Journal of Human Sport and Exercise
E-ISSN: 1988-5202
jhse@ua.es
Universidad de Alicante
España

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Journal of Human Sport and Exercise, vol. V, núm. II, 2010, pp. 265-279
Universidad de Alicante
Alicante, España

**Journal of Human Sport and Exercise** *online*
*J. Hum. Sport Exerc.*
*Official Journal of the Area of Physical Education and Sport.*
*Faculty of Education. University of Alicante. Spain*
**ISSN 1988-5202 / DOI: 10.4100/jhse**
An International Electronic Journal
**Volume 5 Number 2 May 2010**

**Research Article**

# ANTHROPOMETRY AND MOTOR FITNESS IN CHILDREN AGED 6-12 YEARS

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Received: 9 January 2010; received in revised form: 7 March 2010; accepted: 15 April 2010

## ABSTRACT

This study aimed at evaluating motor abilities and anthropometric parameters in children aged 6-12 years and their interrelationships. One hundred fifty-two children underwent standard anthropometry (BMI, waist circumference, waist-to-hip ratio, sum of five skinfolds) and motor fitness tests (standing long jump and 30m dash). Data were stratified by age (6-7, 8-9, 10-12 years) and sex (M/F), and the Spearman correlation coefficient was used to evaluate the correlation between BMI and the other anthropometric measurements in each class as well as the correlation between anthropometric parameters and fitness tests. The effect of age, sex, and individual anthropometric measurement on velocity or jump length was evaluated by ANOVA. BMI positively correlated with waist circumference and subcutaneous fat, and negatively correlated with body density. Motor fitness was not significantly affected by BMI, while sum of five skinfolds negatively associated with velocity in males aged 6-7 years and with jump length in females aged 8-12 years. Motor fitness significantly correlated with age, and performance was higher in males. Moreover, motor fitness tests positively correlated with each other, especially in females. In the 6-12 years period motor performance improves with age and improvement is partially sex-related; this correlation is higher in boys, possibly because of their lesser amount of fat. Subcutaneous fat is a better predictor of physical fitness than BMI or waist circumference. Results also suggest that explosive strength and velocity are related the 6-12 years age span, possibly because both are power events, which involve horizontal movement of the centre of mass.

***Key words***: physical fitness, pediatric exercise, fitness testing, gender

***Reference Data:*** Milanese C, Bortolami O, Bertucco M, Verlato G, & Zancanaro C. Anthropometry and motor fitness in children aged 6-12 years. *J. Hum. Sport Exerc.* 2010; 5(2):265-279.

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**DOI:10.4100/jhse.2010.52.14**

## INTRODUCTION

Physical growth in children is measured by changes in body size and/or composition as well as physical profile. Physical activity is considered as a key factor for a healthy physical and mental development of children (Denker & Andersen, 2008; Ortega et al., 2008); currently, the increasing prevalence of overweight/obesity in children make children at risk of developing several chronic diseases later in life, also because children who are not physically active are unlikely to become so in adulthood. In the last years, several national and international organizations have recommended that children take part in >60 min physical activities each day in organized form, both inside and outside school (Biddle, 1998; US 2005).

