

Mediating role of physical activity levels on physical fitness in overweight and obese children when Body Mass Index is not a determining factor

Domenico Monacis^{1ACDE}, Giacomo Pascali^{2AB}, Dario Colella^{2AD}

¹ Department of Wellbeing, Nutrition and Sport, Pegaso Telematic University, Italy

² Department of Biological and Environmental Sciences and Technologies, University of Salento, Italy

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Abstract

Background and Study Aim Physical fitness is a crucial health indicator in children and adolescents. Despite the global rise in overweight and obesity, the impact of Body Mass Index (BMI) on physical fitness remains unclear. This cross-sectional study aims to investigate: (R1) the differences in physical fitness components and physical activity levels among children according to gender and BMI, and (R2) the mediating role of physical activity in the relationship between BMI and physical fitness components.

Material and Methods The sample was made of 180 students aged 11-14 years (n=90 – male; n=90 - female) divided according to BMI cutoff in normal weight, overweight and obese. Physical fitness components were assessed with several tests: Standing Long Jump (SLJ), Medicine Ball Throw 2Kg (MBT), Shuttle Run 10x5m (10x5), and One Mile Walk Test. Physical activity levels were evaluated with a self-reported questionnaire. A two-way factorial MANOVA was conducted to assess the effects of gender and BMI on physical fitness. Additionally, a mediation analysis was performed to explore the effect of physical activity on the relationship between BMI and physical fitness.

Results Results revealed significant differences in the Standing Long Jump (SLJ), 10x5 Shuttle Run, One Mile Walk Test, and physical activity levels, with moderate to large effect sizes observed. Males demonstrated higher levels of physical fitness and physical activity levels (PAL) compared to females. Individuals of normal weight were generally more active and stronger than their overweight and obese peers. Mediation analysis revealed that physical activity completely mediates the relationship between BMI and physical fitness components.

Conclusions Results from the present study suggest that the development of physical fitness is not solely determined by BMI, but also depends on the daily practice of physical activity. Future research is needed to assess the effect of physical activity in mediating and moderating the relationship between obesity and physical fitness.

Keywords: obesity, overweight, physical fitness, physical activity, children.

Introduction

Physical inactivity among children and adolescents is a growing global health concern, particularly given its association with various negative health outcomes. The importance of physical activity for enhancing the health status of young populations cannot be overstated. The international literature has extensively documented the positive effects of physical activity on both physiological and psychological aspects of health in young people [1, 2]. Moreover, the World Health Organization (WHO) recommends that children and adolescents engage in at least 60 minutes of moderate to vigorous physical activity daily. This should include activities aimed at developing muscle strength at least three times per week, which have been shown to confer numerous benefits across organic systems as well as cognitive, psychological, emotional, and social domains [3, 4].

Nevertheless, in recent decades there has been a gradual and progressive increase in sedentary levels with a worrying increase in the percentage of overweight and obese children and adolescents. According to the WHO (2024) adult obesity was more the double since 1990, and quadrupled in adolescents, with 37 millions of children under 5 years who were overweight [5]. This negative trend, despite picturing the state of art about the reduction in levels of physical activity and poor eating habits in children and adolescents worldwide, is particularly worrying if considered in relation to the impact that could have on the costs and efficiency of the health system in the coming years. As predicted by the World Obesity Federation measures to combat and prevent overweight and obesity will be necessary, otherwise the economic impact on healthcare system could be higher than 4.32 trillion dollars annually by 2035 [6]. The costs for the management of chronic-degenerative diseases resulting from physical inactivity,

overweight and obesity are around \$173 billion a year in America [7] and 70 billion Euro per years in Europe [8]. Considering the rapid global increase of this negative trend, the numbers could be even higher over the next few years.

Overweight and obesity during childhood are strongly linked to comorbidities development, such as hypertension, metabolic syndrome, diabetes, dyslipidemia and low quality of life [9]. In this context, physical activity, exercise and lifestyles represent important measure to maintain healthy weight and healthy [10]. The concept of physical fitness as health indicator is not new in educational research and public health. By 1988 Lamb et al. [11] recognized the positive role of components of physical fitness as health-indicator in terms of agility, strength, flexibility, speed, aerobic endurance, body composition and posture.

