass index) (Susanne and Bodszar, 1998);
3. Areas (e.g. upper arm muscle area based on arm skinfolds and arm circumference) (Gutin et al., 1996);
4. Regression equations relating body density to anthropometric measurements for a reference population (Parizkova, 1996).

2.1.1. Somatotype

One of the useful indirect techniques of evaluating physique characteristics is somatotyping. It is a composition of human body (Carter, 1996; Carter et al., 1997). The Heath-Carter anthropometric somatotype method is the most commonly used (Heath and Carter, 1967; Carter, 1980; Carter and Heath, 1990). This method divides the human body into the following components:

1. **Endomorphy** refers to the relative fat of subjects. This component characterizes the amount of subcutaneous fat on a continuum from the lowest to the highest values.
2. **Mesomorphy** refers to the relative musculoskeletal robustness in relation to stature. This component characterizes skeletal muscle development on a continuum from the lowest to the highest values.
3. **Ectomorphy** refers to the relative linearity and fragility of the body. This component expresses the predominance of body surface area over body mass.

The combined rating of each component describes an individual's somatotype. If one component is dominant, the somatotype is described by that component (Carter and Heath, 1990). There are three ways of obtaining the somatotype:

- The *anthropometric method,* in which anthropometry is used to estimate the criterion somatotype.
- The *photoscopic method*, in which ratings are made from a standardized photograph.
- The *anthropometric plus photoscopic method (*Carter and Health, 1990)

According to Carter and Heath (1990), the somatotype is an overview of the total physique, which is independent of body size (Heath and Carter, 1967; Carter et al., 1997). In different growth studies, evaluation of the somatotype is particularly important in providing estimates of changes over time associated with children's growth and development (Carter et al., 1997). Previous research has shown that changes in somatotype in children can provide valuable information for understanding their growth and maturity (Claessens et al., 1985; Toselli et al., 1997). For example, Parizkova and Carter (1976) stressed the importance of assessing patterns of growth in individual children rather than relying on group means. In a comprehensive review of longitudinal studies on development and change in somatotype, Carter and Heath (1990) concluded that both individual and group somatotype changed with age and that individual patterns of change are important but could be masked by group variability.

In general, it is well known that males are more mesomorphic and less endomorphic at most ages in comparison with females, while differences in ectomorphy components between sexes are less in most studied samples (Carter and Heath, 1990). Eiben and Nèmeth (2001) underline that changes in proportions and body composition during puberty are mirrored in somatotypes.

Many studies have investigated somatotypes of children in pubertal years (Prokopec and Stehlik, 1988; Duquet et al., 1993; Hebbelinck et al., 1995; Carter et al., 1997; Eiben and Nèmeth, 2001) and peculiarities of sexual maturation (Marshall and Tanner, 1969, 1970; Duke et al., 1980; Lindgren, 1996; Bodzàr, 2000; Macias-Tomel et al., 2000) typically in terms of pubertal stages described by Tanner (Tanner, 1962). Studies in Estonian prepubertal (9- to 11-year-old) children have shown that the dominant component is the mesomorphic one (Jürimäe et al., 1999). With regard to sex-linked differences, the endomorphy was significantly higher in girls, while boys presented significantly higher value for the mesomorphy. No significant differences were observed in the ectomorphy component between boys and girls (Jürimäe et al., 1999). The same sex-linked differences were also observed in another study of 8–9-year-old prepubertal children of Estonia (Veldre, 1996). This is in accordance with the results of 8–9-year-old children in Hungary (Buday, 1990) and Belgium (Hebbelinck et al., 1995). Is the individual somatotype constant, the ways and extent of its change, can adult somatotype be predicted from that of early childhood – these problems are related to the dependence of the somatotype on the environment (Bodzsar and Susanne, 2004).

The fact that female sexual maturation occurs earlier may be explained by the phase lag between the growth spurts of bone and muscle in males and this may contribute to an unstable mesomorphy during puberty. In late stages of female puberty correlation of mesomorphy with age is moderate but closer to the respective index of the boys. Changes of fat distribution occur mostly linked with changes in the somatotype. At the age of 6 the somatotypes of two genders already differ, but until about age 10, the differences do not increase. After this age, however, the changes in first and third components of males and females take an opposite direction, so by the end of puberty, the dimorphic adult somatotype is fully developed. Even adult somatotype is subject to not negligible change depending on life style, nutrition, and physical activity (Zuk, 1958; Heath and Carter, 1971), although some authors regard the somatotype as stable (Claessens et al., 1986; Beunen et al., 1987).

In conclusion, there is a considerable variation in somatotype among children and adolescents, and the differences between sexes lie greatly in the distribution of somatotypes in samples of boys and girls in different ages. Somatotype and its variation are stable features of a person from late childhood, being related to individual differences in the timing and tempo of the adolescent growth spurt and sexual maturation.

2.2. Physical activity in children

Physical activity is defined as a complex set of behaviours that encompass any bodily movement produced by skeletal muscles that result in energy expenditure (Casperson et al., 1985). Physical activity is a component of total energy expenditure, which includes resting metabolism, the termic effect of food, and growth (Rowland, 1998; Baranowski et al., 1992). Physical exercise refers to planned, structured, systematic and purposeful physical activity. Children's and adolescents habitual physical activity is difficult to assess in the context of promoting health (Perusse et al., 1989; Armstrong, 1995).

There are more than 30 different methods of assessing physical activity. Some have been identified but the validity, objectivity and reliability of these methods have not been established with children and adolescents (Sirard and Pate, 2001; Trost, 2001). Measurement methods used to assess physical activity in children include the following procedures (Melanson and Freedson, 1996; Harro, 1997; Harro and Riddoch, 2000; Jürimäe and Jürimäe, 2001):

- questionnaires are commonly used that are directed to the child, parent, or teacher;
- direct observation which lies in monitoring and/or videotaping children in their normal environments;
- activity recall or record is often a subjective method as time is difficult to recall and children cannot provide accurate information about their activities;
- mechanical motor sensors are less costly and time- consuming and also more sensitive to variation in physical activity than many other methods;
- heart rate monitoring is used as a valid and practical indicator of physical activity in children;
- indirect calorimetry is an accurate technique for assessing daily physical activity and determines energy expenditure from oxygen consumption and carbon dioxide production, and
- doubly labeled water is used for the validation of other less direct measurements of physical activity.

The available techniques can be grouped into four categories:

- self-and/or proxy-report;
- observation;
- motion sensor monitoring; and
- physiological analyses.

Self-report and/or proxy-report. Self-report of physical activity is one of the most widely used methods in epidemiological research due to the ease and low cost of implication. Self-report methods include retrospective questionnaires, interviews-administered recall, activity diaries, and mail surveys (Washburn and Montoye, 1986; Sallis, 1991). Proxy reports by parents and/or teachers have been employed in studies with children (Murphy et al., 1988; Noland et al., 1990) and some studies have estimated the level of physical activity through self-report of surrogate measures such as sports participation (Hendry, 1978). Considerable demands are placed on the child`s cognitive abilities to recall specific events from the past (Simons-Morton et al., 1987). Self-administered questionnaires are believed to be less accurate than those administered by an interviewer (Montoye and Taylor, 1984) and large discrepancies have been demonstrated between the two methods (Wessel et al., 1965). Physical activity diaries have been reported to be superior to retrospective questionnaires, but some studies have found that the quality of completed diaries is inconsistent with children (Watson, 1974). Diary measures place a heavy burden on the subjects and keeping a diary may in itself influence physical activity habits (Salonen and Lakka, 1987; Sallis, 1991). Parents and teachers can only give secondary information, especially when it concerns activities outside home or school, and proxy-reports therefore tend to be unreliable (Saris, 1985).

The major advantage of self- and proxy-report measures of physical activity is their low cost. The measures can be used easily with large numbers of subjects and, consequently, despite the well-documented methodological problems concerned with young people's self-reported physical activity, the vast majority of available data have been generated in this manner. Self-report measures do not appear to be useful with children under 10 years of age and with older children and adolescents results must be interpreted with caution. Converting self-report measures of physical activity into predicted energy expenditures is not tenable (Sallis, 1991).

Observation

The assessment of physical activity through the use of observation has inherent appeal and recent technological advances permitting complex observational codes to be entered, stored and analysed by microcomputers have stimulated research into children's physical activity patterns using observational techniques (McKenzie, 1991). Children's physical activity levels can be observed reliably, and observers can be quickly trained to record accurate information. Although instruments, such as the Children's Activity Rating Scale and the Fargo Activity Time Sampling Survey, have the potential to provide valuable information about children's physical activity patterns, comparisons of different systems have not been conducted (Klesges et al., 1984; Puhl et al., 1989).

Motion sensors. Accelerometers

Electronic motion sensors, known as accelerometers, which measure both frequency and intensity of movement in the vertical plane have largely replaced movement counters in physical activity research (Janz et al., 1995). The most popular instrument is the Caltrac accelerometer. The validity and reliability of the Caltrac have been studied in children and although its use has been supported, it has been suggested that sporadic activity patterns may not be adequately represented by a simple unidimensional device (Bray et al., 1992). The Tritrac-R3D activity monitor has been recently developed to correct some of the limitations of the Caltrac monitor. Both Caltrac and Tritrac can be programmed to estimate energy expenditure using basal metabolic rate estimated from stature, body mass, gender, and age, plus total caloric expenditure estimated from activity. This methodology makes a number of unsubstantiated assumptions and for research purposes it is advisable to use activity `counts` as the criterion measure (Freedson, 1991). In recent years accelerometers

(Actigraph) have gained popularity as an objective measurement device for daily physical activity. Dencker and Andersen (2008) presented an excellent review about the use of accelerometers for the measurement of daily physical activity in children. Nowadays the most commonly used accelerometer in physical activity studies is the Actigraph.

Physiological analyses. Energy intake

As young people are subject to the law of conservation of energy, if energy intake is measured over an extended period of time (at least 7 days) and changes in body mass are taken into account, physical activity (energy expenditure) may be quantified in terms of energy intake (Block, 1982). Methods can vary from weighing and analysing the energy content of duplicate food portions to 24 h recall techniques. As self-report methods are the only feasible techniques for large studies, accuracy depends upon the subject's ability to recall and describe the kind and amount of food eaten. A further limitation of dietary estimates is the inability to identify the frequency, duration, and intensity of physical activity (Puhl, 1989).

Energy expenditure

Energy expenditure can be directly measured by determining oxygen uptake (indirect calorimetry), if it is assumed that daily physical activity is almost entirely aerobic. The measurement of VO_2 requires a means of assessing expired respiratory gas volume and analysing it for oxygen and carbon dioxide content (Armstrong and Welsman, 2006).