The capacity of performing physical activity is named physical fitness or motor fitness, albeit these terms are difficult to define (Gallahue, 1982). Physical fitness may be conceived as the capacity to perform one's daily tasks without fatigue; motor fitness, also termed motor ability, refers to a person's performance abilities as affected by the factors of speed, agility, balance, coordination, and power (Gallahue, 2006). Motor abilities represent an integrated outcome of most bodily functions involved in physical activity and can be used to assess the effectiveness of physical education as well as measure the health-related fitness of schoolchildren, provided they are reliably measured by standardized tests such as the EUROFIT test battery (Adam et al., 1988), which has been widely used with children and adolescent (Tomkinson et al., 2007); the Körperkoordinationstest für Kinder (KTK, (Kiphart & Schilling, 1974)), which has been applied for testing coordination skills in children; the MOPER fitness test, adopted in Dutch school children (Leyten, 1982; Kemper & Verschuur, 1995); the FITNESSGRAM® battery test, developed at the Cooper Institute for Aerobics Research to assess health and fitness in children and adolescents; the General Sports-Motor Test (Allgemeiner Sportimotorischer Test (AST), Bös, 2000), specifically designed for obese children. On the other hand, measurement of anthropometric parameters allows monitoring of children's growth in terms of physical dimensions, body composition, and sex dimorphism (Kautiainen et al., 2002; Argyle, 2003; Wells, 2007; Krebs et al., 2008), also in relation to physical fitness (Westerstahl et al., 2003).

Simultaneous assessment of anthropometric parameters and motor abilities will provide more accurate information on the developmental process of children; however, it is not well known whether a relationship actually exists between motor abilities and anthropometric parameters in children or between different motor ability evaluation tests.

The aim of this investigation was to evaluate the possible relationships between selected anthropometric parameters and motor abilities, as well as the motor abilities themselves in 6-12-year-old children. Standard anthropometry and skinfold thickness measurement were carried out. The standing long jump test for explosive strength (the ability to expend a maximum of energy in one explosive act), and the 30m dash test for running speed were used to assess motor ability.

 ISSN 1988-5202

## MATERIAL AND METHOD

*Participants*

A total of 221 children attended the summer camp organized by the Faculty of Motor Sciences of the University of Verona between 2005 and 2007. Of these, 69 were excluded from analysis because they did not complete anthropometric measurements, leaving 152 subjects for the final analysis (103 boys and 49 girls). All children and their parents were thoroughly informed about the purposes and contents of the study, and written informed consent was obtained from one parent. The study protocol is in accordance with the declaration of Helsinki. Measurement sessions were taken over three consecutive years in June/July. When a subject underwent more than one measurement session, the first eligible one was considered.

*Anthropometry*

All measurements were taken by one operator (CM) using conventional criteria and measuring procedures (Lohman et al., 1988). Weight was assessed to the nearest 0.1 kg using a certified electronic scale (Tanita electronic scale BWB-800 MA (Wunder SA.BI. Srl)). Height to the nearest 0.01 m was measured using a Harpenden portable stadiometer (Holtain Ltd., Crymych, Pembs. UK). The body mass index (BMI) was calculated as $kg/m^2$. Girth was taken at the waist and the hip using fibreglass tape; the waist-to-hip (W/H) ratio was calculated. To define overweight and obesity, the cut-offs proposed by Cole et al. (2000), were used.

*Skinfold measurement*

The triceps, subscapular, chest, abdominal, and front thigh skinfold thicknesses were measured by one operator (CM) using a Harpenden calliper (Gima, Modena, Italy) according to standard procedures (Norton & Olds, 1996). Two measurements were taken at each site, and the average of the two readings was considered. If the two measures differed by more than 2 mm, a third measurement was taken, and the two closest were then averaged and recorded as the final value. The equation proposed by Poplawska et al. (2006), was used to estimate body density.

*Assessment of motor fitness*

For standing long jump, the child stands behind a line marked on the ground with feet slightly apart. A two-foot take-off and landing is used, with swinging of the arms and bending of the knees to provide forward drive. The subject attempts to jump as far as possible, landing may be on one or both feet. For 30m dash, the result is the time of the subject's running a 30 meters distance, standing position at the start; the time was fixed with a commercial stop-watch. For each test three trials were performed, the score being the average.

These tests are easy to administer, can be done both in-and outdoors, and paediatric population can be assessed in a short time (Johnson & Nelson, 1986; Van Praagh et al., 1990; Loko et al., 2000; Buonaccorsi, 2003).

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***Statistical analysis***

Children were stratified by age (6-7, 8-9, 10-12 years) and sex (M/F).

