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Assessing the Evolution of Physical Fitness in Children and Adolescents for Evidence-Based Teaching

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Abstract

Physical fitness is one of the most important health indicators in children and adolescents. This study aims to assess the evolution of physical fitness levels in children and adolescents (9 - 14 yrs) related to weight-status, providing evidence-based instructions for physical education teachers, and promoting the quality of physical education programs. The sample consisted of 542 early adolescents aged 9 - 14 years (M = 269, F = 273) recruited from secondary schools in Italy. Physical fitness was assessed with the following motor test: SBJ, MBT, 10 × 5 and One Mile RWt. In addition to descriptive statistics, independent samples T-test and factorial ANOVA were carried out to compare and assess the evolution of motor performances over time. Multiple linear regression analysis was executed to investigate the variance in motor test explained by weight and height. Results evidence a significant increase in SBJ and MBT, but not in 10 × 5 and OneMile Run/Walk test, in about all age groups, both in male and female, normal weight and overweight/obese. Data analysis suggests that strength test in which is required single movement execution is more associated and conditioned by individual growth and anthropometrics factors than test required repeated movement and greater coordinative engagement.

Keywords

Quality of Physical Education, Physical Fitness, Teaching Styles, Regional Observatory

1. Introduction

The increase of overweight and obesity in children and adolescents is one of the most important health-global priorities (Abarca-Gómez et al., 2017), having a significant effect on adult diabetes development (Zhang et al., 2019), increasing common chronic diseases in middle age (Yu et al., 2018) and specific causes of death in adult age (Bhaskaran et al., 2018).

Health benefits of physical activity and fitness levels are well documented and include not only the prevention of overweight and obesity (Al-Khudairy et al., 2017), cardiovascular (Abrignani et al., 2019) muscle and skeletal health improvement (Alves & Alves, 2019), but are also associated with mental health and well-being (Hosker et al., 2019), cognitive and academic performances (Singh et al., 2019).

The new guidelines of World Health Organization suggest that children and adolescents should be active for at least 60 minutes daily of moderate to vigorous aerobic physical activity (MVPA) and regular strength activity (Bull et al., 2020). Unfortunately, about 85% of girls and 78% of boys aged 11 - 17 do not meet international physical activity guidelines, and the percentage of obese children and adolescents has increased exponentially over the last 40 years: in 2016, over 50 million girls and 74 million boys (about the 6% - 7% of teenagers) were overweight or obese (Guthold et al., 2020).

Studies reveal a progressive decline in physical fitness levels among children and adolescents especially in the transition from middle to high school (Pate et al., 2019); children with high overweight/obese BMI show lower performances than those with normal weight BMI, with more significant differences in boys rather than girls (Colley et al., 2019; Dong et al., 2019; Milanovic et al., 2019).

Motor competences and physical fitness levels acquired by children in primary schools are correlated with different developmental pathways: low motor competences are correlated with low physical fitness levels, both predictors of overweight and obesity in adulthood (Rodrigues et al., 2016; Utesch et al., 2019).

The triad of physical inactivity in children (Faigenbaum et al., 2018) identifies three distinct but related factors: exercise deficit disorders, pediatric dynapenia, motor illiteracy, generating a dangerous circular process: subjects with low levels of daily physical activity are less likely to participate in physical activities, even free/unstructured, which involve enjoyment and fun; this determines a lower predisposition to physical or sports practice and to a progressive reduction of the individual motor skills repertoire and the consequent levels of individual motor development.

School-based-intervention program and physical education represent an important area in which motor development, the evolution of motor abilities and motor skills learning integrate each other allowing the achievement of interdisciplinary and transversal objectives related to correct eating habits and healthy lifestyles (Yuksel et al., 2020).

Sedentary habits in developmental age, in particular in the last fifteen years, in addition to being one of the causes of the progressive increase in overweight and obesity in this age group, are among the main causes of the decline in levels of physical activity and motor performance coordinative and conditional, with worrying repercussions, both quantitative and qualitative, on organic, cognitive and social relations development, requiring specific methodological and well-oriented interventions (Myer et al., 2015).

In Italy, the percentage of obese children and adolescents is almost tripled from 1975 to 2016. As regards the percentage of obese children and adolescents, Italy ranks 61st worldwide for females and 46th for males, occupying 6th and 8th place respectively in high-income countries (Guthold, et al., 2020).

