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Physical Fitness Evaluation of School Children in Southern Italy: A Cross Sectional Evaluation

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Abstract: The aim of this work was to evaluate the fitness levels of different physical components in schoolchildren in southern Italy and identify age-related effects of physical performance. One hundred and fifty-four schoolchildren with ages ranging between 6 and 10 years (age 8.1 ± 1.45 years; 33.70 ± 10.25 kg; 131.50 ± 13.60 cm) were recruited for the investigation. Each scholar underwent a fitness-test battery composed of five elements. A Hand-Grip Strength Test to assess the strength of the hand muscles, a Standing Broad Jump Test to assess lower body explosive strength, a Sit-Up Test to exhaustion to evaluate abdominal muscular endurance, a 4 × 10-m Shuttle Run Test to assess agility, and a 20-m sprint test to assess speed. Cross-sectional analysis revealed that boys perform better than girls and that age affects performance. Lower limb measures show a significant increase after 8 years of age, whereas upper limb measures show a significant increase at 7 and 10 years of age. No age-related differences were found in muscular endurance measures. It is possible to consider age-related performance measures to program exercise interventions that follow the growth characteristics of schoolchildren.

Keywords: physical fitness; assessment; children; evaluation

1. Introduction

Physical activity (PA) is a key component in order to maintain and improve health, including physical, mental, and emotional health [1–4]. A considerable amount of evidence exists that supports the concept that PA is able to improve musculoskeletal health, improve cardiovascular fitness, and improve body composition and overall physical fitness [5]. The latter is defined as a state of wellbeing, which refers to the ability to perform daily tasks, sports, or occupations without undue fatigue [6].

Fitness tests are usually assessed in laboratories or fields. However, laboratory tests are more costly and time consuming. Notwithstanding field tests are in general less accurate, are widely used for their lower costs, and require less time for their administration [7].

In order to assess physical fitness through field-based fitness tests, different attempts have been made in both children and adolescents. Successful examples are the Assessing Levels of Physical Activity study (ALPHA study) [8], which aimed to identify reliable fitness tests for children and adolescents; the AVENA study, which aimed to evaluate cardiovascular fitness in youth around Europe [9]; the Healthy Lifestyle in Europe by Nutrition in Adolescence study (the HELENA study) [10], which evaluated physical fitness over 10 European nations; FitnessGram [11], whose purpose was to increase the levels of physical activity in children in the United States; and EUROFIT [12], a program in Europe. All these attempts firstly detected the reliability of the fitness tests for specific populations and secondly provided age-related fitness percentile values [13,14].

In a previous study, we identified five field-based fitness tests to evaluate the level of physical fitness in adolescents and subsequently, in a second study, evaluated physical fitness of adolescents using the selected fitness tests in the context of the Adolescents Surveillance System and Obesity prevention study (ASSO project) [6,15]. These were chosen according to their feasibility, safeness, reliability, and low cost. These tests were the standing broad jump for the evaluation of lower limb strength, the hand-grip test for the evaluation of the strength of the upper limbs, the sit-up to exhaustion for the evaluation of abdominal muscular endurance, the 4 × 10-m shuttle run for the evaluation of agility, and the 20-m shuttle run test for the evaluation of aerobic capacity. Notwithstanding that such a fitness battery was used in adolescents, other studies such as AVENA, FitnessGram, or EUROFIT, have used similar fitness batteries to evaluate physical fitness levels in children [11,12,16,17]. Another similar battery is that proposed by the PREFIT study used in Spanish schoolchildren [18].

In schools or sports, children are generally classified in age groups, and this grouping is usually done according to the age of birth, thus a one year difference will be often present [19]. During development, older individuals usually perform better [20], defining what is known as the relative age effect [21]. If such an effect was not relevant, then it would be of no use to group children according to their age. The age-related effect may be applicable to both physical and mental aspects. To the best of our knowledge, age thresholds at which physical development may induce significant variations in physical fitness has not received considerable attention, thus, the aim of this study was twofold: firstly, to evaluate the fitness levels in schoolchildren from southern Italy through a validated field-based fitness battery and secondly, to determine whether age-related effects in physical performance for each selected measure is present.