Difference in the proportion of overweight/obesity between genders was evaluated by Fisher's exact test. Significance of differences between genders in anthropometric parameters and motor fitness tests was evaluated by ANOVA for quantitative variables, taking into account also age class. BMI, sum of five skinfolds, waist and 30m dash velocity were log-transformed to cope with the assumptions of normality and/or homoscedasticity.

The BMI was assumed to be the gold standard among anthropometric measurements. Spearman rank-order correlation coefficient (Spearman's rho) was used to evaluate the correlation between BMI and different anthropometric measurements (waist, waist-to-hip ratio, body density, sum of five skinfolds) in each sex- age-specific group.

Spearman's rho was also used to evaluate the correlation between the anthropometric measurements (BMI and sum of five skinfolds), and between anthropometric measurements and fitness tests (standing long jump and 30m dash) in either sex or in each sex- age-specific group. Analysis of variance was used to study the effect of age, sex, and anthropometric measurement (either BMI or sum of five skinfolds) on velocity or standing long jump. In this last analysis log transformation of velocity was performed to achieve homoscedasticity, while anthropometric measurements were coded in tertiles. Data analysis was carried out using STATA® version 10.1 (StataCorp, College Station, Texas, USA).

**RESULTS**

The main characteristics of the study population are presented in Table 1 as a function of sex- and age. Overall, the prevalence of overweight-obesity was 17% (18/103) among males and 26% (12/47) among females; of these, 1 boy (1%) and 3 girls (6%) were obese. Girls had thicker skinfolds than boys, the difference being significant in the younger age group, while BMI did not differ between genders. Males showed a better motor performance than females: in particular, boys ran significantly faster than girls in the age range 8-12 years and jumped significantly longer in the age class 8-9 years.

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**Table 1.** Characteristics of the study population as a function of sex and age. Data are reported as median (interquartile range) for quantitative variables (BMI, sum of five skinfolds, velocity in a 30m dash run and length of a standing jump) and as absolute frequencies (percentages) for categorical variables (overweight and obesity).

| | Males 6-7 yrs (n=33) | Females 6-7 yrs (n=12) | Males 8-9 yrs (n=33) | Females 8-9 yrs (n=20) | Males 10-12 yrs (n=37) | Females 10-12 yrs (n=17) | P value * |
|---|---|---|---|---|---|---|---|
| BMI (Kg/m$^2$) | 16.0 (14.7-17.1) | 16.6 (15.1-19.3) | 16.4 (15.5-17.4) | 16.5 (15.7-17.4) | 17.7 (16.0-19.8) | 18.5 (17.1 -19.8) | 0.089 |
| Sum of skinfolds (mm) | 38.6 (33.4-48.8) | 62.9 (41.5-82.4) | 41.2 (34.6-56.4) | 49.9 (42.9-67.0) | 53.3 (41.9-74.2) | 63.8 (54.9-74.8) | **<0.001** |
| Waist | 55.0 (53.5-57.0) | 57.0 (53.0-61.0) | 57.5 (56.0-61.8) | 56.3 (53.0-58.3) | 62.0 (59.0-68.0) | 62.5 (61.0-65.0) | **0.541** |
| Velocity in 30m dash†† (m/s) | 4.35 (4.12-4.64) | 4.14 (3.98-4.58) | 4.64 (4.42-4.86) | 4.31 (4.13-4.64) | 5.02 (4.88-5.42) | 4.81 (4.71-4.92) | **<0.001** |
| Standing jump length†† (m) | 1.24 (1.11-1.30) | 1.16 (1.10-1.27) | 1.38 (1.29-1.44) | 1.22 (1.06-1.38) | 1.57 (1.43-1.65) | 1.52 (1.36-1.61) | **<0.001** |
| Overweight children | 4 (12%) | 3 (25%) | 6 (18%) | 3 (15%) | 7 (19%) | 3 (18%) | 0.158 |
| Obese children | 1 (3%) | 2 (17%) | 0 (0%) | 1 (5%) | 0 (0%) | 0 (0%) | |