Caspersen et al. [12] pointed out the difference between the five health-related – important for public health - components of physical fitness (i.e., cardiorespiratory endurance, muscular endurance, muscular strength, body composition and flexibility) and skills-athletic related fitness (i.e., agility, balance, coordination, speed, power and reaction time). The concept of physical fitness is strictly related to that of health-related fitness as a multidimensional construct linked to the development and/or maintenance of healthy and positive state of being as a consequence of physiological adaptation to increased overload [11, 12, 13].

Health-related physical fitness components are briefly described as follows [12]:

- cardiorespiratory endurance defines the ability of both the circulatory and respiratory system to contrast and eliminate fatigue during sustained physical activity;
- muscular endurance defines the ability of muscle to external force that muscle can exert;
- muscular strength defines to the amount of external force that a muscle can exert;
- flexibility defines to the range of motion available during movement performance;
- body composition defines the relative amounts of muscle, fat, bone and other body parts.

According to recent findings, overweight and obese children showed lower levels of absolute muscular strength [14, 15], aerobic endurance [16, 17], and speed and agility [18, 19]. Cross-sectional studies conducted on Italian children showed that both lower levels of physical activity and increased BMI negatively affected children's physical fitness and health status [20, 21, 22]. Moreover, physical inactivity results in an increase of adiposity and weight status in children, suggesting that recommended levels of physical activity and active lifestyles may reduce the risk of higher adiposity [23, 24].

According to Ortega et al. moderate to vigorous physical activity is positively associated with lower total and central adiposity in children and adults, and, despite the inverse relationship between physical fitness and body fat, active overweight and obese show similar fitness levels to normal weight peers [25]. This is particularly alarming when considered the emergence of progressive reduction in moderate to vigorous physical activity of overweight and obese children aged >6 years [26].

Starting from literature review on this topic, the researcher's interest is focused on the following research questions:

(R1) differences in physical fitness components and physical activity level in children according to gender and BMI;

(R2) the mediating role of physical activity between BMI and physical fitness components.

Based on literature review, the hypothesis tested are that normal-weight children should show better motor performances and higher PAL compared to overweight and obese groups, while better adherence to physical activity and active lifestyles could affect positively all physical fitness components, independently of gender.

Materials and Methods

Participants

The University of Salento (Lecce, Apulia) coordinated the study procedure. The sample was randomly recruited by first grade of secondary schools that joined the "Regional Observatory of Motor Development Project" in Apulia. 180 children aged 11-14 years (Male= 90, F= 90) were involved in this cross-sectional design study. Before data collecting, informed consent was obtained by all children as required by project management. G*Power software was used to calculate adequate sample size to run analysis. Medium effect size $f^2(N) = 0,15$ [27], and α level at 0.05 were set as reference value. Results suggested a sample size of 54 that is met by the sample involved in the present study that is 180.

Research Design

Children were randomly selected from Lecce Apulian Province to increase the representativeness in the target population and reduce variability. After detecting weight and height, participants were classified as normal weight, overweight or obese according to Cole's Scale [28].

A multistage sampling procedure was applied to recruit study population ($N= 180$) according to gender and BMI Cutoff (M= 90, Nw= 30, Ow= 30, Ob= 30; F= 90, Nw= 30, Ow= 30, Ob= 30) from children involved in the "Regional Observatory of Motor Development Project" with no disability or mental/physical impairments or disorders.

Physical fitness assessment provided the Standing Long Jump (SLJ) and Medicine Ball Throw

2Kg (MBT) to evaluate lower and upper limbs strength, respectively [29,30]. Shuttle Run 10x5m (10x5) was proposed as indicator of speed and agility [31], and One Mile Walk Test for aerobic endurance [32].

Levels of Physical Activity (PAL) were assessed with a digitalized version of the Physical Activity Questionnaire for Older Children – Italian [33, 34, 35] to evaluate self-reported daily practice of physical activity during the last week, with values range from 1 (low physical activity) to 5 (high physical activity). Children are usually classified into 3 categories based on their total averages of physical activity results: scores ranging from 1 to 2.33 correspond to low levels of physical activity, from 2.34 to 3.66 to moderate physical activity, and from 3.67 to 5 to high levels of physical activity, respectively.