Heart rate monitoring

A number of self-contained, computerized telemetry systems have been developed for the measurement of heart rate. Typically, these systems consist of a lightweight transmitter, which is fixed to the chest with electrodes, and receiver/microcomputer witch is worn as a watch on the wrist. They are socially acceptable, they permit freedom of movement, they are not immediately noticeable, and therefore should not unduly influence the child's normal physical pattern (Leger and Thivierge, 1988). In comparison with other forms of physiological analysis, heart rate monitoring is the most suitable single method for use in large-scale physical activity studies with children (Saris, 1986). It provides an objective assessment of physical activity patterns and estimation of total energy expenditure of population groups, although its value in predicting individual energy expenditures remains to be proven (Armstrong and Welsman, 1997).

Low to moderate relationships have been reported between self-report measures and heart rate (Biddle et al., 1991) and with monitoring using motion sensors (Sallis et al., 1993). The assessment of young people's habitual physical activity is extremely complex and all current methods have deficiencies. Comparing data generated using different methods is simplistic and, ideally, a combination of different techniques should be used.

During the teen years physical activity consistently declines with age (Armstrong and Welsman, 2006). Two Swedish studies age range of 7–14 years reported that girl`s activity declines with age and although boys` physical activity declines too, this may not commence until the early teens (Skalik et al., 2001; Raustorp et al., 2004). The most substantial study of European children's physical activity using accelerometry was carried out as part of the European Youth Heart Study (Riddoch et al., 2004). As significant gender difference emerged in physical activity with 9-year-old and 15-year-old children: boys of both ages were considerably more active than girls. Riddoch et al. (2004) have reported the results across Denmark, Portugal, Estonia and Norway considering physical activity levels, age and gender differences in children of four countries.

A low level of physical activity in children is a risk factor for several chronic diseases. In Spanish adolescents, sports participation affected perceived health directly and indirectly by decreasing smoking and alcohol consumption, and feelings of depression and psychophysiological symptoms (Pastor et al., 2003). Fox (1988) contended that the physical subdomain of self-esteem consists of several specific subdomains, such as sport competence and physical appearance. In Hong Kong adolescents (Chan et al., 2003), participations in physical activity and body composition expressed as skinfold thicknesses were the two most important predictions of self-perceived fitness. When adolescents and children participate in sports, they tend to perceive their fitness better. As a rule, boys and girls who participate in sports programs are more physically active (Sirard et al., 2006). Finally, sports programme participation has been associated with mental health benefits (Seefeldt and Ewing, 1997).

There is a large proportion of children who do not take part in extra-curricular physical activities (Daley, 2002). There are few studies where the influence of sport participation and taking part in competitions for obtaining recommended level of physical activity has been studied. It was hypothesized that the sport participation is the most important predictor of total physical activity. It is important that school-age physical activity appears to influence adult activity (Telama et al., 1994; Telama et al., 2005; Anderssen et al., 2006).

Whilst children are free to choose their recess activities in school, they are consistent in their choices, limiting physical activity variability. No significant variation in children's recess physical activity levels has emerged across days and seasons (Ridgers et al., 2006).

It seems that although the "active school" model promises to promote school-based physical activity, few intervention trials have evaluated its effectiveness. The use of the "active school" model, can positively alter the school environment (Naylor et al., 2006).

Decrease in physical activity levels and substantial increase in childhood obesity have been argued to coincide with increase in sedentary behaviours.

This was the reason because the national physical activity guidelines for children (Spinks et al., 2006) and a physical activity skill-development program for overweight obese children were published recently in Australia (Cliff et al., 2007). However, the effects of physical activity, drive for thinness, body dissatisfaction and weight concerns were not positively or negatively influenced by the intervention (Gehrman et al., 2006).

Many studies have investigated relationships between physical activity, television viewing and body fat in children and adolescents (Bergman et al., 1998; Hager, 2006; Marshall et al., 2006). Cooper et al. (2006) have reported that TV viewing may have cumulative effects on energy balance and this may lead to accumulated body mass and subsequent obesity. The potential weight change associated with TV viewing lies not with resting energy, but some combination of changes in energy intake and physical activity.

Ferreira et al. (2006) conducted a systematic semi-quantitative review of 150 studies on environmental correlates of youth physical activity published in the past 25 years. The Analysis Grid for Environments Linked to Obesity (ANGELO) framework was used to classify the environmental correlates studied. Most studies retrieved used cross-sectional designs and subjective measures of environmental factors and physical activity. Variables of the home and school environments were especially associated with children's physical activity. Most consistent positive correlates of physical activity were father's physical activity, time spent outdoors and schools physical activity-related policies (in children), and support from significant others, mother's education level, family income, and non-vocational school attendance (in adolescents). Low crime incidence (in adolescents) was characteristic of the neighbourhood environment associated with higher physical activity. Convincing evidence of an important role for many other environmental factors was, however, not found.

In conclusion, physical activity in childhood is important and influences the health in adulthood. For the assessment of physical activity in children there is no universally accepted method. However, physical activity behaviour tends to track moderately from childhood to adolescence (Kristensen et al., 2008). Physical activity is a complex phenomenon with different dimensions and the assessment of young people's physical activity patterns is difficult. A number of techniques have been developed and all have both merits and limitations. No single "gold standard" has emerged and ideally a combination of methods should be used. The ideal combination of techniques required for a comprehensive evaluation of youngsters` physical activity patterns is likely to remain impractical for use with large numbers of young people in the foreseeable future. Males between the ages of 6 and 17 years have been estimated to be 15–25% more physically active than females of the same age (Sallis, 1993). During childhood and adolescence both boys and girls reduce their physical activity as they grow older but the rate of decline is 2.5 times greater in girls than in boys (Sallis, 1993). Similar results have been presented in European youth by

Armstrong and Welsman (2006). European boys of all ages participate more in physical activity than European girls and the gender difference is more marked when vigorous activity is considered. The physical activity levels of both genders are higher during childhood and decline as young people move their teen years. There are no clear country differences in the participation in leisure time physical activity between the Baltic countries and Finland (Harro et al., 2006).

2.3. Motor ability and physical activity

Several motor ability test batteries were presented first in Canada in the early 1980`s (Mosher et al., 1982) and then in United States (Cooper Institute for Aerobics Research, 1987; American Alliance for Health, Physical Education and Dance, 1988; Looney and Plowman, 1990). In Europe the EUROFIT test battery was presented in 1988 (EUROFIT, 1988). The highly standardized European Fitness Test Battery has been used to assess the affects of physical education and to measure the health-related fitness of schoolchildren. EUROFIT comprises numerous health- and performance- related fitness tests, including; 20m endurance shuttle-run, handgrip strength, standing broad jump, flexed arm hang, sit-ups, 10 x 5m shuttle-run, plate tapping, sit-and-reach and Flamingo balance. Recently excellent review about the EUROFIT tests results were presented by Tomkinson et al. (2007). Higher performance levels of young people from Northern and Central Europe were found to be due to the place of exercise and sport in the national psyche, the background expectations regarding physical activity, and the tradition of participation.

Whether a relationship truly exists between the physical activity levels of children, their motor abilities level and their anthropometric parameters is controversial. This is partly due to the variety of self-report methods (e.g. questionnaires) and objective methods (e.g. movement counters) used in studies to quantify physical activity (Rowlands et al., 1997). As a rule, there is a close relationship between physical activity and aerobic fitness in adults (Blair et al., 1989), but this relationship is questionable in children (Morrow and Freedson, 1994), or in some studies this relationship was significant (Rowlands et al., 1999). Physical activity may have different effects on motor abilities and probably the intensity of exercising is the important factor in several studies (Butcher and Eaton, 1989; Gutin et al., 2005; Ruiz et al., 2007) emphasized that only vigorous physical activity is associated with the highest cardiorespiratory fitness level in children and adolescents. There is a lack of studies about the relationship of physical activity and the level of other motor abilities, e.g. speed, strength, coordination, etc. (Freedson and Rowland, 1992). Rowlands et al. (2000) mentioned that the best strategy for improving the health of children and adolescents thorough exercise may be creating a life-style pattern of regular physical activity that will carry over adult years rather than promoting childhood physical fitness.

The motor ability of Estonian and Lithuanian children was comparable with children of other European countries. Results of some tests were significantly better in Estonian children compared with Lithuanian children of the same age and sex (Jürimäe and Volbekiene, 1998).

2.3.1. Motor abilities (physical fitness) in children and adolescents

Physical fitness is the capacity to perform physical activity and makes reference to a full range of physiological qualities (Fox and Biddle, 1988; Ortega et al., 2008). Physical fitness is a product of training (physical activity) and heredity. Physical fitness characteristics are at least moderately determined by genes (Bouchard et al., 1992; Thomis et al., 1998; Tiainen et al., 2004). Physical fitness is a concept which refers to a set attributes that relate to the ability to perform physical activity (Casperson, 1989).

It is widely believed that the secular trends of children and adolescents on aerobic fitness tests, in physical performances and in cardiorespiratory fitness and body mass index are declining (Tomkinson et al., 2003 (a, b); Moller et al., 2007).

Some data suggest that secular changes in fitness test performance, while consistent between children of different ages and sexes, varied by test and were not always in line with European or global changes. Recent study described secular changes in EUROFIT test performance of children and adolescents from Estonia and Lithuania. It also showed that on the average, Estonian and Lithuanian children outperform their European colleagues in fitness tests (Jürimäe et al., 2007).

In the literature there are many studies about the health-related fitness in the youth ages and relationships between adolescent physical activity and adult health-related fitness (Marshall et al., 1998; Mikkelsson et al., 2006). There are three main health-related physical fitness components – endurance, muscular fitness and speed/agility (Ortega et al., 2008). The first laboratory-based studies of children's aerobic fitness were carried out by Morse et al. (1949) and Astrand (1952) and the findings of these pioneer works have since been supplemented by data from most parts of the world (Bar-Or, 1983; Krahenbuhl et al., 1985).

Mikkelsson et al. (2006) had reported that relationship between fitness tests and adult health-related physical fitness was moderate. Preadolescents who have high adiposity are more likely to remain the same into adolescence. Stable adiposity characteristics may induce greater risk for developing diseases later in life (Marshall et al., 1998). The same problems are indicated in young Finnish men during the last 15 years – the increase in body mass and the decrease in physical fitness (Santtila et al., 2006).

Lifetime programmes targeting fitness components have poor tracking (Trudeau et al., 2003). Daily physical activity between 13 and 27 years of age reported in a higher cardiorespiratory fitness at 27 years (Kemper et al., 2001).

From the somatotype components, mesomorphy has a low positive and endomorphy negative correlation with physical fitness (Carter, 1990). Ectomorphy shows either none or a slight positive association with physical fitness test scores (Beunen et al., 1977).

The relative importance of aerobic fitness and habitual physical activity to short- and long-term health has been widely debated (Armstrong, 1992). The evidence linking young people's aerobic fitness to their level of physical activity is, however, conflicting and must be interpreted in the light of the problems associated with assessing both physical activity and aerobic fitness. However, the simple explanation for the lack of relationship between habitual physical activity and aerobic fitness probably lies in the low level of physical activity of most young people. Children and adolescents rarely experience physical activity of sufficient intensity and duration to increase peak VO_2, and structured exercise training programmes appear to be necessary for the improvement of aerobic fitness (Armstrong and Welsman, 1997).