**Significance of differences between genders was evaluated by ANOVA for quantitative variables, taking into account also age class. Logarithmic transformation was used as appropriate. Fisher's exact test was used to evaluate significance of the association between sex and overweight/obesity.*

*†† This information was available in 29 subjects in Males aged 6-7 years and in 32 subjects in Males aged 8-9 years.*

*Anthropometric measurements*

The correlations between BMI and the other anthropometric or body composition parameters are summarized in Table 2. BMI directly correlated with the waist circumference and the sum of five skinfolds, and inversely with body density in both sexes and at all ages considered. These correlations were rather strong: Spearman's rho ranged between 0.60 and 0.94 for the former correlations and between -0.56 and -0.88 for the latter. A weaker, although significant, direct correlation was observed between BMI and centrality index in males aged 6-7 years and in children of both sexes aged 10-12 years. No significant correlation was observed between BMI and waist-to-hip ratio.

*Motor fitness tests*

In bivariate analysis (Table 3) BMI was correlated neither with velocity in a 30m dash nor with explosive strength in a standing long jump in any sex or age class. Sum of skinfolds was inversely correlated with standing long jump in females aged over 8 years; the negative correlation between sum of skinfolds and velocity was significant (P=0.050) in males aged 6-7 years and presented a borderline significance (P=0.059) in females of the oldest age class. In males a significant inverse correlation was found between sum of skinfolds and velocity in the 6-7 years age class. No significant correlation was found between waist circumference and motor tests.

***Table 2***. *Correlation between Body Mass Index, taken as a gold standard, and other anthropometric measurements in males and females at different ages. The correlation was evaluated by Spearman's rank-order correlation coefficient; significance value is reported in parentheses.*

| | Males 6-7 yrs (n=33) | Females 6-7 yrs (n=12) | Males 8-9 yrs (n=33) | Females 8-9 yrs (n=20) | Males 10-12 yrs (n=37) | Females 10-12 yrs (n=17) |
|---|---|---|---|---|---|---|
| Waist | **0.866 (P<0.001)** | **0.908 (P<0.001)** | **0.829 (P<0.001)** | **0.7834 (P<0.001)** | **0.944 (P<0.001)** | **0.934 (P<0.001)** |
| Waist-to-hip ratio | -0.114 (P=0.528) | 0.028 (P=0.931) | -0.256 (P=0.151) | 0.266 (P=0.258) | 0.209 (P=0.214) | -0.093 (P=0.722) |
| Sum of skinfolds | **0.779 (P<0.001)** | **0.867 (P<0.001)** | **0.815 (P<0.001)** | **0.597 (P=0.006)** | **0.880 (P<0.001)** | **0.681 (P=0.003)** |
| Body Density | **-0.757 (P<0.001)** | **-0.811 (P=0.001)** | **-0.799 (P<0.001)** | **-0.562 (P=0.010)** | **-0.881 (P<0.001)** | **-0.762 (P<0.001)** |

**Table 3**. Correlation between anthropometric parameters (BMI, waist circumference, and sum of five skinfolds) and fitness tests (30m dash and standing long jump). The correlation was evaluated by Spearman's rank-order correlation coefficient; significance value is reported in parentheses.