Assessment was conducted by physical education (PE) teachers and a team of Graduate in Motor and Sports Science involved in the Regional Observatory Project during curricular PE lessons from October to December 2023.

Statistical Analysis

In addition to descriptive statistic (mean \pm standard deviation), a two-way factorial MANOVA was performed to assess main and interaction effects of gender and BMI Cutoff on physical fitness components. Factorial MANOVA was robust (participants per group > 10) to any divergence from multivariate normality, and multivariate homogeneity of variance-covariance matrix assumption was assessed with Levene's test. Due to small and unequal sample size, Pillai's F statistic was used to evaluate main effect of gender and BMI Cutoff on dependent variables (SLJ, MBT, 10x5 and Mile). The effect of Gender was analyzed in simple effects MANOVAs for each BMI Cutoff and vice versa. Partial eta squared (η^2) has been used to estimate effect size, interpreting results as follows: 0.01 = small effect, 0.06 = medium effect, and 0.14 or higher = large effect [27]. Furthermore, independent t-test have been performed to assess significant differences according to gender and Bonferroni correction has been applied for multiple-comparison adjustment. Cohen's d was used as effect size value: 0.2 = small effect, 0.5 = medium effect, and 0.8 = large effect [27]. Mediation analysis was conducted according to Preacher and Hayes methods [36], setting BMI as independent variable, physical fitness components (SLJ, MBT, 10x5 and Mile) as DV, PAL as mediating factor and gender as confounders. The following indices were carried out:

- total effect of the independent variable (IV) on dependent variable (DV);
- the direct effect of IV on DV controlled per mediation variable (MV),
- indirect effect, that is product of IV on MV effect

and the MV on DV effect.

If the indirect effect was significant, mediation was defined as partial, and total if indirect effect was non-significant. All significant indexes were set at $p < .05$. SPSS (ver. 26) was used to perform all statistical analysis.

Results

Sample's descriptive profile of anthropometric characteristics, physical fitness components and physical activity levels are reported in Table 1 divided by gender and BMI Cutoff. Descriptive analysis generally reveals physical fitness and physical activity levels in both male and female normal weight sample, compared to overweight and obese peers.

Multivariate analysis of variance highlighted significant main effect for both gender ($F = 11.529$, Pillai's trace = 0.274, $p < .001$) and BMI Cutoff ($F = 13.886$, Pillai's trace = 0.621, $p < .001$). Interaction effect ($F = 2.864$, Pillai's trace = 0.17, $p = 0.002$) was also significant. Since both main and interaction effect were significant, post-hoc analysis was performed for all variables considered (Table 2).

Results from ANOVA (Table 3) revealed that both gender and cutoff were significant predictors in SLJ ($F_{\text{gender}} = 27.985$, $p < .001$; $F_{\text{cutoff}} = 42.791$, $p < .001$), 10x5 ($F_{\text{gender}} = 34.930$, $p < .001$; $F_{\text{cutoff}} = 29.050$, $p < .001$), One Mile Wt ($F_{\text{gender}} = 20.654$, $p < .001$; $F_{\text{cutoff}} = 28.734$, $p < .001$) and PAL ($F_{\text{gender}} = 22.031$, $p < .001$; $F_{\text{cutoff}} = 3.149$, $p = 0.045$), while MBT showed significant difference according to gender ($F_{\text{gender}} = 11.455$, $p < .001$). Moreover, large effect size ($\eta^2 > .06$) emerged for all variables involved in the running analysis. Post-hoc test highlighted better male performance in SLJ ($p < .001$, Cohen's $d = -.791$), MBT ($p < .001$, Cohen's $d = -.505$), 10x5 ($p < .001$, Cohen's $d = .903$), Mile ($p < .001$, Cohen's $d = .685$), and PAL ($p < .001$, Cohen's $d = -.710$), with absolute value of effect size ranging from .505 to .903. Moreover, normal weight showed higher lower limbs strength ($p < .001$) and aerobic endurance ($p < .001$) compared to overweight and obese peers. Normal weight showed better performance than obese children in 10x5, but no difference were highlighted for MBT. Finally, overweight children were generally more physically active than obese peers ($p = .043$). All analysis showed moderate to large effect size.