In conclusion, there is little evidence to suggest that young people have low levels of aerobic fitness and it appears that the peak VO_2 of children and adolescents has remained remarkably consistent over the last 50 years. Habitual physical activity has little or no relationship with peak VO_2 probably because young people rarely experience the amount of physical activity associated with the promotion of aerobic fitness.

Exercise training during childhood and adolescence does not induce permanent increases in aerobic fitness and once training stops its effects begin to decay. In this context it may therefore be more important to engender positive attitudes to physical activity and to encourage young people to adopt more active lifestyles than to promote exercise training programmes exclusively devoted to the improvement of aerobic fitness (Armstrong, 1995).

2.3.2. Self-perceived motor abilities in children

It is well known that self–perception has become very important in characterizing both physical and psychological adaptation of the world (Lintunen, 1995). However, only very few studies have been performed where perceived fitness or fitness components of children have been studied (Marsh, 1993; Marsh and Redmayne, 1994). For example, March (1993) indicated in 9–15-year-old Australian schoolchildren that perceived fitness correlated significantly with cardiovascular endurance, muscular strength, and body composition. In another study, March and Redmayne (1994) concluded that perceived fitness correlated with perceived endurance and strength, while the relations with perceived flexibility and balance were significant but relatively low. Jürimäe and Rego (2002), indicated that 16–18-year–old boys perceived their endurance better than girls did (r=0.65 and r=0.48, respectively). Strength was perceived significantly by boys (r=0.34) and girls (r=0.26). Flexibility was also perceived significantly by boys (r=0.42) and girls (r=0.55) as well as body composition (r=0.47 and r=0.48, respectively).

Piek et al. (2006) studied the relationship between fine and gross motor ability, self-worth and self-perceptions in children and adolescents. It was found that children with more highly perceived scholastic competence were in younger group and had better fine motor skills. The finding was that the specific types of motor deficit for children with motor disorders, within the academic setting.

According to Gruber (1986), self-concept is our perception of self and self-esteem is a value we place on our self-image. Self-esteem is non-existent at birth and forms during childhood and adolescence. Its source is the interaction between the person and environmental/social experiences (Dishman, 1989).

2.4. Physical activity and anthropometric parameters in children

Is there a significant relationship between physical activity level and anthropometrical parameters in children? Are the taller or obese less active? There is available data about the physical activity and obesity. Excellent reviews have been presented by Bar-Or and Baranowski (1994), and Ward and Evans (1995). The growing problem of adult obesity is reflected by an increase in childhood and adolescent overweight and obesity. Japanese authors have reported a doubling in childhood obesity in the 10 years to 1987 with the highest frequency of cases observed in early pubescence (Sasaki et al., 1987).

The simple, inexpensive, and non-invasive nature of anthropometric body composition assessment methods have popularized their use with children and adolescents. Stature-mass indices such as the Quetelet index, more usually referred to as the BMI have been widely used (Kemper, 1985). However, although the BMI may be useful to monitor adolescent growth (Rolland-Cachera et al., 1991), the inability of the index to differentiate between lean and fat components of body composition prescribe its use as a measure of body fatness when other methods are either unavailable or not practicable (Lohman, 1989). For example, during adolescence an increase in BMI in boys may reflect a rapid development of muscle and bone rather than the accumulation of fat (Lohman et al., 1984).

Skinfolds are easily measured and routinely used to estimate body fatness (Harsha et al., 1978). However, the change in the relationship between anthropometric dimensions and body fatness during maturation, as estimated from body density, precludes the accurate prediction of young people's total body fatness from skinfold data (Lohman et al., 1984). Multicomponent, criterion-referenced skinfold prediction equations which account for age, gender, and maturational stage have been developed and received support but further investigations are required to explore their validity (Lohman, 1992). Nevertheless, skinfold thicknesses provide a useful indicator of children's and adolescents` subcutaneous fatness and inter-study comparisons can be based upon raw scores without attempting to convert to percentage body fat (Armstrong et al., 1991). However, consideration must be given to the large inter-observer variability typically associated with skinfold measurements.

The validity of the method is dependent upon stringent preparatory measures including standardization of fasting state, phase of menstrual cycle and prior physical activity (Liang and Norris, 1993).

In conclusion, some body fat is essential for normal physiological function but an over-accumulation is associated with increased morbidity and mortality from a variety of metabolic diseases. Recent years have seen major advances in methodologies for estimating body fatness but assessment during childhood and adolescence remains problematic. Adult-derived equations for converting body density determined during underwater weighing, or skinfolds to percentage body fat are inappropriate with young people and youth-generated equations require further validation. Stature-mass indices provide some useful information regarding changes in body composition with growth but are unable to distinguish between fat and lean components of body composition.

Whether a relationship truly exists between the physical activity levels of children, their motor abilities level and their anthropometrical parameters, is controversial.

How the other detailed anthropometrical parameters (girth, lengths, breadths/lengths) influence physical activity or motor ability, or how the anthropometrical parameters influence health-related fitness – cardiorespiratory endurance, muscular strengths and endurance of flexibility in children is not well-known.

3. AIMS OF THE INVESTIGATION

The general aim of the present investigation was to evaluate the relationships between anthropometric parameters, different aspects of physical activity, motor abilities and perceived motor abilities in 10–17-year-old children. We hypothesized that specific anthropometric parameters are better predictors of motor abilities than simple body height and body mass, and that physical activity is not dependent on anthropometric parameters. Finally, our children possibly perceive highly their main motor abilities (endurance, strength, etc.).

The specific aims of our study were:

1. to investigate the relationships between anthropometric parameters (skinfolds, girths, lengths and breadths/lengths), somatotype components, and physical activity with motor abilities in prepubertal, pubertal and postpubertal children (Paper I);
2. to estimate the relationships between self-perceived and actual indicators of motor abilities in children and adolescents of different age and sex (Paper II);
3. to investigate the influence of sports participation outside school with perceived and actual physical fitness and total physical activity in children (Paper III).

4. MATERIAL AND METHODS

4.1. Subjects

A total of 525 boys and girls aged 10–17 years were studied. They were divided into the next groups:
10–11-year-old boys (n = 56);
10–11-year-old girls (n = 64);
12–13-year- old boys (n = 68);
12–13-year-old girls (n = 68);
14–15-year-old boys (n = 70);
14–15-year-old girls (n = 71);
16–17-year-old boys (n = 68);
16–17-year-old girls (n = 60);
All the pupils were from the small town of Vändra (Estonia). Physical education consisted of 2–3 compulsory physical education lessons per week. All children, parents and teachers were thoroughly informed about the purposes and contents of the study and written informed consent was obtained form the parents and children. Measurements were performed at school before lunch time during physical education lessons. The pupils did not exercise before testing. The study was approved by the Medical Ethics Committee of the University of Tartu, Estonia.

4.2. Anthropometric measurements

Body height (Martin metal anthropometer) and body mass (medical electronic scale, A & D Instruments, LtD, UK) of the subjects were measured to the nearest 0.1 cm and 0.05 kg, respectively. BMI was calculated (kg/m²). All anthropometric parameters were measured according to the protocol recommended by the International Society for Advancement of Kinanthropometry (Norton and Olds 1996; ISAK, 2001). In total nine skinfolds (triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh, medial calf, mid axilla) were measured. All 9 skinfolds were summarized as a subcutaneous body fat parameter. Additionally, 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. The anthropometric measurements were performed by a well-trained anthropometrist (Level 1

ISAK anthropometrist). The mean of three trials was used in the analysis. The CENTURION KIT instrumentation was used (Rosscraft, Surrey, BC, Canada), except for skinfold thicknesses, which were measured using Holtain (Crymmych, UK) skinfold caliper.

Somatotype components (endomorphy, mesomorphy, ectomorphy) were estimated according to protocol of Carter and Heath (1990) using the next equations:

Endomorphy	$= -0.7182 + 0.1451\ X - 0.00068\ X^2 + 0.0000014\ X^3$	
Mesomorphy	$= 0.858\ HB + 0.601\ FB + 0.188\ AG + 0.161\ CG - 0.131\ SH + 4.5$	
Ectomorphy	$= 0.732\ HWR - 28.58$	(If $HWR > 40.74$)
	$= 0.463\ HWR - 17.615$	(If $39.65 < HWR \leq 40.74$)
	$= 0.5$	(If $HWR \leq 39.65$),

where: X = sum of tree skinfolds (triceps, subscapular, supraspinale) (mm), (for application to children, X is multiplied by 170.18/height (cm) to yield height-corrected endomorphy); HB = humerus breadth (cm); FB = femur breadth (cm); AG = corrected arm girth (cm); CG = corrected calf girth (cm); SH = standing height (cm); HWR = height (cm) over cube root of weight (kg).

4.3. Physical activity measurements

Physical activity was assessed using the simple questionnaire of Telama et al. (1996), where the next questions were used:

Items	Code for physical activity index (PAI)
1. How much are you breath-taking and sweating when you engage in physical activity and sport?	
Not at all	1
Moderately	2
Lot of	3
2. How often do you engage in intensive physical activity?	
Not at all	1
Once a month or more	1
Once a week	2
2–3 time a week	2
4–6 time a week	2
Every day	3

3. How many hours a week do you engage in intensive physical activity?

Not all	1
½ hour a week	1
1 hour a week	2
2–3 hours a week	2
4–6 hours a week	2
Over 7 hours a week	3

4. How long time do you usually spend for physical activity?

Less than 20 min.	1
20–40 min.	2
40–60 min.	2
More than 60 min.	3

Finally the physical activity index (PAI) was calculated.

4.4. Motor ability (EUROFIT) tests

The following EUROFIT (1988) tests were used after a short (about 10 minutes) standardized warm-up (light running, jumping and stretching exercises) to measure motor abilities: 20m endurance shuttle-run, handgrip dynamometry, sit-and-reach, 10x5 m shuttle-run, handgrip strength, standing broad jump, flexed arm hang, sit-ups, plate tapping.

As a rule, in the first testing session the tests were completed in the following order: sit-and-reach, handgrip strength, standing broad jump and 10x5 m shuttle-run. In the second testing session the following tests were completed: plate tapping, bent arm hang, sit-ups, 20m shuttle-run. All equipment was regularly calibrated throughout the testing period.

4.5. Self-perceived fitness

Self-perceived fitness (total fitness, endurance, strength, flexibility and body composition) was assessed using a slightly modified version of the questionnaire by Delignieres (1994). This questionnaire has been described by Lamb and Haworth (1998). (see APPENDIX).

Self-perceived endurance, strength, flexibility and body composition was compared with the measured 20m endurance shuttle-run, handgrip strength, sit-and-reach and sum of skinfold thicknesses respectively.