The Regional Observatory on the monitoring of motor development of adolescents, at the University of Foggia, Didactics Laboratory of Motor Activities, involves numerous schools and arises from the need to periodically acquire, annually, quantitative and qualitative data on the development of health-related motor skills and physical activity levels in developmental age. These data constitute direct information on the evolution of children's motor skills in a geographical area and, indirectly, on the degree of effectiveness of the interventions carried out in schools and on the quality of physical education in secondary schools; promote the self-assessment of motor performance and health conditions by students, a prerequisite for education in daily motor activities.

The aim of this study is to assess the evolution of physical fitness levels in children and adolescents (9 - 14 yrs) related to weight-status, interpreting data to raise physical education teaching process.

2. Materials and Methods

2.1. Sample

The sample consists of 542 early adolescents aged 9 - 14 years (M = 269, F = 273) recruited from secondary schools in Foggia, South of Italy. The following research project (2019-2021), approved by the Administration of the Puglia Region (southern Italy), concerns the implementation of the Regional Observatory on the monitoring of physical efficiency related to adolescent health, involves secondary schools and it will be coordinated by the University of Foggia (Italy) - degree course in Sciences and Techniques of Preventive and Adapted Motor Activities-Laboratory of Didactics of Motor Activities. Children and parents were informed about the study purposes and contents and written informed consent was obtained from one parent. After detecting anthropometrics data (height, weight and BMI), participants were divided into different groups according to gender, BMI Cutoff (Normal-weight vs Overweight-Obese) and age group (9 - 10 yrs, 11 - 12 yrs and 13 - 14 yrs). Cole's scale (2000) was used to determine if children were classified as Normal Weight or Overweight/Obese. **Table 1** shows main children's anthropometrics characteristics.

2.2. Procedure and Assessment

Children were evaluated during physical education lessons by PE teachers from January to March 2020. Process monitoring has been conducted with the supervision of the University of Foggia. The following motor tests were assessed: standing broad jump (SBJ) and medicine ball throw (MBT) to evaluate strength

Table 1. Descriptive statistics and differences in mean of anthropometric characteristics.

Gender	Group	Age	N	Height	Weight	BMI
Male	Nw	9 - 10	39	1.45 ± 0.07	37.32 ± 5.19	17.47 ± 1.74
	Ow-Ob	9 - 10	44	1.49 ± 0.09	54.40 ± 7.94	21.34 ± 1.56
	Nw	11 - 12	36	1.51 ± 0.10	41.71 ± 8.32	17.97 ± 1.93
	Ow-Ob	11 - 12	57	1.58 ± 0.07	61.41 ± 9.43	24.40 ± 2.75
	Nw	13 - 14	59	1.63 ± 0.08	51.16 ± 8.22	18.97 ± 1.91
	Ow-Ob	13 - 14	34	1.63 ± 0.08	67.78 ± 9.42	25.35 ± 2.81
Female	Nw	9 - 10	55	1.48 ± 0.08	38.89 ± 6.54	17.62 ± 2.00
	Ow-Ob	9 - 10	33	1.48 ± 0.08	53.81 ± 9.71	24.21 ± 2.87
	Nw	11 - 12	54	1.54 ± 0.08	44.13 ± 9.96	18.34 ± 2.99
	Ow-Ob	11 - 12	33	1.55 ± 0.07	59.91 ± 8.29	24.75 ± 2.91
	Nw	13 - 14	60	1.58 ± 0.06	47.82 ± 6.01	19.08 ± 1.90
	Ow-Ob	13 - 14	38	1.60 ± 0.07	66.81 ± 8.29	25.95 ± 3.04

of the lower and upper limbs, shuttle run 10 × 5 (10 × 5) and OneMile Run/Walk test (OneMile RWt) to evaluate resistance. For each test were performed two trials, reported the best results.