Results of mediation analysis are summarized in Table 4. As confirmed by previous analysis, finding revealed significant total effect of BMI on SLJ ($p < .001$), 10x5 ($p < .001$) and One Mile Wt ($p < .001$), while indirect effect was non-significant for all variables considered. Furthermore, since the direct effect of BMI on physical fitness components controlled per PAL was significant for SLJ, 10x5 and One Mile Wt, it can be assumed that PAL totally mediate their relationship.

Table 1. Anthropometric and physical fitness components measures

Measures		Normal Weight					Overweight					Obese				
Group		N	Min	Max	Mean	SD	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Female	Age	30	13.00	13.00	13.00	0.00	30	12.00	13.00	12.73	0.45	30	11.00	13.00	12.37	0.85
	Weight (Kg)	30	34.00	65.00	49.59	7.36	30	46.00	75.00	61.07	6.99	30	54.00	100.0	76.73	11.56
	Height (m)	30	1.44	1.76	1.59	0.08	30	1.45	1.73	1.60	0.07	30	1.41	1.72	1.59	0.07
	BMI	30	14.15	25.08	19.94	2.38	30	21.50	27.14	23.82	1.31	30	25.65	36.36	30.15	3.36
	SLJ	30	1.10	1.90	1.47	0.20	30	0.95	1.53	1.26	0.15	30	0.60	1.55	1.06	0.21
	MBT	30	3.00	7.20	5.01	1.03	30	3.10	5.98	4.64	0.71	30	2.90	8.40	5.24	1.35
	10x5	30	15.27	28.60	21.61	3.01	30	19.96	27.11	23.86	1.61	30	21.24	29.39	25.93	1.87
	Mile	30	7.46	14.20	10.27	2.02	30	7.57	15.50	11.21	2.09	30	7.30	19.78	13.15	3.55
	PAL	30	1.01	2.61	2.04	0.41	30	1.44	2.98	2.09	0.47	30	1.00	3.19	2.07	0.61
	Male	Age	30	13.00	13.00	13.00	0.00	30	12.00	13.00	12.47	0.51	30	11.00	13.00	12.40
Weight (Kg)		30	31.00	63.00	48.22	9.14	30	46.00	71.00	60.38	6.62	30	55.00	96.00	77.27	9.44
Height (m)		30	1.46	1.79	1.60	0.08	30	1.44	1.78	1.61	0.09	30	1.43	1.80	1.63	0.10
BMI		30	14.54	22.64	18.62	2.34	30	20.9	26.31	23.60	1.55	30	26.08	30.47	28.33	1.11
SLJ		30	1.07	2.20	1.70	0.26	30	0.95	1.99	1.43	0.27	30	0.60	2.10	1.26	0.37
MBT		30	3.10	8.50	5.80	1.31	30	3.25	8.13	5.59	1.19	30	0.21	9.70	5.43	1.79
10x5		30	18.25	24.46	21.25	1.50	30	15.45	27.82	20.07	3.07	30	16.53	28.50	23.41	2.77
Mile		30	6.27	12.29	8.45	1.61	30	6.50	12.78	9.69	1.38	30	7.30	16.13	11.80	2.34
PAL	30	1.74	3.09	2.40	0.44	30	1.57	4.21	2.70	0.61	30	1.51	3.67	2.24	0.62	

Note: SLJ - Standing Long Jump; MBT - Medicine Ball Throw; 10x5 - Shuttle Run 10x5m; Mile - One Mile Walk Test; PAL - Levels of Physical Activity

Table 2. Multivariate Test

Variables	MANOVA					
	df	F	Pillai's Trace	Num df	Den df	p
Gender	1	11.529	0.274	5	153.000	< .001
BMI Cutoff	2	13.886	0.621	10	308.000	< .001
Gender x BMI Cutoff	2	2.864	0.170	10	308.000	0.002

Discussion

The aim of this study was to assess (R1) the effect and incidence of gender and BMI in determining the components of physical fitness, and (R2) the mediation analysis between physical activity, BMI and physical fitness.

As reported in results, MANOVA highlighted that both main effect for gender and BMI Cutoff were significant, as well as interaction effect (R1). In fact, ANOVA analysis revealed significant differences in SLJ, 10x5, One Mile Wt, and PAL with moderate to large effect size, and post-hoc test showed higher levels of physical fitness and PAL in male than female, and normal weight were generally more active and stronger than overweight and obese peers.