4.6. Sport participation outside school

Questions about the satisfaction with physical activity, participation in organized physical activity and competitions and watching competitions were recorded using questionnaire of Telama et al. (1996):

Items	Original score
1. What do you usually do in leisure time?	
I am usually indoors and read or something like that:	
I spend my time indoors and outdoors	1
I usually walk or spend time with my friends	2
I am usually outdoors and exercise rather much	3
2. Are you a member of the sports club?	
No	1
Yes	2
3. Do you participate in regional competition?	
No	1
Yes	2
4. Do you watch competitions?	
No	1
Yes	2

4.7. Statistical analysis

Standard statistical methods were used to calculate mean ($\overline{X}$) and standard deviation (±SD). Statistical comparisons between same age boys and girls were made using independent t–tests. Spearman correlation coefficients were used to estimate the associations between dependent variables (Study I, Study II). The effect of satisfaction with physical exercise, watching competitions, participation in competitions and participation in organized physical activity to PAI was analyzed by stepwise multiple regression analysis. (Study III). Statistical significance was set at $p < 0.05$.

5. RESULTS

Mean basic anthropometric parameters and somatotype components of children are presented in Table1.

Table 1. Mean basic anthropometric parameters and somatotype components of children ($\overline{X}$ ±SD).

	Age group	n	Boys	n	Girls	p
Age (yrs)	10–11	56	10.5±0.5	64	10.6±0.5	>0.05
	12–13	68	12.8±0.4	68	13.0±0.3	<0.05
	14–15	70	14.4±0.5	71	14.5±0.5	>0.05
	16–17	68	16.5±0.5	60	16.4±0.5	>0.05
Body height (cm)	10–11	56	143.0±5.6	64	140.5±6.5	<0.05
	12–13	68	149.8±7.4	68	154.3±8.3	<0.05
	14–15	70	168.4±10.3	71	164.2±7.0	<0.05
	16–17	68	178.1±6.2	60	165.9±5.7	<0.05
Body mass (kg)	10–11	56	34.2±3.3	64	33.2±3.0	>0.05
	12–13	68	39.8±5.0	68	44.1±8.2	<0.05
	14–15	70	56.1±12.0	71	55.7±10.6	>0.05
	16–17	68	67.5±10.9	60	58.8±6.8	<0.05
BMI (kg/m^2)	10–11	56	16.7±1.0	64	16.9±1.9	>0.05
	12–13	68	17.7±1.3	68	18.3±2.0	<0.05
	14–15	70	19.5±2.3	71	20.6±3.1	<0.05
	16–17	68	21.2±2.9	60	21.4±2.4	>0.05
SOMATOTYPES						
Endomorphy	10–11	56	2.0±0.5	64	2.6±0.9	<0.05
	12–13	68	2.4±0.7	68	3.0±0.6	<0.05
	14–15	70	4.3±1.6	71	3.8±1.0	<0.05
	16–17	68	5.1±1.5	60	4.2±0.8	<0.05
Mesomorphy	10–11	56	4.0±0.8	64	3.7±1.0	>0.05
	12–13	68	4.1±1.0	68	3.0±1.1	<0.05
	14–15	70	6.7±2.0	71	3.7±1.6	<0.05
	16–17	68	8.5±0.9	60	4.5±1.6	<0.05
Ectomorphy	10–11	56	3.7±0.8	64	3.4±1.4	>0.05
	12–13	68	3.6±0.9	68	4.0±1.0	>0.05
	14–15	70	3.8±0.9	71	3.1±1.3	<0.05
	16–17	68	3.6±1.2	60	2.8±1.2	<0.05

Body height was higher in boys, except for 12–13- year-olds, where the girls were taller. Body mass was higher in girls at the age of 12–13 years and in boys at the 16–17 age groups. BMI was significantly higher in girls at the age groups of 12–13 and 14–15 years. From the somatotype components, in two younger groups of girls was more endomorphy and contrary to the older groups, less endomorphy than boys. As a rule, boys are more mesomorphic than girls (except for 10–11-year-olds). Boys were more ectomorphic in two older groups. Mean skinfold thicknesses, girths, lengths and breadths/lengths of the children are presented in Table 2.

Table 2. Mean skinfold thicknesses, girths, lengths and breadths/lengths of the subjects ($\overline{X}$ ±SD).

	BOYS				GIRLS			
	10–11 yrs n=56	12–13 yrs n=68	14–15 yrs n=70	16–17 yrs n=68	10–11 yrs n=64	12–13 yrs n=68	14–15 yrs n=71	16–17yrs n=60
SKINFOLDS (mm)								
Triceps	8.0±2.4	9.1±2.5	16.1±8.3	19.2±8.2	11.0±3.2	11.4±2.8	15.2±5.7	17.6±5.0
Subscapular	6.7±1.5	7.5±2.0	10.5±2.9	15.3±5.6	7.4±2.9*	8.6±2.1*	11.1±3.2	12.0±2.3
Biceps	6.4±1.8	7.3±2.2	10.4±2.4	14.8±4.7	7.7±2.6*	9.3±2.7*	10.3±2.8	10.9±2.0
Iliac crest	5.6±2.1	7.0±2.5	12.6±2.1	16.2±5.2	6.6±2.6	8.6±2.1*	11.1±3.3	13.8±2.3
Supraspinale	6.3±1.8	7.5±2.2	13.5±5.7	15.3±6.2	7.7±3.6*	9.1±2.4*	11.5±3.3	12.0±2.1
Abdominal	8.9±2.8	10.1±3.0	20.7±9.5	23.0±8.1	10.5±4.2*	10.9±2.7	16.6±4.3	17.3±3.1
Front thigh	13.1±1.6	12.5±2.5	19.7±6.9	22.5±8.0	16.7±5.3*	17.0±4.7*	24.7±8.2	28.8±5.6
Medial calf	10.4±1.6	10.9±2.1	18.0±5.4	20.2±5.4	10.7±3.3	13.0±2.8*	19.3±5.3	21.8±3.5
Mid-axilla	7.0±1.4	8.3±1.5	13.6±4.8	16.0±4.6	7.0±3.0	8.5±1.9	10.0±2.4	10.6±1.6
GIRTHS (cm)								
Head	52.9±0.8	53.5±1.1	56.7±1.8	58.1±0.5	52.8±1.1	53.2±1.1	54.6±1.4	55.0±1.1*
Neck	26.8±1.2	27.5±1.0	31.5±2.9	32.2±2.0	27.1±0.9	28.0±1.9	31.1±2.3	32.2±0.8
Arm relaxed	19.5±1.6	21.0±1.6	24.7±2.3	26.9±2.0	20.0±1.8	21.4±1.8	23.9±3.2	24.4±2.1
Arm flexed and tensed	21.7±1.8	22.8±1.5	25.9±2.1	27.9±2.1	21.0±1.6	23.0±1.7	24.4±2.6	25.2±2.3
Forearm	20.2±1.8	21.3±1.4	24.2±2.4	25.8±2.9	19.4±1.3	21.0±1.4	26.0±3.5	28.3±3.2
Wrist	14.3±0.9	14.8±1.0	15.8±2.2	17.7±1.4	13.5±0.7	14.7±1.2	14.8±0.6	14.6±0.4*
Chest	64.5±3.2	67.2±4.3	77.7±5.8	80.5±4.4	64.7±3.0	71.6±5.6	79.7±5.1	81.9±2.2
Waist	56.6±3.0	57.8±5.1	64.8±6.0	67.9±4.6	56.5±3.2	60.5±4.1	64.8±3.2	66.4±2.1
Gluteal	68.9±3.6	70.0±5.2	82.0±7.3	84.6±4.8	70.9±3.8	73.5±6.5	85.6±10.7	90.8±5.9
Thigh I	42.4±2.1	42.9±3.0	52.9±7.5	55.4±8.8	42.0±2.7	46.1±3.7	54.2±8.0	57.8±7.1
Thigh II	40.2±2.6	40.2±3.1	50.5±6.5	53.9±3.5	40.0±2.4	43.6±3.5	50.9±7.6	54.1±5.4
Calf	28.8±1.7	28.8±3.5	36.8±5.7	40.2±4.6	28.1±2.1	30.9±3.0	34.9±2.6	36.1±1.1
Ankle	19.4±1.6	21.3±2.3	23.9±2.6	25.0±3.3	18.8±1.2	20.8±1.3	21.3±1.6	21.5±0.9

	BOYS				GIRLS			
	10–11 yrs n=56	12–13 yrs n=68	14–15 yrs n=70	16–17 yrs n=68	10–11 yrs n=64	12–13 yrs n=68	14–15 yrs n=71	16–17yrs n=60
LENGTHS (cm)								
Acr-rad	29.2±1.7	28.5±2.2	31.7±2.0	31.9±2.1	26.4±1.9*	28.9±2.7	30.7±1.7	30.7±1.9
Rad-styl	23.1±1.1	23.1±1.7	25.3±2.3	25.7±2.6	20.9±1.7	22.6±1.5	23.4±1.2	23.4±1.0*
Midstyl-dact	15.0±1.3	15.7±1.4	17.5±1.0	17.7±0.5	15.2±1.2	15.6±0.8	17.0±1.1	17.7±1.4
Iliospinale	43.2±4.0	45.5±3.2	48.8±3.3	48.9±6.2	39.2±3.4	46.7±4.0	51.8±3.2*	52.7±3.5*
Trochanterion	36.8±5.8	38.4±5.7	48.1±7.9	52.0±5.9	35.6±5.6	39.8±4.3	40.8±2.4*	45.9±1.8*
Troch-tib-lat	31.9±3.0	31.6±4.1	39.7±6.0	43.7±3.7	29.9±2.3	32.8±2.2	38.7±3.4	40.4±1.1*
Tib-lat to floor	43.0±2.9	44.7±2.9	42.3±4.0	42.2±3.5	41.7±2.3	45.0±3.0	43.6±2.4	43.0±2.0
Tib med-spy tib	30.6±1.7	32.7±3.2	36.7±3.1	36.6±3.8	29.9±1.7	32.3±1.9	35.0±1.4	35.3±1.0
BREADTHS/ LENGTHS (cm)								
Biacromial	30.6±1.4	32.0±1.5	34.8±3.0	34.3±3.4	30.2±2.1	32.6±2.5	34.9±1.8	35.4±1.1
Biiliocristal	22.2±2.1	23.3±1.3	26.6±2.5	27.6±2,4	22.7±1.9	24.2±2.1	27.1±2.6	28.5±1.9
Foot lengths	22.5±0.9	23.7±0.9	29.9±3.7	34.2±1.0	21.6±1,1	23.1±0.9	23.8±0.6	24.1±0.5
Sitting height	70.9±1.8	73.7±3.2	87.1±7.5	91.2±2.5	72.7±2.9	75.7±3.6	83.5±5.6	86.6±3.6
Transv chest	21.4±1.4	22.5±1.6	25.4±1.8	25.3±2.5	21.0±1.3	23.4±2.0	24.7±1.8	24.8±1.0
A-P chest depth	14.7±2.5	13.9±1.9	16.4±2.8	17.1±2.8	13.8±1.1	14.2±1.5	14.9±1.9	15.6±1.1
Humerus	5.7±0.2	6.7±0.7	9.4±1.5	10.9±0.3	5.6±0.4	6.1±0.4	7.2±1.4	7.7±1.3
Femur	8.6±0.3	8.5±0.4	10.5±1.4	11.7±0.3	8.1±0.4	8.1±0.5	8.7±0.6	8.9±0.5

*$p<0.05$ between same age boys and girls

The skinfolds, as a rule, were thicker in girls compared with boys in two youngest groups. As a rule, there are no statistically significant differences between boys and girls in girth parameters. In older groups some of the length parameters are bigger in boys. There are no differences in breadths/lengths between sexes.