2. Materials and Methods

2.1. Participants

One hundred and fifty-four school children with ages ranging between 6 and 10 years (age 8.1 ± 1.45 years; 33.7 ± 10.25 kg; 131.5 ± 13.6 cm) from an elementary school in southern Italy were recruited for this investigation. The school was selected within the context of a project (Alfabetizzazione Motoria) to which the school had adhered that was organized by the National Olympic Committee (CONI) and by the Ministry of Education of the University and Research (MIUR) with the aim to promote physical activity in elementary schools. All schoolchildren were tested at the beginning of the project. An initial number of 169 children had been tested, however, only the children that performed all the selected tests of the fitness battery were included for the analysis. Children with medical issues or physical and mental disabilities were not included in the study. The final 154 participants were 80 males (age 8.10 ± 1.40 years; 34.70 ± 9.90 kg; 132.90 ± 8.30 cm) and 74 females (age 8 ± 1.50 years; 32.70 ± 10.60 kg; 129.70 ± 17.70 cm). The principles of the Italian data protection (196/2003) were guaranteed. The Ethical Committee of the DISMOT department approved the project (approval number: 4, approval date: 29 July 2010). The study was undertaken in accordance with the deontological norms laid down in the Helsinki Declaration and the European Union recommendations for Good Clinical Practice.

2.2. Methods

The participants undertook a modified ASSO Fitness Test Battery (FTB) [6] that comprised of five selected tests for the assessment of the physical fitness components: (1) the Hand-Grip Strength Test (HG) to assess upper body strength, (2) the Standing Broad Jump Test (SBJ) to assess lower body explosive strength, (3) the Sit-Up Test to exhaustion (SUT) to assess abdominal muscular endurance, (4) the 4 × 10-m Shuttle Run Test (4 × 10 mSRT) to assess agility, and (5) the 20-m sprint test (20 mST) to assess speed [6,16,22,23]. All tests were performed three times and the best score was retained for investigation except for the sit-up test to exhaustion, which was performed only once. At least one parent of each participant had to present a signed consent form in order to allow the children to participate in the study.

All participants were tested during school hours, from 9 to 12 am, by the same investigator. One test per day was administered, in order to allow each child to properly understand the indications of the investigator and not bias the results through progressive fatiguing.

Prior to the administration of the fitness battery, anthropometric measures of each participant were assessed using a scale with a 0.1 kg sensitivity (Seca 709, Seca, Hamburg, Germany) for weight and a wall-stadiometer with a 1 mm sensitivity (Seca 220, Seca) for height.

On the first day, the HG was administered. The test consisted of grabbing a digital handheld dynamometer (KERN MAP 80 K1, Kern & Sohn GmbH, Balingen, Germany) with the arm fully extended, not touching the body, and squeezing the dynamometer at maximum strength. This task was carried out while standing. Each participant repeated the task three times with the right hand (HG R) and three times with the left hand (HG L). Between each task each participant had a two-minute rest to allow for a full recovery. The highest of the three trials was considered for statistical analysis.

On the second day, the participants had to perform the SBJ. The test consisted of jumping forward the maximum possible distance, starting from a standing position. Each participant was required to stand with his/her heels on a line that represented the starting point. The feet had to be parallel to each other. Each participant was allowed to squat before the jump and swing the arms forward during the jump. The measurement of the SBJ was calculated from the starting line to the point at which the heels of the participant touched the ground. A tape measure was used to evaluate performance. Each participant performed three trials with a two-minute rest between each task and the greatest of the three tasks was considered for analysis.

On the third day, the participants performed the SUT. The participants had to lay supine on the floor with the knee joints flexed at 90°, hands at the side of their head, and their elbows pointing straight forward. The correct sit-up execution was considered when the elbows touched the knees during the concentric phase of the movement and then the shoulders touched the floor during the eccentric phase of the movement [22]. If the participants were not able to lift the back from the floor a number of 0 repetitions were counted. The test ended when the participants were not able to perform the repetitions with the correct form above described. The participants were not allowed to recover during the test. The SUT was performed only once.