| | | Males 6-7 yrs (n=29) | Females 6-7 yrs (n=12) | Males 8-9 yrs (n=32) | Females 8-9 yrs (n=20) | Males 10-12 yrs (n=37) | Females 10-12 yrs (n=17) |
|---|---|---|---|---|---|---|---|
| BMI | 30m dash | -0.156 (P=0.421) | -0.252 (P=0.430) | 0.032 (P=0.864) | -0.014 (P=0.955) | 0.100 (P=0.555) | -0.215 (P=0.408) |
| | Standing long jump | -0.169 (P=0.380) | 0.285 (P=0.370) | 0.149 (P=0.416) | -0.403 (P=0.079) | -0.162 (P=0.337) | -0.393 (P=0.119) |
| Sum of skinfolds | 30m dash | **-0.368 (P=0.050)** | -0.406 (P=0.191) | 0.058 (P=0.754) | -0.148 (P=0.535) | 0.056 (P=0.744) | -0.466 (P=0.059) |
| | Standing long jump | -0,285 (P=0.134) | 0.155 (P=0.631) | 0.056 (P=0.761) | **-0.640 (P=0.002)** | -0.280 (P=0.093) | **-0.575 (P=0.016)** |
| Waist | 30m dash | -0.324 (P=0.087) | -0.269 (P=0.399) | 0.018 (P=0.923) | 0.039 (P=0.869) | 0.124 (P=0.466) | -0.223 (P=0.390) |
| | Standing long jump | -0.151 (P=0.436) | 0.293 (P=0.355) | 0.105 (P=0.568) | -0.184 (P=0.439) | -0.110 (P=0.519) | -0.431 (P=0.084) |

 ISSN 1988-5202

These patterns are further illustrated in two representative pictures: Figure 1 shows the absence of correlation between BMI and standing long jump in females of whatever age; Figure 2 illustrates the negative correlation between sum of five skinfolds and standing long jump in females aged 8-9 years and 10-12 years, but not in those aged 6-7 years.

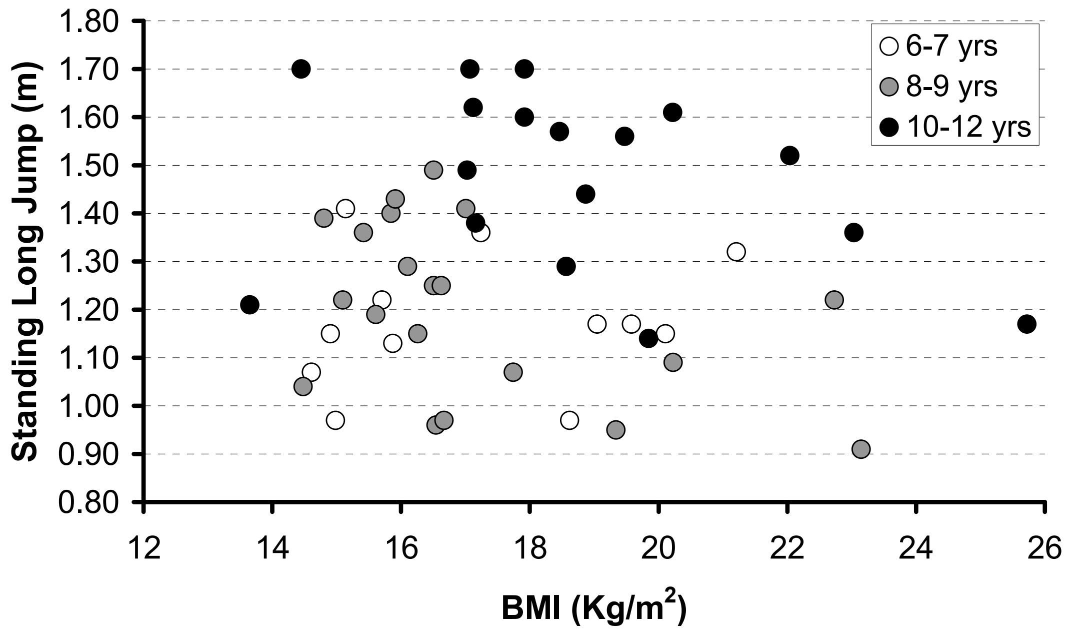


**Figure 1.** Performance in standing long jump, as a function of BMI in girls aged 6-7 (white circles), 8-9 (grey circles) and 10-12 years (black circles). Spearman's rho for the whole sample was 0.016 (p= 0.916).