These results are confirmed by other findings in literature, suggesting gender differences [37, 38] and the inverse relation between BMI and physical fitness [14, 39]. Higher body weight and BMI lead to negative consequences on muscle strength and explosive power [22], cardiorespiratory fitness and muscles endurance [40, 41].

The research question n2 concerns the analysis of the mediating role of PAL between BMI and health-related physical fitness. Results highlighted that PAL is a total mediator the relation between BMI and physical fitness components, suggesting that the development of physical fitness is not linked and determined exclusively by BMI, but it deepens on daily practice of physical activity.

Recent findings seem to support these evidence.

Table 3. Independent t-test and post-hoc analysis.

Main differences between Groups													
Tests	Variables	SS	df	MS	F	p	η^2	Group	MD	SE	t	Cohen's d	p
SLJ	Gender	1.78	1	1.78	27.985	< .001	0.097	F - M	-0.200	0.038	-5.290	-0.791	< .001
	Cutoff	5.46	2	2.73	42.791	< .001	0.297	Nw - Ow	0.239	0.046	5.164	0.947	< .001
								Nw - Ob	0.426	0.046	9.228	1.685	< .001
								Ow- Ob	0.186	0.046	4.025	0.738	< .001
MBT	Gender	18.63	1	18.63	11.455	< .001	0.061	F - M	-0.643	0.190	-3.384	-0.505	< .001
	Cutoff	2.82	2	1.41	0.869	0.421	0.009	Nw - Ow	0.293	0.233	1.259	0.230	0.420
								Nw - Ob	0.068	0.233	0.292	0.053	0.954
								Ow- Ob	-0.225	0.233	-0.967	-0.177	0.599
10x5	Gender	221.47	1	221.47	34.930	< .001	0.135	F - M	2.274	0.385	5.910	0.903	< .001
	Cutoff	368.38	2	184.19	29.050	< .001	0.225	Nw - Ow	-0.617	0.477	-1.293	-0.245	0.401
								Nw - Ob	-3.346	0.473	-7.078	-1.329	< .001
								Ow- Ob	-2.730	0.464	-5.887	-1.084	< .001
Mile	Gender	106.67	1	106.67	20.654	< .001	0.082	F - M	1.557	0.343	4.545	0.685	< .001
	Cutoff	296.80	2	148.40	28.734	< .001	0.229	Nw - Ow	-1.095	0.422	-2.595	-0.482	0.028
								Nw - Ob	-3.122	0.419	-7.459	-1.374	< .001
								Ow- Ob	-2.027	0.418	-4.843	-0.892	< .001
PAL	Gender	6.45	1	6.44	22.031	< .001	0.110	F - M	-0.384	0.082	-4.694	-0.710	< .001
	Cutoff	1.84	2	0.92	3.149	0.045	0.032	Nw - Ow	-0.176	0.101	-1.750	-0.325	0.190
								Nw - Ob	0.065	0.101	0.640	0.119	0.798
								Ow- Ob	0.241	0.099	2.425	0.445	0.043

Note: SS - Sum of Square; MS - Mean Square; MD - Mean Difference; SLJ - Standing Long Jump; MBT - Medicine Ball Throw; 10x5 - Shuttle Run 10x5m; Mile - One Mile Walk Test; PAL - Levels of Physical Activity

Table 4. Mediation Analysis

Effect Type	BMI Effects	Estimate	Std. Error	z-value	p	95% Confidence Interval
Direct Effect	BMI → SLJ	-0.036	0.004	-9.079	< .001	[-0.044, -0.028]
	BMI → MBT	0.015	0.020	0.760	0.448	[-0.024, 0.054]
	BMI → 10x5	0.298	0.041	7.191	< .001	[0.217, 0.379]
	BMI → Mile	0.254	0.036	6.993	< .001	[0.183, 0.325]
Indirect Effect	BMI → PAL → SLJ	0.0005	0.001	-0.435	0.663	[-0.003, 0.002]
	BMI → PAL → MBT	-0.002	0.005	-0.435	0.664	[-0.012, 0.008]
	BMI → PAL → 10x5	0.004	0.008	0.432	0.666	[-0.013, 0.020]
	BMI → PAL → Mile	0.004	0.008	0.432	0.666	[-0.012, 0.019]
Total Effect	BMI → SLJ	-0.036	0.004	-8.864	< .001	[-0.044, -0.028]
	BMI → MBT	0.013	0.021	0.632	0.527	[-0.027, 0.053]
	BMI → 10x5	0.302	0.042	7.154	< .001	[0.219, 0.385]
	BMI → Mile	0.258	0.037	6.946	< .001	[0.185, 0.330]