2.3. Statistical Analysis

After verified normal distribution of data with Saphiro-Wilk test, descriptive statistic was carried out presenting results as Means ± SD. Independent samples T-test (Student's test) was performed to compare motor performances between Nw and Ow-Ob groups, according to gender and age group. Cohen's *d* value was carried out to measure the strength of the relationship between two variables (*effect size*): Very small (less than or equal to 0.20), Small (from 0.20 to 0.50), Medium (from 0.50 to 0.80) and Large (greater than 0.80), according to Cohen (1988). After verifying homoscedasticity condition (Levene's test), factorial ANOVA 2 (Nw vs Ow-Ob) × 3 (9 - 10 vs 11 - 12 vs 13 - 14) × 2 (Male vs Female) was carried out to examine the evolution in motor performances over time, and Fisher-test was used to analyze difference between means. Partial eta squared was also calculated, interpreting data with the following scale: Very small (less than or equal to 0.01), Small (from 0.01 to 0.06), Medium (from 0.06 to 0.14) and Large (greater than 0.14), according to Pierce et al. (2004). In addition, post-hoc test (Tuckey S-D) was executed to investigate which age's group shows higher significant differences. A stepwise multiple linear regression analysis was executed to investigate the variance in motor test explained by weight and height. In addition, partial (*r*), and semi-partial correlation (*sr*) were carried out to better explain variance between variables. All significance levels were set at $p < 0.05$.

3. Results

Table 2 summarizes the results of motor test. Normal weight group shows better performances in all motor tests, except for MBT.

Table 3 reports statistical significative differences between Nw and Ow-Ob groups. SBJ and One Mile RWt data show more statistical significance than MBT and 10 × 5. Large levels of effect size ($d > 0.80$) were reported in male 9 - 10 yrs, male 13 - 14 yrs and female 9 - 10 years for SBJ (respectively $d = 1.27$, $d = 0.98$, $d = 0.86$); female 11 - 12 yrs showed large effect size in MBT ($d = 0.83$) and male 11 - 12 yrs in One Mile RwT ($d = 0.93$). Medium levels of effect size can be evidenced in male 11 - 12 yrs and female 13 - 14 yrs for SBJ, male 11 - 12 yrs for MBT, all 10 × 5 shuttle run test.

Factorial ANOVA between results is presented in Table 4. Data analysis shows how results are statistically different according to gender, BMI and age group independently, but not combined together. Particularly, gender influenced all motor test with medium to large value of partial eta squared ($\eta_p^2 > 0.14$), BMI influenced SBJ ($\eta_p^2 = 0.126$) and One Mile RWt ($\eta_p^2 = 0.072$) and age group influenced SBJ and MBT ($\eta_p^2 = 0.090$, $\eta_p^2 = 0.256$).

Table 2. Descriptive statistics and differences in mean of the results of the SBJ, MBT, 10 × 5 and one mile RWt.

Gender	Group	Age	SBJ (m)	MBT (m)	10 × 5 (sec)	One Mile RWt (m)
Male	Nw	9 - 10	1.46 ± 0.17	3.89 ± 0.75	21.16 ± 2.88	9.87 ± 1.73
	Ow-Ob	9 - 10	1.22 ± 0.19	4.17 ± 1.00	22.48 ± 3.05	11.21 ± 2.61
	Nw	11 - 12	1.50 ± 0.23	4.63 ± 0.99	20.65 ± 2.52	9.18 ± 2.39
	Ow-Ob	11 - 12	1.35 ± 0.26	5.13 ± 1.02	2213 ± 3.13	11.14 ± 1.81
	Nw	13 - 14	1.71 ± 0.27	5.90 ± 1.46	20.08 ± 2.82	8.67 ± 21.50
	Ow-Ob	13 - 14	1.46 ± 0.19	6.02 ± 1.23	21.30 ± 2.84	9.83 ± 3.13
Female	Nw	9 - 10	1.31 ± 0.25	3.42 ± 0.97	22.63 ± 3.25	11.70 ± 2.01
	Ow-Ob	9 - 10	1.10 ± 0.22	3.69 ± 0.91	23.72 ± 2.60	13.43 ± 4.20
	Nw	11 - 12	1.26 ± 0.20	3.72 ± 0.87	22.68 ± 2.86	11.80 ± 1.86
	Ow-Ob	11 - 12	1.20 ± 0.17	4.55 ± 1.12	24.33 ± 3.12	13.01 ± 1.59
	Nw	13 - 14	1.39 ± 0.23	4.65 ± 1.04	23.01 ± 5.70	10.87 ± 2.53
	Ow-Ob	13 - 14	1.24 ± 0.26	4.78 ± 1.09	23.40 ± 2.77	11.80 ± 3.16

Table 3. Significant differences between groups according to BMI.