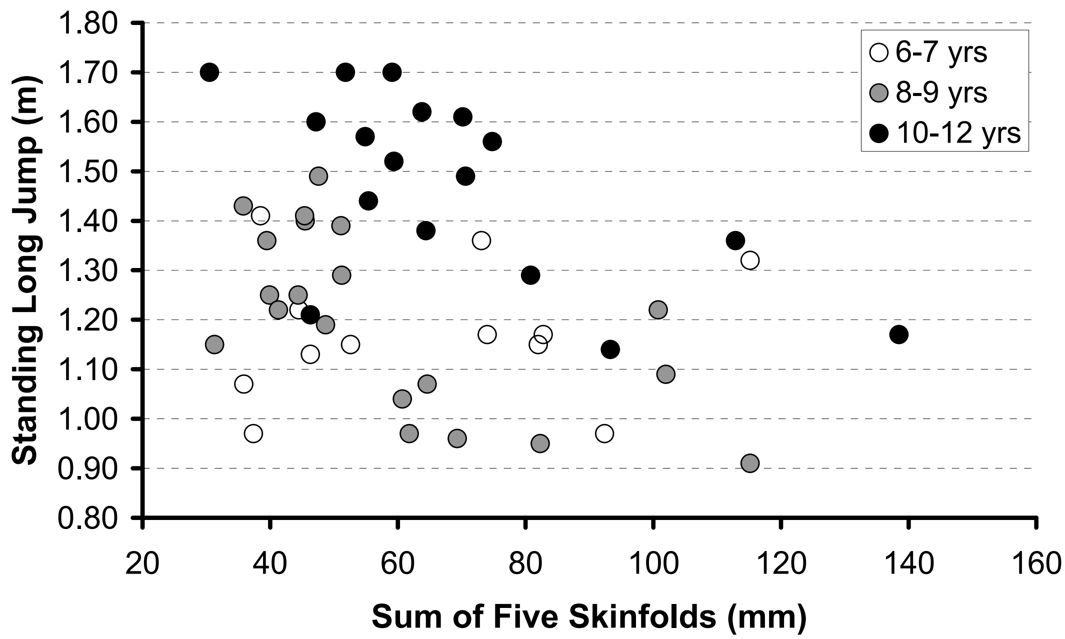


**Figure 2.** Performance in standing long jump, as a function of the sum of five skinfolds in girls aged 6-7 (white circles), 8-9 (grey circles) and 10-12 years (black circles). Spearman's rho for the whole sample was -0.236 (p=0.103).

These findings were confirmed when considering simultaneously both sexes and all ages by ANOVA: log-velocity or standing long jump was not related with either BMI (P=0.691 and P=0.252, respectively) or waist (P=0.511 and P=0.188). The negative effect of skinfold thickness on standing jump was clearly significant (P=0.007) and borderline on velocity (P=0.087). Physical fitness improved significantly with age (P<0.001) and was higher in males.

Velocity and explosive strength were significantly correlated (Spearman's rho= 0.73 in males and 0.74 in females). The correlation was also significant when separately considering each age-sex combination (Table 4). Correlation was particularly strong, Spearman's rho exceeding 0.60, in females aged 6-7 and 8-9 years, decreasing to 0.50 in the 10-12 years group. In males the strength of the correlation increased with advancing age, the Spearman's rho being 0.44, 0.46 and 0.61 in boys aged, respectively, 6-7, 8-9 and 10-12 years.