On the fourth day, the participants were asked to perform the 4 × 10 mSRT. Each participant was asked to run back and forth four times within two lines 10 m apart at his/her maximum possible speed. Each participant had to start behind the start line and had to cross the opposite line before they had to change direction and start running to the opposite line again. Each participant started running upon receiving the verbal command "go" from the investigator. The test ended when the participant crossed the finish line at the end of the fourth shuttle. Time was measured with a stopwatch. Each participant performed three tasks with a two-minute rest between each task. The fastest of the three measures was retained for investigation.

On the fifth day, the participants were asked to perform a 20 mST. Each participant was asked to run within two lines 20 m apart at the maximum possible speed. Each participant had to start behind the start line. The test started when each participated received the verbal command "go" from the investigator and ended when the participant crossed the finish line. Time was measured with a stopwatch. Each participant performed three tasks with a two-minute rest between each task. The fastest of the three measures was retained for investigation.

2.3. Statistical Analysis

Descriptive statistics were used for anthropometric parameters and for performance representation of the entire sample and the stratified samples. Unpaired *t*-tests with Welch's correction were used to evaluate differences between performance measures and between age groups of the same performance measure. ANOVA was used to determine a significant effect of age on performance and a subsequent intra-group analysis to identify the age thresholds. Analysis was performed using SPSS Statistica 10.0

(Statsoft, Tulsa, OK, USA) for Windows and Prism 6 (GraphPad software, Inc., La Jolla, CA, USA) for graph creation.

3. Results

Descriptive characteristics of the sample are presented in Table 1.

Table 1. Descriptive characteristics of the sample.

Male						
Age (years)	8.10 ± 1.40	6	7	8	9	10
Subjects (n)	80	14	13	19	17	17
Body Mass (kg)	34.70 ± 9.90	26.1 ± 6.3	30.6 ± 7.6	33.9 ± 9.6	38.6 ± 9.6	42.2 ± 8.0
Height (cm)	132.90 ± 8.30	123.1 ± 6.1	127.5 ± 6.0	133.4 ± 5.8	137.0 ± 6.5	140.8 ± 4.1
Female						
Age (years)	8 ± 1.50	6	7	8	9	10
Subjects (n)	74	17	17	8	15	17
Body Mass (kg)	32.70 ± 10.60	25.1 ± 4.8	28.5 ± 6.2	31.6 ± 9.5	39.4 ± 11.8	38.2 ± 11.0
Height (cm)	129.70 ± 17.70	119.2 ± 4.8	118.7 ± 28.3	131.0 ± 4.3	138.2 ± 6.7	142.8 ± 7.0

Data are presented as means ± standard deviations.

The general outcome of the performance measures shows an increase according to age in both males and females. This trend is evident in all physical measures, as shown in Table 2. Stratified performance measures are reported in Table 3 for male participants and Table 4 for female participants. Single performance measures for both males and females are shown in Figures 1–5.

Table 2. Performance measures of the entire sample.

Age	SBJ (cm)	4 × 10 m (s)	SUT (reps)	HG R (kg)	HG L (kg)	20 mST (s)
6	115.6 ± 16.9	15.8 ± 1.6	16.7 ± 16.6	7.7 ± 2.2	7.2 ± 2.1	5.49 ± 0.52
7	118.3 ± 17.4	15.6 ± 1.7	24.9 ± 21.9	10.6 ± 2.4	9.8 ± 2.5	5.15 ± 0.59
8	126.9 ± 18.8	14.3 ± 1.9	42.4 ± 41.3	13.1 ± 3.2	11.2 ± 3.2	5.09 ± 0.62
9	137.6 ± 19.1	14.5 ± 1.5	50.3 ± 46.2	14.7 ± 3.4	13.2 ± 3.6	4.98 ± 0.60
10	140.6 ± 18.3	13.4 ± 1.1	55.91 ± 34.9	16.5 ± 3.3	14.7 ± 3.5	4.78 ± 0.42

Data are presented as means ± standard deviations. SBJ: Standing Broad Jump Test; SUT: Sit-Up Test to exhaustion; HG R: Hand-Grip Strength Test for the right hand; HG L: Hand-Grip Strength Test for the left hand; 20 mST: 20-m sprint test.