			SBJ		MBT		10 × 5		One Mile RWt	
Gender	Group	Age	*d*	*p*	*d*	*p*	*d*	*p*	*d*	*p*
Male	Nw/Ow-Ob	9 - 10	1.27	0.000	0.30	0.170	0.45	0.047	0.60	0.008
	Nw/Ow-Ob	11 - 12	0.60	0.005	0.48	0.024	0.50	0.019	0.93	0.000
	Nw/Ow-Ob	13 - 14	0.98	0.000	0.08	0.674	0.42	0.047	0.44	0.038
Female	Nw/Ow-Ob	9 - 10	0.86	0.000	0.28	0.195	0.35	0.105	0.55	0.012
	Nw/Ow-Ob	11 - 12	0.60	0.207	0.83	0.000	0.54	0.014	0.66	0.003
	Nw/Ow-Ob	13 - 14	0.63	0.003	0.12	0.541	0.07	0.701	0.32	0.113

Post-hoc analysis in **Table 5** evidence significant differences in motor abilities evolution. SBJ and MBT show an increasing score from 9 - 10 yrs to 13 - 14 yrs in Nw and Ow-Ob group, both in male and female (even if girls reported less evidence than boys).

No significant differences were given by 10 × 5 and One Mile RWt. Multiple regression analysis, shown in **Table 6**, confirmed height and weight as predictors for SBJ and MBT ($R^2 = 0.207$, $R^2 = 318$), explaining only 4.0% and 6.3% of the variance in 10 × 5 and OneMile RWt.

Table 4. Factorial ANOVA between.

	Gender		BMI		Age		Gender * BMI * Age	
	p	η_p^2	p	η_p^2	p	η_p^2	p	η_p^2
SBJ	0.000	0.151	0.000	0.126	0.000	0.090	0.673	0.001
MBT	0.000	0.126	0.000	0.026	0.000	0.256	0.720	0.001
10 × 5	0.000	0.079	0.000	0.030	0.239	0.005	0.779	0.001
One Mile RWt	0.000	0.153	0.000	0.072	0.000	0.046	0.567	0.002

Table 5. Post hoc test showing significant evolution in motor abilities.

	Male					
	Nw			Ow-Ob		
	10 - 12 yrs	12 - 14 yrs	10 - 14 yrs	10 - 12 yrs	12 - 14 yrs	10 - 14 yrs
SBJ	0.684	0.000	0.000	0.016	0.075	0.000
MBT	0.021	0.000	0.000	0.000	0.001	0.000
10 × 5	0.704	0.592	0.144	0.837	0.417	0.209
One Mile RWt	0.335	0.499	0.019	0.989	0.043	0.042
	Female					
	Nw			Ow-Ob		
	10 - 12 yrs	12 - 14 yrs	10 - 14 yrs	10 - 12 yrs	12 - 14 yrs	10 - 14 yrs
SBJ	0.435	0.008	0.174	0.143	0.822	0.031
MBT	0.229	0.000	0.000	0.004	0.609	0.000
10 × 5	0.998	0.875	0.904	0.663	0.358	0.881
One Mile RWt	0.970	0.064	0.107	0.849	0.252	0.083

Table 6. Multipe regression analysis.

	Weight * Height	Weight			Height		
	R^2	B	r	sr	B	r	sr
SBJ	0.207**	−0.455	−0.370	−0.355	0.570	0.447	0.445
MBT	0.318**	0.173	0.161	0.135	0.439	0.384	0.343
10 × 5	0.040**	0.250	0.195	0.194	−0.205	−0.161	−0.160
One Mile RWt	0.063**	0.314	0.245	0.245	−0.253	−0.200	−0.198

** = $p < 0.01$.

4. Discussion

The systematic assessment of children's physical activity and physical fitness levels together with the motor learning processes, allows to acquire transversal and longitudinal information on the evolution of motor skills and abilities, necessary to structure and adapt educational process. The quantitative and qualitative data acquired can be used to carry out systematic monitoring of adolescent motor development and "surveillance" studies, necessary to evaluate multi-component interventions, promoting awareness of their own health condition in the students.

Results confirm previous studies highlighting that overweight and obese children and adolescents show lower motor performances than normal weight peers (Grao-Cruces et al., 2018; Kwieciński et al., 2018; Abdelkarim et al., 2019) in all tests except in the medicine ball throw test (MBT). Xu et al. (2020) evidenced better performances in lower limb strength, flexibility, agility and cardiorespiratory fitness, in normal weight adolescents than the obese peers.