Mean physical activity indexes (PAI) in children and adolescence are presented in Figure 1.

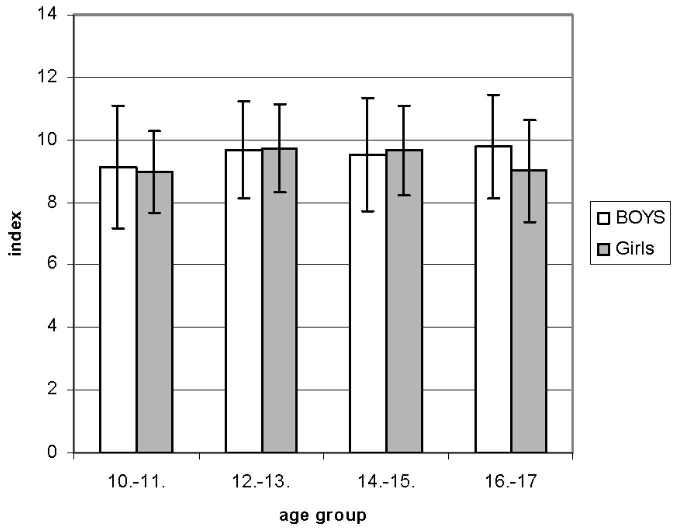

Figure 1. Mean ($\overline{X}$ ±SD) physical activity indexes (PAI) in children of different age and sex

There are no differences in PAI between sexes. Mean EUROFIT tests results are presented in Table 3.

Table 3. Mean ($\overline{X}$ ±SD) EUROFIT tests results in children of different age and sex

	Age group	Boys	Girls
Flamingo balance (mistakes)	10–11	10.5±2.0	9.6±3.0*
	12–13	10.4±3.0	7.3±1.9***
	14–15	8.3±3.2	6.3±2.6**
	16–17	7.9±2.7	5.4±2.0***
Plate tapping (sec)	10–11	12.9±1.1	13.5±1.7
	12–13	13.3±1.5	11.9±1.3**
	14–15	12.5±1.1	11.7±1.2*
	16–17	11.7±0.9	11.6±0.9

	Age group	Boys	Girls
Sit-and-reach (cm)	10–11	21.6±2.8	22.4±2.9
	12–13	21.9±3.4	24.9±4.2**
	14–15	23.2±3.5	30.2±8.2***
	16–17	21.2±2.8	30.9±8.7***
Standing broad jump (m)	10–11	1.5±0.1	1.4±0.2*
	12–13	1.6±0.2	1.5±0,1
	14–15	1.7±0.1	1.7±0.2
	16–17	1.8±0.1	1.7±0.2*
Sit-ups (time/ 30 sec)	10–11	19.5±2.8	15.2±4.3**
	12–13	21.8±3.5	20.1±2.7*
	14–15	22.0±2.7	21.0±4.0
	16–17	22.1±2.7	21.8±3.1
Bent arm hang (sec)	10–11	41.7±77.1	53.5±145.8
	12–13	95.9±179.4	61.8±138.2
	14–15	76.8±149.3	73.9±154.0
	16–17	85.0±155.0	62.0±133.8
Hand grip (kg)	10–11	23.8±3.7	10.6±2.8***
	12–13	23.3±4.3	14.5±2.2***
	14–15	31.2±6.3	24.3±8.6***
	16–17	43.9±6.9	25.8±6.9***
Shuttle-run (sec)	10–11	18.1±0.9	20.3±2.2**
	12–13	18.2±1.0	19.0±1.5*
	14–15	18.0±0.8	18.2±1.0
	16–17	18.2±0.9	18.0±0.8
Endurance shuttle-run (min)	10–11	6.8±1.7	6.2±1.3*
	12–13	7.4±1.3	6.8±0.9**
	14–15	7.9±0.9	7.3±1.1*
	16–17	8.2±0.9	7.4±0.9**

* $p< 0.05$, ** $p<0.01$, *** $p<0.001$

As a rule, boys' results in different EUROFIT tests are significantly better compared to girls. Only in Flamingo balance the results were better in girls compared to boys (see Table 3).

In Table 4 relationships between somatotype components, EUROFIT test results and PAI are presented.

Table 4. Relationships between EUROFIT tests results with somatotype components and physical activity index (PAI).

	Age group	Endomorphy		Mesomorphy		Ectomorphy		PAI	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Flamingo balance	10–11	–0.08	–0.14	0.16	–0.02	–0.08	–0.06	–0.05	–0.01
	12–13	0.23	0.28*	0.17	0.36*	–0.29*	–0.27*	–0.25*	–0.09
	14–15	0.18	–0.23	–0.41*	–0.13	–0.17	0.09	–0.01	–0.27*
	16–17	0.17	0.07	–0.12	0.11	–0.02	–0.17	–0.07	–0.16
Plate tapping	10–11	–0.09	–0.12	0.13	0.14	0.08	0.13	–0.06	0.15
	12–13	0.24*	–0.11	0.13	0.26*	–0.03	–0.11	–0.22	–0.09
	14–15	–0.04	–0.10	–0.20	–0.17	–0.06	–0.07	0.14	0.09
	16–17	0.04	–0.13	0.04	–0.01	0.03	–0.02	0.14	–0.03
Sit-and-reach	10–11	0.07	–0.09	–0.18	–0.05	0.18	0.09	0.14	0.05
	12–13	0.01	0.03	–0.06	0.01	0.10	0.09	0.11	0.12
	14–15	0.10	0.08	0.18	0.16	0.05	0.04	–0.05	0.03
	16–17	–0.19	0.18	0.12	0.09	–0.02	–0.02	0.06	–0.05
Standing broad jump	10–11	0.04	–0.01	–0.21	0.06	–0.03	0.24	–0.09	0.07
	12–13	–0.20	0.06	–0.22	–0.31*	0.18	0.21	0.30*	0.14
	14–15	0.13	0.16	0.13	0.05	–0.10	0.11	0.12	0.14
	16–17	–0.07	0.08	–0.29*	0.05	0.15	0.04	0.04	0.16
Sit-ups	10–11	0.24	–0.01	0.01	0.02	–0.32*	0.25*	0.12	–0.09
	12–13	–0.36*	–0.01	–0.31*	0.25*	0.19	0.01	0.31*	0.04
	14–15	–0.06	0.00	–0.09	0.12	–0.03	–0.03	–0.02	0.16
	16–17	–0.09	–0.04	–0.18	0.00	–0.03	0.07	–0.00	0.13
Bent arm hang	10–11	–0.04	–0.20	0.15	–0.02	0.07	0.18	0.06	0.13
	12–13	–0.22	–0.18	–0.22	0.05	0.17	0.19	0.28*	0.06
	14–15	–0.17	–0.06	–0.28*	–0.15	–0.03	0.08	0.10	0.29*
	16–17	–0.11	–0.05	0.10	0.04	–0.01	0.04	0.16	0.23
Handgrip	10–11	0.16	0.08	–0.02	0.12	0.01	0.19	0.06	0.02
	12–13	–0.03	0.20	–0.07	–0.01	0.05	–0.08	0.22	–0.08
	14–15	0.18	0.34*	0.47*	0.25*	0.04	–0.19	–0.04	–0.11
	16–17	0.03	0.33*	0.06	0.24	–0.09	–0.28*	–0.05	–0.26*
Shuttle-run	10–11	–0.08	0.10	0.20	0.12	–0.00	–0.18	0.05	–0.05
	12–13	0.31*	0.03	0.22	0.40*	–0.26*	–0.26	–0.41*	–0.08
	14–15	0.12	–0.14	0.00	–0.02	–0.03	–0.08	–0.08	0.05
	16–17	0.26*	–0.04	–0.07	–0.02	–0.11	0.00	–0.26*	–0.06
Endurance shuttle-run	10–11	–0.13	–0.28*	–0.04	–0.07	–0.03	0.29*	0.28*	0.30*
	12–13	–0.33*	–0.16	–0.40*	0.01	0.22	0.33*	0.33*	0.30*
	14–15	–0.07	0.02	0.01	–0.03	0.11	0.14	0.30*	0.36*
	16–17	–0.13	–0.10	0.02	–0.18	–0.09	0.18	0.31*	0.40*
PAI	10–11	0.06	–0.21	0.11	0.21	0.04	0.01		
	12–13	–0.14	0.04	–0.19	0.01	0.21	0.08		
	14–15	–0.06	–0.15	0.01	–0.23	0.03	0.06		
	16–17	–0.12	–0.12	0.08	–0.25*	–0.08	0.22		

* $p<0.05$

PAI first of all correlated significantly with endurance (20m endurance shuttle-run) in all age and sex groups. There are only a few significant relationships with other EUROFIT tests results (see Table 4).

In Table 5 stepwise multiple regression analysis results are presented of anthropometric parameters (skinfolds, girths, lengths, breadth/lengths as dependent variables) to the different EUROFIT tests results and PAI (independent variables).

Table 5. Stepwise multiple regression analysis results presenting groups of anthropometric parameters (skinfolds, girths, lengths, breath/lengths) to the different EUROFIT tests results and PAI (R^2 x 100).