Table 3. Performance measures of the male participants.

Age	SBJ (cm)	4 × 10 m (s)	SUT (reps)	HG R (kg)	HG L (kg)	20 mST (s)
6	122.1 ± 16.8	15.4 ± 1.95	11.2 ± 8.9	8.4 ± 2.3	7.7 ± 2.3	5.36 ± 0.55
7	124.8 ± 20.2	15.8 ± 1.87	25.85 ± 28.9	11.8 ± 2.2	10.7 ± 2.9	5.01 ± 0.56
8	135.5 ± 18.4	13.6 ± 1.2	47.0 ± 46.7	13.6 ± 3.2	11.9 ± 3.4	5.08 ± 0.71
9	142.1 ± 19.1	13.8 ± 1.5	68.1 ± 54.9	15.5 ± 3.8	14.2 ± 3.9	4.77 ± 0.55
10	143.4 ± 15.5	12.9 ± 0.8	64.1 ± 32.5	18.4 ± 3.3	16.2 ± 3.6	4.62 ± 0.30

Data are presented as means ± standard deviations.

Table 4. Performance measures of the female participants.

Age	SBJ (cm)	4 × 10 m (s)	SUT (reps)	HG R (kg)	HG L (kg)	20 mST (s)
6	110.3 ± 14.6	16.1 ± 1.2	21.3 ± 20.1	7.1 ± 1.5	6.8 ± 0.9	5.59 ± 0.48
7	113.3 ± 13.6	16.1 ± 1.4	24.2 ± 15.5	9.7 ± 2.1	9.1 ± 1.9	5.26 ± 0.61
8	118.2 ± 15.3	15.8 ± 2.4	30.9 ± 21.4	11.6 ± 2.9	9.71 ± 2.1	5.11 ± 0.35
9	126.5 ± 14.4	15.1 ± 1.2	32.7 ± 26.8	13.9 ± 2.9	12.2 ± 3.2	5.18 ± 0.60
10	137.9 ± 18.2	13.9 ± 1.2	48.2 ± 36.2	14.8 ± 2.2	13.3 ± 2.8	4.92 ± 0.47

Data are presented as means ± standard deviations.

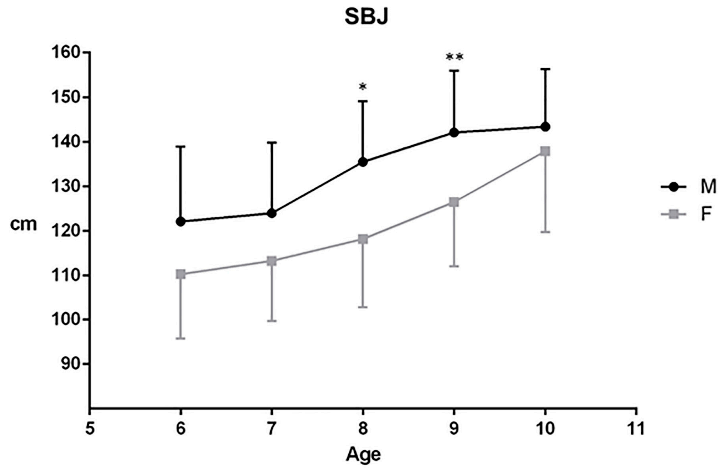

Figure 1. Standing broad jump of male and female schoolchildren stratified by age. Differences between male (M) and female (F) * $p < 0.05$; ** $p < 0.01$.