This study evidences a significant increase in SBJ and MBT in about all age groups, both in male and female, normal weight and overweight/obese. No statistical differences were carried out regarding the evolution of 10 × 5 and One-Mile RWt in different ages. Moreover, data evidence that weight and height are important predictors for SBJ and MBT test, explaining the 20.7% and 31.8% of the total variance, respectively. This suggests that strength test in which are required single movement execution are more associated and conditioned by individual growth and anthropometrics factors, than test required repeated movement and greater coordinative engagement (such as 10 × 5 and One Mile Test).

Kalac and Gontarev (2015) evidenced that voluminosity, associated with a high percentage of fat tissue, is negatively associated with coordination, agility and speed, and muscle mass is positively correlated with the explosive strength of the lower extremities. Ito et al. (2020) found that weight-height ratio was correlated with acute aerobic exercise and endurance exercise (more markedly for boys). Fiori et al. (2020) affirmed that 1) the effect of body mass index on children's physical fitness intensifies with age, and 2) overweight and obesity are inversely correlated with aerobic capacity, agility, lower limb strength and balance but positively correlated with upper limb strength.

Several studies evidenced that MVPA (moderate to vigorous physical activity) is strongly associated with motor performances, and inversely related to adiposity (Júdice et al., 2017; Santos et al., 2019; Jones et al., 2020). Interventions aimed at improvement of resistance and cardiorespiratory fitness in youth and adolescents are often based on the amount of daily/weekly physical activity (3 - 5 times a week), and the evolution in motor performances is dose-effect dependent (Brustio et al., 2020; Martin-Smith et al., 2020; Nevill et al., 2020).

Another important element to consider to interpretate the no significant differences in motor abilities evolution is the quality of movement. Molina-Garcia et al. (2019) suggest that children with high BMI demonstrate lower functional movement quality independently of fitness level, whereas children with better fitness level (i.e., cardiorespiratory fitness, lower limbs muscular strength, and speed-agility) demonstrate greater functional movement quality independently of fatness level. Findings showed better motor coordination improvements and performances in children and adolescents with slower increasing BMI, suggesting a decrease in motor competences with an increase in BMI (Lopes et al., 2020; Lopes et al., 2018).

5. Conclusion

The study can provide some methodological indications necessary to raise the quality of teaching in PE. The data show a nonlinear and significant evolution of motor performances and abilities from 9 - 10 yrs to 13 - 14 yrs, despite differences between normal weight and overweight/obese group.

Reduced motor performances should be considered the result, and not the cause, of a process strictly related with two other factors:

- Decrease in MVPA in children and adolescents, both normal weight and overweight children;
- Reduction of movement quality and proficiency, according to less levels of motor coordination.

Results show that physical fitness is strictly correlated to anthropometric factors during single strength test, while speed and endurance tests are less correlated to anthropometric factors. This implies that, in order to adequately develop the levels of physical fitness, it is not necessary to make students exercise repeatedly and in a given task only, for example run for 20 minutes, perform a given circuit three times, or perform 10 push up, etc. Certainly, this method of teaching-learning, based on the mechanical repetition of tasks, favors the development, even quite rapid, of motor skills, but what happens to the qualitative learning process of movement? And physical activity levels? Can every one perform and complete the tasks proposed by the teacher?

The following implications for practice can be inferred. Teacher should enable children to perform all the proposed motor tasks, adapting the activities to the motor skills of children with a high BMI, in the parameters of executive difficulty, duration and intensity.

In this way, teacher increases both quantitative levels of physical activity, and quality of motor skills learning, promoting success and motivation, fundamental factors to ensure the adherence to physical activity into adult age. The use of different teaching styles could help teacher to modulate and adapt some variants of movement (space, setting, duration, playing field, rules, tools, etc.), to allow children to participate in activities successfully, and increase time spent in physical activity (Myer et al., 2015).

The introduction of new and different opportunities to be physically active during, before and after school day, for examples in the form of active breaks, active lessons, increasing the number of PE in the curricula, active transport, etc., could be viable solutions to increase physical activity levels, both in non-structured (play) and structured form (game).

Teachers should encourage this type of non-linear approach and learning, as it represents the basis and fundamental prerequisite for any other type of motor learning, physical fitness development and for reaching the individual and personal stages of proximal development in physical education.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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