ISSN 1988-5202

**Table 4.** Correlation between standing long jump length and velocity. The correlation was evaluated by Spearman's rank-order correlation coefficient; significance value is reported in parentheses.

| | | Males 6-7 yrs (n=29) | Females 6-7 yrs (n=12) | Males 8-9 yrs (n=32) | Females 8-9 yrs (n=20) | Males 10-12 yrs (n=37) | Females 10-12 yrs (n=17) |
|---|---|---|---|---|---|---|---|
| Jump length | Velocity | **0.428 (P=0.020)** | **0.721 (P=0.008)** | **0.532 (P=0.002)** | **0.613 (P=0.004)** | **0.630 (P<0.001)** | **0.600 (P=0.011)** |

**DISCUSSION AND CONCLUSION**

The main results of the present study, conducted in 152 children aged 6-12 years from the Verona area, are the following:

1. The waist circumference and the amount of subcutaneous fat positively correlate with BMI, but the W/H ratio does not.
2. Motor fitness tests significantly correlate with age, and performance is higher in males.
3. The BMI does not correlate with motor fitness tests.
4. The amount of subcutaneous fat is inversely correlated with motor fitness tests.
5. Motor fitness tests positively correlate with each other, especially in females.

Over the first decade, the children's growth is almost linear (Rogol, 2002), boys and girls accruing lean body mass at similar rates (Fomon et al., 1982; Van der Sluis et al., 2002; Wells, 2007); however, females show a tendency to get higher percentage body fat (Wells, 2007; Arfai et al., 2002); in accordance, females showed higher sum of five skinfolds in our study group while BMI and waist circumference were not significantly different (Table 1). Fundamental movement pattern are mastered by the age of 5 or 6 years and thereafter most indices of motor performance are tied to age and exhibit similar performance curves in the two sexes prior to puberty (Thomas & French, 1985).

The positive correlation between BMI and sum of skinfolds and, accordingly, the inverse relationship between the BMI and estimated body density (Table 2) were expected, because the sample group was from a well-nourished population, whereas BMI is more an index of muscle mass in undernourished populations (see e.g., Monyeki et al., 2005). BMI did not correlate with the W/H ratio, but showed a clear tendency to positively correlate with the waist circumference (a good predictor of abdominal adipose tissue in children see e.g., Brambilla et al., 2006), especially in males (Table 2).

Moreover, during early childhood motor fitness improve with age (Arceneaux et al., 1997; Benefice et al., 1999; Davies & Rose, 2000; Butterfield et al., 2002). Accordingly, we found a significant (P<0.001) relationship between age and motor fitness. However, only a few studies attempted to establish differences in motor fitness between boys and girls during development phase. Early childhood is a period when the first sex-related differences can be observed in performing the same motor tasks; in particular, better performance in males has been observed in test of strength (Backman, 1988; Benefice et al., 1999), speed (Benefice et al., 1999; Toriola & Igbokwe, 1986) and coordination (Levy & Hobbes, 1979). It has been suggested that most differences in gross motor activities in young boys and girl are small and associated with differences in activity levels (Manios et al., 1999); however, physical activity is difficult to measure in children and adolescent (Welk et al., 2000), so we did not investigate the physical activity patterns of the children in this study.

It has been shown (Butcher & Eaton, 1989) that somatic dimensions are associated with fundamental motor skills. Generally, body size and weight are negatively correlated to motor fitness tests where the body is projected or work is performed against gravity (as a running, jumping, sit-ups); however, the association between biological factors and motor skills/abilities in prepuberty was found to be relatively low in several studies (Silva et al., 1984; Ball et al., 1992). Fiørtoft (2000), using the EUROFIT test battery found that in 5-7-year-old children weight and height have no impact on best test performance while age and sex present major and minor effect, respectively; no difference in motor skills was found between sexes. Berk (1997) showed that boys are generally slightly more advanced than girls in regard to force and power; however, according to Malina et al. (2004) "in early childhood there are minimum gender differences in motor development and, consequently, in motor tests. These differences become significant later, from the age of 10 years on when sexual maturation starts" (Davies & Rose, 2000; Haywood & Getchell, 2001). Our findings support the view that in the 6-12 years period motor performance improves with age and is higher in males. However, in our pre-puberty population we could not record the large improvement in motor performance observed in males after puberty.