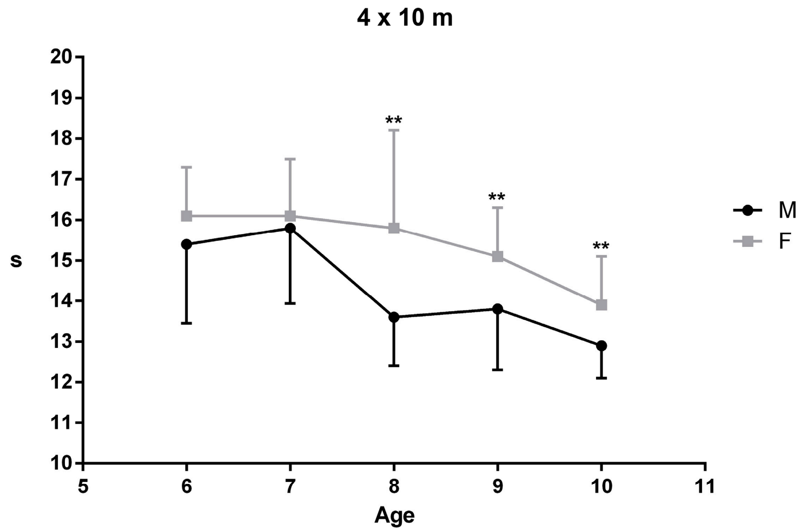

Figure 2. 4 × 10 m shuttle run test of male and female schoolchildren stratified by age. Differences between male (M) and female (F) ** $p < 0.01$.

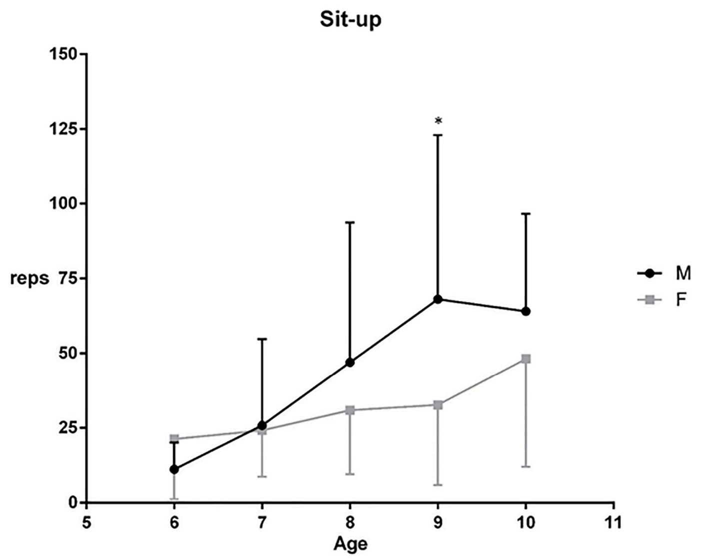

Figure 3. Sit-up test of male and female schoolchildren stratified by age. Differences between male (M) and female (F) * $p < 0.05$.

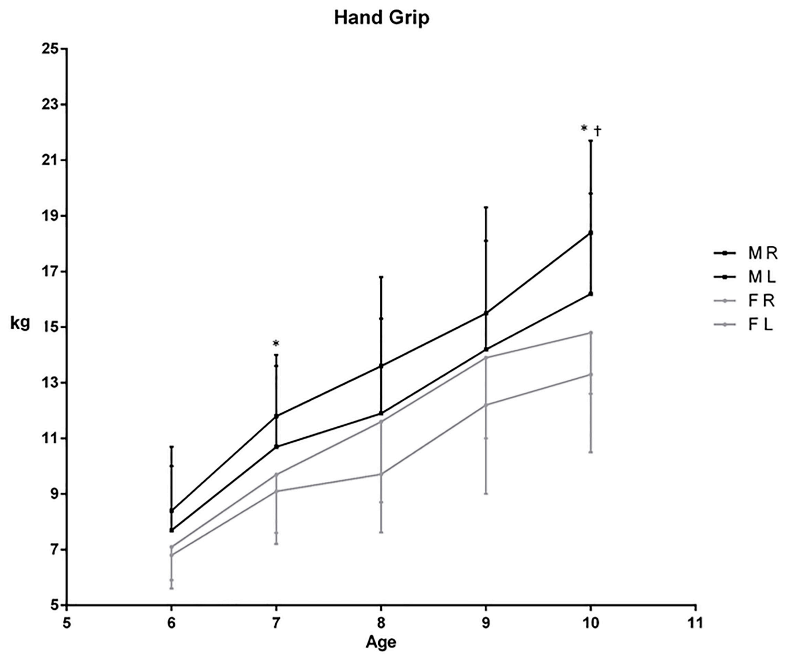

Figure 4. Hand-grip test results for both the right (R) and left (L) hands of male (M) and female (F) schoolchildren stratified by age. Differences between male and female * $p < 0.05$; † $p < 0.001$.