EUROFIT TESTS	Age group	SKINFOLDS		GIRTHS		LENGTHS		BREADTHS/ LENGTHS	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Flamingo balance	10–11	5.24	39.02	27.70	31.85	4.01	35.81	17.51	27.06
	12–13	10.85	12.06	12.12	12.66	7.39	14.32	14.05	7.29
	14–15	19.01	14.74	28.53	30.40	30.16	26.74	19.01	18.93
	16–17	9.10	10.25	21.36	28.19	13.91	7.91	14.94	13.94
Plate tapping	10–11	12.41	32.08	39.69	22.36	13.38	14.93	9.86	2.28
	12–13	12.25	4.12	27.35	32.60	14.51	25.22	22.21	14.18
	14–15	–	7.77	10.66	21.23	16.26	14.72	–	27.64
	16–17	–	3.86	13.90	6.67	–	9.29	7.15	24.28
Sit-and-reach	10–11	17.22	16.77	26.94	17.52	8.90	15.20	7.00	4.94
	12–13	–	8.61	5.62	9.76	3.82	5.81	8.27	11.33
	14–15	10.40	17.78	33.26	21.29	9.87	16.13	10.40	21.59
	16–17	4.62	14.92	12.21	11.15	–	16.10	2.31	14.95
Standing broad jump	10–11	28.36	19.53	23.08	27.38	8.30	30.85	30.81	40.95
	12–13	17.25	11.09	32.37	18.84	25.23	15.70	2.49	13.06
	14–15	6.51	13.05	5.14	40.06	9.99	27.31	6.51	21.94
	16–17	28.38	6.24	26.86	13.61	24.24	10.80	18.30	26.82
Sit-ups	10–11	15.08	30.36	14.07	46.72	12.01	54.95	18.88	42.05
	12–13	26.48	–	30.09	7.49	28.32	14.39	2.94	–
	14–15	3.13	6.51	18.66	7.76	3.23	18.60	3.13	12.62
	16–17	15.23	–	30.68	21.02	9.07	–	11.49	–
Bent arm hang	10–11	11.33	10.33	60.94	11.61	2.28	11.96	6.28	17.73
	12–13	10.84	26.06	13.64	50.77	14.51	19.03	7.89	38.60
	14–15	24.86	15.82	14.86	4.04	39.88	4.84	24.86	4.90
	16–17	13.15	11.12	13.94	10.27	7.82	2.36	8.71	8.06
Hand- grip	10–11	17.11	29.82	16.22	43.53	16.32	31.82	7.62	29.03
	12–13	27.24	11.27	32.36	14.52	18.44	9.53	28.16	6.07
	14–15	17.81	39.09	31.27	28.97	34.96	43.62	17.81	26.59
	16–17	–	24.23	10.04	18.24	–	7.00	17.19	4.81

EUROFIT TESTS	Age group	SKINFOLDS		GIRTHS		LENGTHS		BREADTHS/ LENGTHS	
		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Shuttle-run	10–11	21.34	20.60	13.46	17.64	–	13.85	18.12	9.61
	12–13	19.35	3.35	25.11	25.33	12.76	19.20	6.92	24.75
	14–15	3.56	11.48	10.06	26.81	13.08	35.71	3.56	14.42
	16–17	13.92	–	24.24	9.21	8.76	–	4.11	7.88
Endurance shuttle run	10–11	20.01	27.15	15.11	10.98	12.15	8.49	24.68	26.30
	12–13	30.76	34.71	38.40	27.08	40.75	11.44	12.50	10.96
	14–15	3.71	6.21	18.08	17.46	16.26	17.72	3.71	28.29
	16–17	9.10	15.05	8.51	26.38	8.47	14.03	13.62	17.19
PAI	10–11	10.93	17.35	–	8.36	7.71	–	16.77	4.21
	12–13	12.04	21.04	11.70	15.41	13.25	12.75	5.46	8.93
	14–15	16.10	17.89	10.90	9.50	1.72	14.79	–	11.54
	16–17	7.52	12.89.	20.38	5.54	14.50	10.17	13.41	4.37

The influence of anthropometric parameters on EUROFIT tests results and PAI is significant, but as a rule, low to moderate.

In Table 6 mean perceived motor abilities scores are presented.

Table 6. Mean (X±SD) perceived motor abilities scores in boys and girls.

	10–11-year-olds		12–13-year-olds		14–15-year-olds		16–17-year-olds	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Fitness	7.6±2.8	6.6±2.6*	6.9±2.1	6.9±2.2	7.3±2.5	6.8±2.1	7.0±2.5	6.6±2.3
Endurance	7.1±2.6	6.6±2.4	6.6±2.3	5.7±2.3	7.0±2.3	6.6±2.3	7.1±2.5	6.6±2.3
Strength	7.1±2.1	6.3±2.0*	6.9±2.3	6.4±1.8	7.2±1.7	6.5±1.9*	6.8±2.1	6.5±1.9
Flexibility	7.1±2.6	6.6±2.1	7.6±1.8	6.7±1.9***	7.0±2.3	6.5±2.2	6.1±2.2	6.8±2.5
Body composition	8.0±1.8	7.5±1.7	7.2±1.7	6.4±2.3*	7.1±1.7	6.1±1.9**	7.4±1.4	6.8±1.8*

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

There were no statistically significant differences between sexes in perceived fitness (except 10–11-year-olds) and endurance (see Table 6). Girl`s self-perceived strength was lower in age groups 10–11 and 14–15-year-old. Self-perceived flexibility was lower in girls at the age group of 12–13 years. Body composition was perceived as lower by girls but not in the 10–11-year-old age group. EUROFIT tests results which characterized endurance (20m endurance shuttle-run), strength (handgrip dynamometry) and flexibility (sit-and-reach) are presented in Table 3.

In Table 7 are presented relationships between self-perceived and measured motor abilities in boys and girls.

Table 7. Relationships between self-perceived and measured motor abilities in boys and girls.

	10–11-year-olds		12–13-year-olds		14–15-year-olds		16–17-year-olds	
	Boys (n=56)	Girls (n=64)	Boys (n=68)	Girls (n=68)	Boys (n=70)	Girls (n=71)	Boys (n=68)	Girls (n=60)
Endurance shuttle-run-perceived endurance	0.34*	0.31*	0.46*	0.39*	0.51*	0.38*	0.50*	0.41*
Handgrip strength – perceived strength	0.03	0.12	0.17	0.14	0.07	0.03	0.21	0.04
Sit-and-reach – perceived flexibility	0.11	0.11	0.30*	0.38*	0.32*	0.38*	0.40*	0.40*
Sum of skinfolds– perceived body composition	–0.21	–0.29*	–0.47*	–0.41*	–0.40*	–0.46*	–0.40*	–0.38*

*p<0.05

Children significantly perceived their endurance, flexibility (except 10–11-year-olds) and body composition (except for 10–11-year-old boys). The relationships were not significant between handgrip dynamometry and perceived strength.

The relationships between satisfaction with physical activity, participation in organized physical activity, participation in competitions and watching competitions and PAI, perceived and real fitness are presented in Table 8.

Relationships between the participation in organized sports and PAI in all age and sex groups was high (r=0.30–0.61). The children who were participating in different competitions had also higher PAI (r=0.39–0.55). The association of watching different competitions with PAI is significant only in the oldest age group (r=0.34 in boys and r=0.37 in girls). From the perceived motor abilities, the endurance correlated with the satisfaction of exercising (except in 10–11 year-olds, r=0.28–0.49). In 14–15- and 16–17-year-olds, satisfaction with exercising was correlated with perceived strength (r=0.30–0.42). Endurance shuttle-run test results correlated with satisfaction with exercise, except for in 10–11-year-olds (r=0.29–0.50). Sum of skinfolds was not correlated with satisfaction with exercise.

Table 8. Relationships between PAI, perceived and actual motor abilities, satisfaction of exercising, participation and watching competitions in different sex and age children

	Satisfaction with exercising		Participation in organized physical activity		Participation in competitions		Watching competitions	
	boys	girls	boys	girls	boys	girls	boys	girls
10–11-year-olds	n = 56	n = 64						
PAI	0.20	0.41*	0.38*	0.30*	0.44*	0.39*	0.20	0.22
Perceived endurance	0.11	0.18	0.13	0.22	0.30*	0.16	0.13	0.23
strength	0.32*	0.18	0.09	0.10	0.48*	0.07	0.23	0.12
flexibility	0.02	0.19	0.03	0.16	0.28*	0.19	0.10	0.19
body composition	0.01	0.03	0.04	0.07	0.13	0.09	0.25	0.21
Endurance shuttle-run	0.00	0.15	0.17	0.12	0.31*	0.31*	0.22	0.09
Sit-and-reach	–0.16	0.15	–0.08	0.10	0.06	0.05	–0.04	–0.19
∑ of skinfolds	–0.20	–0.18	–0.28*	–0.30*	–0.41	–0.39	0.11	0.21
12–13-year-olds	n = 68	n = 68						
PAI	0.37*	0.45*	0.61*	0.56*	0.48*	0.50*	0.06	0.06
Perceived endurance	0.28*	0.30*	0.40*	0.37*	0.57*	0.68*	0.11	0.03
strength	0.40*	0.19	0.32*	0.29*	0.50*	0.44*	0.02	0.07
flexibility	0.18	0.10	0.18	0.12	0.20	0.07	0.01	0.00
body composition	0.11	0.08	0.01	0.14	–0.04	–0.10	0.02	0.07
Endurance shuttle-run	0.50*	0.32*	0.39*	0.32*	0.44*	0.40*	0.10	0.09
Sit-and-reach	0.00	–0.04	0.01	0.08	0.04	0.04	0.05	0.03
∑ of skinfolds	0.18	0.14	0.10	0.06	0.07	0.07	0.02	0.03
14–15-year-olds	n = 70	n = 71						
PAI	0.44*	0.51*	0.60*	0.60*	0.55*	0.53*	0.13	0.14
Perceived endurance	0.37*	0.40*	0.44*	0.38*	0.45*	0.37*	0.20	0.10
strength	0.42*	0.30*	0.50*	0.70*	0.36*	0.30*	0.11	0.13
flexibility	0.07	0.08	0.05	0.11	0.13	0.01	0.14	0.07
body composition	0.07	0.07	0.06	0.10	0.11	0.10	0.07	0.06
Endurance shuttle-run	0.46*	0.50*	0.61*	0.37*	0.30*	0.36*	0.10	0.07
Sit-and-reach	0.09	0.03	0.01	0.10	0.08	0.07	0.08	0.06
∑ of skinfolds	0.05	0.04	0.07	0.05	0.05	0.06	0.01	0.04
16–17-year-olds	n = 68	n = 60						
PAI	0.26*	0.27*	0.38*	0.33*	0.51*	0.55*	0.34*	0.37*
Perceived endurance	0.49*	0.31*	–0.06	–0.15	0.39*	0.31*	0.20	0.28*
strength	0.31*	0.30*	0.06	–0.24	0.22	0.10	0.14	0.48*
flexibility	–0.06	0.24	–0.12	–0.14	0.10	0.07	0.14	0.27*
body composition	–0.12	0.23	–0.01	0.22	0.07	0.17	–0.13	0.24
Endurance shuttle-run	0.42*	0.29*	–0.37	–0.24	0.42*	0.41*	0.21	0.04
Sit-and-reach	0.03	0.01	–0.06	–0.21	0.12	0.21	0.13	–0.10
∑ of skinfolds	0.08	0.18	0.05	0.05	0.20	0.16	0.07	0.01

* $p < 0.05$, PAI – physical activity index

Participation in organized physical activity was correlated significantly with perceived endurance (r=0.37–0.44) and strength (r=0.29–0.70) in 12–13- and 14–15-year-old groups. However, actual results of endurance shuttle-run test correlated with participation in organized physical activity only in 12–13- and 14–15-year-old groups (r=0.32–0.61). Interestingly, the sum of skinfolds correlated negatively with participation in organized physical activity only in the youngest age group (r=–0.28 and r=–0.30 in boys and girls respectively).