Previous studies have demonstrated that growth and body composition affects physical fitness in children (Pate et al., 1989; Taylor & Baranowski, 1991; Malina, 1995; Pejčić et al., 2004). In general, fatness negatively affects health- and performance related physical fitness (Cureton et al., 1991; Malina, 1995), and body size correlates variably with fitness items in children. As to the relationship between body composition and motor performance in children, we found that in the whole sample subcutaneous fat was negatively correlated with standing long jump and, at borderline significance, with velocity. When subjects were stratified by age class and sex, males aged 6-7 years only showed a negative correlation between sum of skinfolds and velocity, and females aged over 8 years showed a negative correlation between sum of skinfolds and standing long jump (Table 3). Overall, these findings show that subcutaneous fat is a better predictor of physical fitness than BMI or waist circumference in children, but should be used with caution. Indeed, while Raudsepp and Päll (1999) found that the sum of five skinfolds was significantly negatively related with motor fitness in 7-9 years girls after controlling for the effect of physical activity, Ellery (1991) found no correlation between skinfold thickness and gross motor skill performance. However, the correlation between body composition and motor abilities was found to be moderate in several studies (Hensley et al., 1982; Pissanos et al., 1983; Malina et al., 1995; McKenzie et al., 2002). At variance with our results showing no influence of either BMI or waist on motor performance, Graf et al. (2004) found an inverse relationship between BMI and either a body gross motor development test (KTK), or a 6-min run in 668 children aged 6 years. Okely et al. (2004) showed that children's ability to perform fundamental motor skills (especially the

 ISSN 1988-5202

locomotor ones) was significantly related to BMI and waist circumference. Such discrepancies may arise from differences in experimental protocols and/or measured parameters which make comparison difficult; a relevant confounding factor is probably the prevalence of overweight/obesity in the sample; for example, in 709 Greek elementary school children BMI was inversely correlated with performance in several EUROFIT test, but 25.8% of the sample was overweight and 14.8% was obese, both figures being much higher than in our study group (20 and 4%, respectively) (Tokmakidis et al., 2006). On the other side, in South African children aged 7-14 years BMI was positively correlated with standing long jump (Monyeki et al., 2005), probably because in a undernourished population BMI should be interpreted as an indicator of muscle mass. These observations, taken together, suggest that individual variability of BMI within the normal range does not affect motor fitness, while having a significant influence in very lean or overweight/obese children.

In the developing child, linear growth, weight, and muscle size are important contribute to strength. The strength increases fairly linearly until puberty, to increase thereafter at different rates for males and females. We found significant correlations between standing long jump and 30m dash in both sexes and at all ages suggesting that explosive strength and velocity are related the 6-12 years age span. Accordingly, it has been shown that muscle strength is an important component of running speed (Berg et al., 1986; Farrar et al., 1987); moreover, the relationship between standing long jump and 30m dash may be due to the fact both are power events which involve horizontal movement of the centre of mass. This finding confirm and extend the findings of a meta-analysis based on sixty-seven studies on the EUROFIT tests performance of healthy European children (Tomkinson et al., 2007): considering the correlation matrix for mean z-scores for nine EUROFIT test, standing long jump was strongly correlated with many others and showed the best consistency between males' and females' performances within a country (+0.96). However, the Italian studies considered in the meta-analysis were all performed in the age range 12-19 years; results presented herein were obtained in children aged 6-12 years, thereby integrating previous information for that country.

In conclusion, we suggest that the BMI should not be used to infer on the motor fitness status of children, the amount of subcutaneous fat being more reliable. The correlation between the standing long jump and 30m dash indicates that the two tests assess, at least in part, similar motor abilities; this casts doubts on the usefulness of administering both tests in a battery if independent motor abilities are to be evaluated.

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