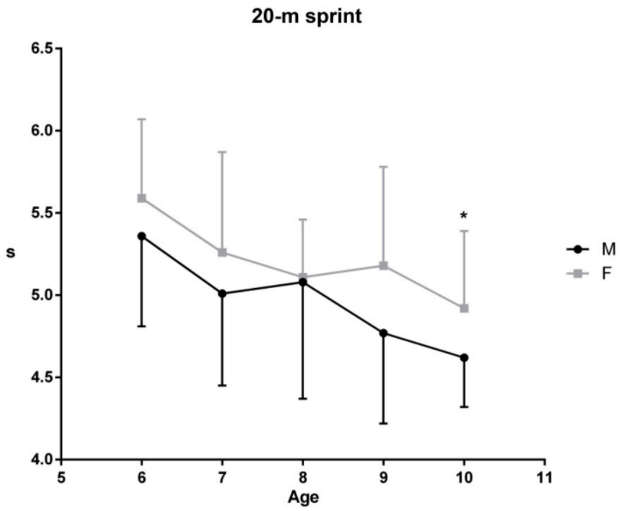

Figure 5. 20-m sprint test of male and female schoolchildren stratified by age. Differences between male (M) and female (F). * $p < 0.05$.

Statistical analysis showed significant differences between male and female participants across all tests, with better performance measures for the male schoolchildren. Analysis of variance has also shown a significant effect of age on the performance measures. However, when sub-analysis on single components was performed to determine which age groups had the greatest differences, each test showed different outcomes. In particular, a significant effect on the 4 × 10 mSRT was evident between 6 and 7 years of age, and in the HG between 7 and 8 years of age. This analysis, however, did not take into account gender differences. Major results are presented in Table 5.

Table 5. Statistical differences between groups.

Tests	Gender	Age	6	7	8	9	10
SBJ	<0.0001	<0.0001	ns	ns	0.047	0.007	ns
4 × 10 m	<0.0001	<0.0001 [b]	ns	ns	0.004	0.008	0.005
SUT	0.022	<0.0001	ns	ns	ns	0.03	ns
HG R	0.0002	<0.0001 [a,b]	ns	0.011	ns	ns	0.0005
HG L	0.0012	<0.0001 [a]	ns	0.048	ns	ns	0.012
20 mST	0.0047	<0.0001	ns	ns	ns	ns	0.034

Gender: unpaired *t*-test between male and female of the whole sample; Age: one-way ANOVA [a]: 6 vs. 7, [b]: 7 vs. 8, between age groups regardless of gender; Age groups (6, 7, 8, 9, 10) unpaired *t*-test between male and female of the same age; ns: not significant.

At 7 and 10 years of age the strength of the upper limbs shows significant differences between male and female participants, whereas the lower limbs (SBJ) show differences in performance only between 8 and 9 years of age across gender. A significant difference between male and female schoolchildren is also shown at ages 8, 9, and 10 in regard to the 4 × 10-m shuttle run test used for agility.

4. Discussion

The aims of this study were twofold: (1) to assess physical fitness in schoolchildren and (2) to identify the age-related effects on physical fitness in this population. Physical fitness increases according to age, thus there is a significant age-related effect for all physical measures. Secondly, there is a significant difference between male and female schoolchildren, with the male children performing significantly better than the female children. In addition, age thresholds of increased performance have been determined and a significant increase of the strength of the lower limbs is present at 8 years of age, whereas a significant increase of the strength of the upper limbs is present at 7 and 10 years of age. The speed and agility measures are seen to significantly increase from 9 to 10 years of age.