Participation in competitions in the youngest age group correlated with perceived endurance (r=0.30), strength (r=0.48) and flexibility (r=0.28) in boys. In 12–13- and 14–15-year-olds, the relationship was significant with perceived endurance (r=0.37–0.68) and strength (r=0.30–0.50) in boys and girls. In 16–17-year-olds, the relationship was significant with perceived endurance only (r=0.31–0.39). Actual results in endurance shuttle-run test correlated with the participation in competition in every age and sex group (r=0.30–0.44). Watching competitions was not correlated with perceived or actual motor abilities except for perceived endurance (r=0.28), strength (r=0.48) and flexibility (r=0.27) in 16–17-year-old girls.

Stepwise multiple regression analysis indicated that the participation in organized physical activity was the most important predictor of PAI. In boys organized physical activity characterized PAI in 16.4% (R^2 x 100, in 10–11 year olds), 36.7% (in 12–13-year-olds), 35.9% (in 14–15-year-olds, in combination with participation in competitions) and 16.9% (in 16–17-year-olds). In 10–11-year-old girls participation in organized sport influenced PAI in 11.2% (R^2 x 100). In the older age groups participation in organized physical activity in combination with participation in competitions influenced PAI in 23.4% (R^2 x 100, in 12–13-year-olds), 30.1% (14–15-year-olds) and 21.1% (16–17 year olds). Interestingly, perceived neither actual physical fitness did not influence PAI.

6. DISCUSSION

6.1. Anthropometry, physical activity and motor ability in children (Study I)

In our children the influence of skinfold thicknesses on the EUROFIT tests results was significant, but not high (see Table 5). In weight-bearing test as bent arm hang, the influence was from 10.33 to 26.06% of the total variance (R^2 x 100). Hand grip strength depended 11.27–39.03% on the skinfold thicknesses. Endurance shuttle-run test was highly influenced by the skinfold thicknesses in the beginning of puberty (12–13-years-old boys – 30.76% and girls – 34.71%). The importance of body fatness as a determinant of performance on weight-bearing field tests is well known (Krahenbuhl et al., 1977; Dollman et al., 2002). In bent arm hang and handgrip strength especially in girls the girths parameters are more important than skinfolds (see Table 5). According to evidence (a) there is a stronger negative relationship between fat mass and distance running, than between fat mass and sprint running and jumping, and (b) there is a stronger positive relationship between fat-free mass and jumping and sprint running, that between fat-free mass and distance running (Tomkinson et al., 2007). However, the length and breaths/lengths influence on motor ability tests results is about the same as in skinfolds (see Table 5). We can conclude that in the strength tests the results are not dependent only on the body fatness (skinfolds) but also on girths, lengths and breadths/lengths. Previous studies have demonstrated that growth and body composition effects physical fitness in children (Behnke and Wilmore, 1974; Pate at al., 1989; Malina et al., 1995; Mota et al., 2002). Fatness as a rule has negative influence on both health and performance-related physical fitness (Cureton et al., 1991; Malina et al., 1995). Raudsepp et al., (1997) indicate that in prepubertal girls the sum of five skinfolds is significantly negatively related to motor fitness only after controlling for the effect of physical activity. In Swedish children a strong correlation was found between grip strength and body height and mass (Hagerross and Rosblad, 2002).

Somatotype components influence on the motor ability tests results is low (see Table 4). There are more significant relationships during the pubertal ages (12–13- or 15–16-year-olds). Slaughter et al. (1977) found that somatotype accounted for 12 to 18% of the variance in physical fitness in 7–12-years-old boys. We do not agree with the opinion of Slaughter et al. (1977) that body height contributes considerably more to the prediction of motor abilities than somatotype components in prepubertal children.

There are very few data about the relationship between performance and skill-related tests results and anthropometric parameters. In our study in such kind of tests as Flamingo balance or plate tapping, the relationship was significant but not very high (see Table 4) and the most important parameters were girths and lengths.

Physical activity is a very complex behaviour to quantify, and most studies have made use of methods with some degree of subjectivity (e.g. questionnaires) and there is no single method of measuring habitual physical activity in large epidemiological studies. There are several questions concerning the specificity and amount of physical activity needed to have a beneficial effect on physical fitness during childhood and adolescence. Recently Chiodera et al (2008) concluded that professionally guided programme of physical education in the primary school likely leads to significant progress in the development of conditional and coordinative abilities, without altering BMI values. Results of the present study indicate that PAI is correlated only moderately with some EUROFIT tests results (see Table 4). Only endurance shuttle-run tests results in all age and sex groups are correlated significantly with PAI (Table 4, in boys r=0.28–0.33 and in girls r=0.30–0.40). These relationships have been previously well studied. Morrow and Freedson (1994) indicate that in children and adolescents there was a small to moderate relationship between physical activity and aerobic fitness. In our study there were no differences in physical activity between boys and girls. It is somewhat surprising, considering girls carry higher levels of body fat and are less active than boys (Cale and Almond, 1992). On the contrary, in our study there were no significant differences in PAI between sexes but the skinfold thicknesses were higher in girls groups (see Table 2). Additionally, the relationships may depend on the method used for measuring physical activity (Morrow and Freedson, 1994; Cavill et al., 2001). Interestingly, Boreham et al., (1997) concluded that in 12–15-years-old children the endurance shuttle-run test results depended on the physical activity assessed by questionnaire level only in boys, in girls sporting participation is more important.

The influence of anthropometric parameters on PAI is quite low and the highest determinants are skinfold thicknesses. The influence of skinfold thicknesses was from 10.93 to 17.52% (R^2 x 100) in boys and from 17.35 to 22.89% in girls from the total variance (see Table 5). Interestingly, the influence of skinfold thicknesses increased with age and the influence was higher in girls compared to boys. Recently Lohman et al. (2006) found that both fat and fat free mass were associated with physical activity, both make an independent contribution to three indices of moderate to vigorous physical activity, in adolescent girls. Rowlands et al. (1999) reported a significant negative correlation between physical activity measured by Tritrac motion sensor and the sum of skinfolds in children.

Some studies support the existence of a significant relationship between physical activity and body fat (Suter and Hawes, 1993), but several studies have fond no evidence of a relationship between physical activity and body fat (Armstrong et al., 1991). Our results support the meta-analysis conclusion by

Rowlands et al. (2000) that there is a small to moderate relationship between physical activity and body fat in children. In young children forty-five minutes of moderate physical activity and fifteen minutes of vigorous physical activity were associated with reduced body fat and BMI (Wittmeier et al., 2008). One of the main complications is the variability of the methods used both for the measurement of physical activity and body composition. Recently Matton et al. (2006) concluded that in Flemish females anthropometric and fitness characteristics demonstrate higher level of stability from adolescence to middle adulthood than physical activity. Weight status during adolescence is indicative of adult weight status, and a pattern of less activity rather than activity tends to continue from youth to adulthood. The second longitudinal study (Yang et al., 2006) indicates that in Finland maintaining a high level of physical activity from youth to adulthood is independently associated with lower risk of abdominal obesity among women, but not men.

In our study the influence of girths, lengths and breaths/ lengths on the physical activity as a rule was significant but quite low. This is partly contradictory with other studies. For example Beunen et al. (1992) study in Belgium boys (13–18 years of age) indicates no specific influence of physical activity on lengths and breadths.

It was concluded that anthropometric parameters moderately influenced EUROFIT tests results in our boys and girls. Only endurance shuttle-run results in all age and sex groups correlated significantly with PAI from measured EUROFIT tests. Physical activity did not depend on the anthropometric parameters.

6.2. Self-perceived and actual motor abilities in children (Study II)

There is evidence to suggest that boys report higher physical self-perceptions (Biddle et al., 1992; Harris, 1993), or it is quite feasible that children overrate (or under rate) their fitness when measured against a multi-component "objective" construct (Marsh, 1993; Marsh et al., 1994).

Our study indicates that children and adolescents physically perceived their endurance, flexibility, and body composition as satisfactory. However, they did not perceive significantly their strength. Lamb and Haworth (1998) indicated that the relationship was highest with endurance from the motor abilities in boys (r=0.70). The perception of strength compared with handgrip dynamometry was not significant in our study (see Table 7). Previous results of our group (Jürimäe and Jürimäe, 2001) in 16–18-year-old adolescents suggested that this relationship is significant but low (r=0.18 to r=0.34). On the contrary Lamb and Haworth (1998) have obtained one of the highest relationships (r=0.73) between perceived and measured strength in boys. The occurrence of significant relationships are surprising in our study, probably it is necessary to use other tests for the measurement of strength in children and adolescents in the future. On the other hand, the mean results of handgrip dynamometry were slightly lower in our study than the mean results of same age Estonians (Jürimäe et al., 1998). In our study, the modest correlation (from r=0.30 to r=0.40, except for 10–11-year-olds) was obtained between perceived and measured flexibility (see Table 7). The flexibility is a specific health-related physical fitness component which is frequently measured by sit-and-reach test. However, the validity of this test is rather questionable (Tomkinson and Olds, 2003b).

In our study, boys (except for 10–11-year-olds) and girls perceived significantly their body composition measured by the sum of skinfold thickness measurements (see Table 7). In similar studies of Lamb and Haworth (1998) and Fox (1994), the subjects did not perceive significantly their body composition. However, it has to be considered that body composition in different studies has been measured using different methods.

It was concluded that children and adolescents perceived their basic motor abilities as satisfactory except for strength ability. However, better markers for direct measurement of motor abilities are needed before final conclusions can be made.

6.3. Sport participation outside school and total physical activity in children (Study III)

We have indicated that the organized physical activity outside school and participation in different competitions were the main factors which increased PAI in children of different ages and both sexes. This is very important because physical activity habits developed early in life may continue into adulthood (Telama et al., 2005). Relationships between sports participation and physical activity were stronger for vigorous physical activity than for moderate-to-vigorous physical activity (Pfeiffer et al., 2006).

The literature identifies different demographical, psychological, social, and environmental factors (i.e. correlates) that may influence a young person's physical activity (Pfeiffer et al., 2006). As in previous investigation (Taks et al., 1993), sports participation, especially in girls, decreased between the ages of 13 and 18. A well organized training process among children would probably significantly increase the satisfaction with physical activity. The participation in competitions is one part of school sport activities. However, passive watching of competitions does not influence children's physical activity, their perceived or real motor abilities, as a rule (see Table 8).