Note: SLJ - Standing Long Jump; MBT - Medicine Ball Throw; 10x5 - Shuttle Run 10x5m; Mile - One Mile Walk Test; PAL - Levels of Physical Activity.

According to Ortega et al. being normal weight or not being obese is not enough for maintaining health, and adequate physical fitness levels are unavoidable to gain and achieve health [42].

A recent study classified cardiometabolic risk factors categories in adolescents according to physical fitness, physical activity, and body composition [43]. Results highlighted that being fat and unfit lead to develop the highest cardiometabolic risk, rather than adolescents who had high BMI and higher cardiorespiratory fitness and muscular strength. Moreover, despite the well-known relation between parental physical activity and weight status on children's BMI [44, 45], leisure-time physical activity (> 3 times a week) significantly contributes to reduce prevalence of obesity in children, even if their parents were overweight/obese [46]. Another study demonstrated that children's adherence to international guidelines on physical activity (60 minutes of PA per day) could reduce the risk of being overweight and obesity by about 7% [47].

However, findings revealed that children with high body weight and high health-related physical fitness showed higher cardiometabolic risk compared with children with high physical fitness and low body weight [48]. On the contrary, Gomes et al. suggested that muscle strength was an important indicator for reducing the risk of developing cardiometabolic risk, regardless of physical activity [49].

These results are even more important if considering that higher aerobic endurance and muscle strength have the potential to enhance quality of life in children and adolescents [50]. Moreover, aerobic endurance and speed-agility mediate the negative association between excessive body weight and academic performance in children [51]. A recent study of) has highlighted the fundamental role of cardiorespiratory fitness as a fully mediator between motor competence and daily physical activity in both boys and girls, while according to González-

Gálvez et al. cardiorespiratory fitness is a full mediator between obesity and PAL [52]. Moreover, cross sectional studies have already shown that the incidence of overweight and obesity is strictly related with lower levels of physical activity [53, 54].

Conclusions

The assessment of health-related physical fitness components in early adolescence is an unavoidable prerogative for national and international institutional policies in public health. The present study highlights the importance of physical activity and body weight management in determining adequate levels of physical fitness.

The proposed mediation models can be useful for teachers and educators to carried out methodological and didactic implication in the field of physical activity and in the light of growing increase of overweight and obesity during developmental age. On the one hand, the need to enhance the quantitative and qualitative opportunities for being physically active at school, and on the other hand the need to involve institutions and families to promote physical activity interventions during extra-curricular physical activity and leisure time. In fact, despite school-based interventions can have important potential for health promotion of children in terms of obesity, physical fitness and obesity prevention, other interventions should engage and involve families and group of peers in leisure time to best increase time spent in physical activity and moderate to vigorous intensity.

Furthermore, future research could analyze the mediating role of physical activity between anthropometric characteristics and physical fitness considering different/multiple methods for assessing overweight and obesity, age and sport participation as covariates, and assess the effectiveness of structured experimental interventions in modifying the relation between obesity and physical fitness.

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Information about the authors:

Domenico Monacis; (Corresponding author); <https://orcid.org/0000-0001-6000-7579>; Domenico.monacis@unipegaso.it; Department of Wellbeing, Nutrition and Sport, Pegaso Telematic University; Naples, Italy.

Giacomo Pascali; <https://orcid.org/0009-0003-1617-403X>; Giacomo.pascali@unisalento.it; Department of Biological and Environmental Sciences and Technologies, University of Salento; Lecce, Italy.

Dario Colella; <https://orcid.org/0000-0002-8676-4540>; Dario.colella@unisalento.it; Department of Biological and Environmental Sciences and Technologies, University of Salento; Lecce, Italy.

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