The increase of performance according to age and the differences between male and female schoolchildren are in line with other studies in the literature [24–26]. In a sample of German schoolchildren [24], a significant age effect was seen amongst different fitness tests. In particular, an increase of the upper limb strength measures was seen in both boys and girls around 9 and 10 years of age. Another population study based on Spanish schoolchildren evaluated the physical fitness of 1725 children with ages ranging from 6 to 12 years, using the FitnessGram battery. The results of the study posit increased physical fitness of boys compared to girls in all fitness measures, showing a linear increase across age [25]. It is interesting to note that our modified ASSO FTB shares common fitness tests with the FitnessGram battery (Hand-grip, Standing Broad jump Test, Sit-up test, and a shuttle run test) and that our physical measures are in agreement with those of Gulias-Gonzales et al. [25]. A third study analyzing Polish schoolchildren [26] used the EUROFIT battery to assess physical fitness in children and adolescents. The results provide percentile values over a large population for 14 different fitness measures, of which three are in common with our battery (Hand-grip, standing broad jump, and the 4 × 10-m shuttle run). Notwithstanding the analyzed population comes from a different geographical area, the results support the greater physical fitness of boys compared to girls, increased measures according to age, and similar physical outcomes when compared to our analyzed sample from southern Italy.

Many studies have provided percentile values for physical fitness tests for both children and adolescents and the results of all these studies are again in agreement with our results, with boys performing better than girls, and older children performing better than younger ones [24]. All these studies, in particular, have observed increased performance values for strength (e.g., Hand-grip), power (e.g., standing broad jump), agility (e.g., 4 × 10-m shuttle run), muscular endurance (e.g., Sit-ups), and endurance (e.g., 20 m shuttle run test) [27,28]. The reported tests are all included in our ASSO FTB, except for the endurance measures. These outcomes are helpful to consider for the identification of physical fitness characteristics in a specific sample of schoolchildren, and the results obtained here seem similar to other cohorts analyzed elsewhere.

The progressive stages of puberty, revised by Schell et al. [29], highlight an s-shaped development from birth to adulthood, with a fast growth from 0 to 6 years old, followed by a constant growth from 7 to 11 years old, and fast growth again during puberty. Genes, hormones, nutrients, environment, and physiological systems such as the genital system influence this growth pattern. The most evident change may be seen in anthropometric characteristics such as weight and height that will influence the athletic performance with changes in energy expenditure, as well as force and power production [30].

The review by Ford et al. [30] tried to determine critical periods during development to identify performance changes, and several aspects have been taken into account. In regard to muscle growth, it has been seen that at 7 years of age in both males and females there is a significant increase of muscle mass, especially in the cross-sectional area. Concomitantly, between 6 and 8 years of age a remodeling of the cerebral cortex and increase of the dendritic density is also present. This developmental stage may explain why between 7 and 8 years of age a significant increase in the performance of the upper and lower limbs is displayed. Between 8 and 10 years of age, the most prevalent developmental increases are seen on the hormonal system and in the aerobic capacity [22]. Around 9 years of age, there is an increased release of catecholamines and a higher response to insulin and glucagon, whereas development of the cardiorespiratory system is prevalent around 10 years of age. Between 10 and 12 years of age there is notable development of nerve pathways and increases in motor skill development are also present [22]. These developmental stages are useful to explain our results, where the running skills of the children start to increase at 10 years of age. The main limit of our study is the sample size, which in our case is confined to only one elementary school. Thus, this means that the results may be relevant to the analyzed sample and not extended for general conclusions. Notwithstanding such limits, the results of this study seem to be in line with other studies in the literature.

5. Conclusions

An age relative effect is present between 6 and 10 years of age with differences between the analyzed male and female schoolchildren from southern Italy. Our results highlight that the strength of the upper limbs develops earlier than lower limbs and that speed and agility are greater around 10 years of age.

The results of the present study support the already existing literature and could help teachers and sport professionals to understand the different fitness developmental phases through the use of the selected fitness tests and motor development intervention programs.

Author Contributions: Ewan Thomas has conceived the manuscript, collected and analyzed the data and drafted the manuscript. Antonio Palma has revised the drafted manuscript and gave the final approval.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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