Some studies (Daley, 2002) reported that children's perceptions of their physical competence are important and consistent with predictions of their participation, effort and long-term interest in sport and physical activity. First of all, self-perceived endurance and strength correlated with satisfaction with exercising. Interestingly, children who enjoyed physical exercise had better results in endurance shuttle-run, except for the youngest age group. In addition, perceptions of competence were related to emotions and motivation to participate in physical activity. Finally, the obligatory physical education in school should emphasize the health-related fitness activities and extracurricular activities which should include the participation in different programmes with orientations in competitive sports.

The relationship between health-related physical fitness and physical activity in children was significant but moderate (Lamb and Haworth, 1998). In this study, only the results of endurance shuttle-run correlated with participation in organized physical activity in 12–13- and 14–15-year-olds.

There is a need for further longitudinal study to investigate the relationship between extracurricular physical activity and sports participation and perceived and actual physical fitness in schoolchildren. Extracurricular activities were piloted as a time for both physical activity and weight loss (Treuth et al., 1998). In this study, participation in organized physical activity and participation in competitions were associated with decreased sum of skinfolds only for the youngest boys and girls.

7. CONCLUSIONS

1. Anthropometric parameters moderately influenced EUROFIT tests results. Only endurance shuttle-run test results in all age and sex groups correlated significantly with physical activity index from the measured EUROFIT tests. Physical activity, as a rule, did not depend on the anthropometric parameters. The somatotype components influence on the motor ability test results was low.
2. Children and adolescents perceived their basic motor abilities (endurance, flexibility, body composition) to be satisfactory, except for strength.
3. Children who participated in organized physical activity and in competitions had a higher physical activity index. Passive watching of competitions was not related to children`s physical activity or their perceived or measured motor abilities.

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APPENDIX

Self-perceived Fitness Questionnaire

In each of the fitness scales below, please circle the value (1 to 13) that you think best describes your current level. The statements that appear above the options are there as a guide to help you understand what each scale refers to. Please answer honestly, as all information given will be treated in strict confidence.

FITNESS

1. I am completely unfit.
2.
3. I have a poor fitness level with regard to my age.
4.
5. My fitness is slightly below the average for those of my age.
6.
7. My fitness is quite normal with regard to my age.
8.
9. My fitness is slightly above average for those of my age.
10.
11. I have a very good fitness level with regard to my age.
12.
13. I am exceptionally fit.

STRENGTH

This scale refers to your capacity to perform intense muscular work of a short duration, e.g. lifting, carrying heavy objects (weights).

1. I have absolutely no strength.
2.
3. I have poor strength with regard to my age.
4.
5. My strength is slightly below the average for my age.
6.
7. My strength is quite normal to my age.
8.
9. My strength is slightly above average for those of my age.
10.
11. I am very strong with regard to my age.
12.
13. I have exceptional strength.

ENDURANCE

This scale refers to your ability to sustain prolonged effort, e.g. in running, walking, cycling.

1. I have absolutely no endurance
2.
3. I have poor endurance with regard to my age.
4.
5. My endurance is slightly below the average for those of my age.
6.
7. My endurance is quite normal with regard to my age.
8.
9. My endurance is slightly above average for those of my age.
10.
11. I have very good endurance with regard to my age.
12.
13. I have exceptional endurance.

FLEXIBILITY

This scale refers to your capacity to perform movements requiring bending, stretching etc.

1. I am definitely not flexible.
2.
3. I have poor flexibility with regard to my age.
4.
5. My flexibility is slightly below the average for those of my age.
6.
7. My flexibility is quite normal with regard to my age.
8.
9. My flexibility is slightly above average for those of my age.
10.
11. I have very good flexibility with regard to my age.
12.
13. I have exceptional flexibility.

BODY COMPOSITION

This scale refers to the relative amounts of muscle in your body.

1. I am abnormally fat.
2.
3. I am too fat with regard to my age.
4.
5. I am a little too fat with regard to my age.
6.
7. My body fat is quite normal with regard to my age.
8.
9. I am quite lean with regard to my age.
10.
11. I am very lean with regard to my age.
12.
13. I am exceptionally lean.

SUMMARY IN ESTONIAN

Antropomeetria, kehalise aktiivsuse ning motoorse võimekuse omavahelised seosed 10–17-aastastel lastel ja noortel

Sissejuhatus

Laste ja noorte tervis on otseselt seotud nende kehalise aktiivsusega. Teisalt on aga teada, et just puberteedieas väheneb kehaline aktiivsus. Paljud lapsed on ülekaalulised ja füüsiliselt nõrgad. Vähe on uuritud seda, kuidas laste kehaline aktiivsus on seotud nende kehalise võimekusega ja kuidas nad tunnetavad oma kehalist vormi, jõudu ja vastupidavust. Kooli kehalise kasvatuse tundide üheks eesmärgiks on parandada õpilaste kehalist võimekust. Kehalise võimekuse hindamiseks on soovitatud kasutada palju erinevaid teste, neist üks tuntumaid on EUROFIT testide kompleks. Meile teadaolevalt ei ole detailselt uuritud antropomeetriliste näitajate tähtsust mitmesuguste motoorsete testide tulemuste suhtes.

Käesoleva uurimistöö eesmärgiks oli kompleksselt uurida antropomeetriliste näitajate ning kehalise aktiivsuse tähtsust motoorsete testide (EUROFIT) tulemuste suhtes erinevas vanuses ja erinevast soost lastel. Samuti uurida seoseid laste tunnetatud ja tegeliku motoorse võimekuse vahel.

Uurimistöö ülesanded:

1. Uurida antropomeetriliste näitajate (nahavoltide paksused, ümbermõõdud, pikkused ja laiused/pikkused) ja somatotüübi komponentide, motoorse võimekuse ja kehalise aktiivsuse omavahelist seost prepuberteedi-, puberteedi- ja postpuberteedialistel lastel.
2. Hinnata tunnetatud ja tegeliku motoorse võimekuse näitajate seost erinevas vanuses ja erinevast soost lastel ja noortel.
3. Hinnata, kas väljaspool kooli spordiga tegelemine on kehalise aktiivsuse üks peamine mõjuv faktor lastel.

Uuritavad ja metoodika

Uuritavateks oli 525 poissi ja tüdrukut vanuses 10–17 aastat, kes olid jaotatud nelja rühma sõltuvalt nende vanusest ja soost:

- 10 –11-aastased poisid (n=56) ja tüdrukud (n=64)
- 12–13-aastased poisid (n=68) ja tüdrukud (n=68)
- 14–15-aastased poisid (n=70) ja tüdrukud (n=71)
- 16–17-aastased poisid (n=68) ja tüdrukud (n=60)

Uuritavatel mõõdeti:

- keha pikkust (cm), keha kaalu (kg), arvutati KMI (kg/m^2)
- antropomeetrilisi näitajaid vastavalt ISAKi (1996) soovitustele:
  9 nahavolti, 13 ümbermõõtu, 8 laiust, 8 pikkust/laiust
- arvutati Heath-Carteri (1990) metoodika alusel järgmised somatotüübi komponendid:
  endomorf, mesomorf, ektomorf
- motoorset võimekust, kasutades üheksat EUROFIT (1988) testide kompleksi kuuluvat testi.

Uuritavatel hinnati:

- kehalist aktiivsust, kasutades Telama (1996) küsimustikku
- väljaspool kooli spordiga tegelemist, kasutades Telama (1996) küsimustikku
- tunnetatud ja tegeliku motoorse võimekuse näitajate seost (üldine kehaline võimekus, vastupidavus, jõud, painduvus ja keha koostis) kasutades Delignieri (1994) modifitseeritud küsimustiku versiooni (Lamb ja Haworth, 1998). Hinnanguid võrreldi 20m vastupidavus-süstikjooksu, käe dünamomeetria ja istest ettepainutuse testide tulemustega ning mõõdetud nahavoltide paksuste summaga.

Järeldused

1. Antropomeetrilised näitajad mõjutavad mõõdukalt EUROFIT testide tulemusi. Ainult vastupidavuse süstikjooks korreleerub kõigis vanuselistes ja soolistes gruppides kehalise aktiivsuse indeksiga. Kehaline aktiivsus ei sõltu reeglina antropomeetrilistest näitajatest. Somatotüübi komponentide mõju motoorse võimekuse testide tulemustele oli nõrk.
2. Lapsed ja noored tajuvad oma motoorse võimekuse (vastupidavus, painduvus, keha koostis) taset rahuldavalt, v.a. jõud.
3. Lapsed, kes osalesid sporditreeningutel ja võtsid osa võistlustest, omasid kõrget kehalise aktiivsuse indeksit. Passiivne võistluste jälgimine, kehaline aktiivsus, tunnetatud ning tegelik motoorne võimekus ei olnud omavahel seoses.

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PUBLICATIONS

I

Saar M., Jürimäe T.
The relationships between anthropometric parameters,
physical activity and motor abilities in 10–17 years old Estonians.
Journal of Human Movement Studies, 2004; 47, 1: 1–12

II

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of motor abilities in children and adolescents.
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III

Saar M, Jürimäe T.
Sports participation outside school is a main factor influencing total physical activity in children.
Perceptual and Motor Skills, 2007; 105: 559–562

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Educational Career

2002–2008	University of Tartu, Faculty of Exercise and Sport Sciences, Doctoral study
1995–1998	University of Tartu, Faculty of Exercise and Sport Sciences, MSc
1977–1982	University of Tartu, Faculty of Exercise and Sport Sciences, BSc
1972–1976	Jõgeva Secondary School

Working Experience

2006–	University of Tartu, Institute of Sport Pedagogy and Coaching, Research Fellow
1999–2006	Vändra Gymnasium, Senior teacher
1985–1999	Jõgeva Gymnasium, Teacher

Special Course

2007	International Summer Course for PhD Students (Pühajärve)
1997	Level 1 Technical Anthropometry Course (Tartu)

Main Research Interests

- Children's physical activity
- Kinantropometry
- Motor Ability

CURRICULUM VITAE

Meeli Saar

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Haridustee

2002–2008	Tartu Ülikooli kehakultuuriteaduskond, doktoriõpe (ekstern)
1995–1998	Tartu Ülikooli kehakultuuriteaduskond, MSc
1977–1982	Tartu Ülikooli kehakultuuriteaduskond, BSc
1972–1976	Jõgeva Keskkool

Töökogemus

2006–	Tartu Ülikool, Kehakultuuriteaduskond, spordipedagoogika ja treeninguõpetuse instituut, kinantropomeetria õppetool, erakorraline teadur
1999–2006	Vändra Gümnaasium, vanemõpetaja
1985–1999	Jõgeva Gümnaasium, õpetaja

Erialane enesetäiendus

2007	Rahvusvaheline doktorantide suvekursus (Pühajärve)
1997	Level 1 Technical Anthropometry Course (Tartu)

Peamised uurimisvaldkonnad

- Laste kehaline aktiivsus
- Kinantropomeetria
- Motoorne võimekus

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