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Norm-Referenced Percentile Values for Physical Fitness in Apulian Children: Findings from the SBAM! Regional Project

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Abstract

Physical fitness is a key health indicator in children and adolescents, playing a fundamental role in promoting healthy lifestyle and preventing overweight and obesity-related diseases. This study aimed to develop age- and sex-specific normative values for physical fitness among Apulian primary school children participating in the SBAM! regional project. A cross-sectional sample of 9,777 children aged 8–9 years (52.1% boys) from 130 schools across all six provinces of Apulia was assessed. Physical fitness tests included standing long jump (SLJ), 6-minute walking test (6MWT), 4×10 m shuttle run (SR), and body mass index (BMI). Percentile values were developed using the LMS method, and MANOVA/ANOVA were used to examine differences by sex, age, and province. Principal component analysis (PCA) explored the latent structure of physical fitness. Sex- and -age referenced percentile values have been developed from all participants in the SBAM! project for each province. Age and the age×sex interaction significantly predicted performance across fitness tests. Provincial effects and interactions involving province were statistically detectable, but their effect sizes' magnitude was very small ($\omega^2 \approx 0.001$). PCA revealed a two-factor structure: one related to physical fitness (SLJ, 6MWD, SR), and another reflecting anthropometric characteristics (BMI). Overall, Apulian children demonstrated fitness levels comparable to peers from other Italian regions. These findings emphasise the value of regional fitness surveillance and provide educators and policymakers with practical normative benchmarks to support targeted, health-oriented physical education initiatives.

Keywords: *physical fitness, childhood, BMI, norm-referenced value*

Introduction

International literature has widely recognized the robust association between physical fitness and health status in children and adolescents (Ortega et al., 2008; Ruiz et al., 2011). Physical fitness has been well-recognized as a global indicator of health, reflecting not only the physiological outcomes of regular physical activity, but also the health benefits related to lifestyles behaviours, balanced nutrition and overall well-being.

In the last decades, physical fitness has been conceptualized as a crucial health indicator and significant determinant affecting health status in children, categorized into Health-Related Physical Fitness (HRPF), which includes cardiorespiratory endurance, muscular strength and endurance, flexibility and body composition, and Skill-Related Physical Fitness (SRPF), encompassing power, agility, coordination, reaction time, speed and balance (Ruiz et al., 2011).

Higher cardiorespiratory fitness is positively associated with higher levels of daily physical activity and plays an important role in preventing cardiovascular diseases, excess of adiposity and weight gain (Demchenko et al., 2025; Fiori et al., 2020; Ortega et al., 2013), while lower muscular strength is a significant predictor of unhealthy outcomes in children, increasing the increasing the possibility to develop insulin-resistance, cardiometabolic risk-index and overall cardiometabolic diseases (Moreno-Gonzalez et al., 2025). Furthermore, the development of muscular strength and coordinative abilities in primary school children is increasingly recognised as essential not only for physical health but also for cognitive, psychological, and behavioural development (León-Reyes et al., 2025).

Due to its global impact on well-being, physical fitness assessment has become widely recognized as an indirect indicator of general health status in children and adolescents, playing a significant role in public health policies. In this context, many studies have been conducted to assess and develop cut-off points and references values for components of physical fitness to early identify children and adolescents who may be at higher risk for adverse health outcomes (Galvani et al., 2024; Ortega et al., 2023; Vaccari et al., 2021). Schools are an ideal setting for such monitoring, as children are easily accessible for both data collection and subsequent health promotion interventions. Moreover, this age range is a crucial period for physical development, often coinciding with significant growth spurts (Spinelli et al., 2023) and a stage in the Italian national curriculum where children start to be actively engaged in structured physical education.

However, existing datasets often lack regional granularity, making them less suitable for assessing micro-territorial differences that may arise from varied socioeconomic, educational, and environmental contexts. This limitation is particularly critical in Southern Italy; for instance, Apulia is the fifth region in Italy with the highest percentage of overweight (21.2%) and obese (14.8%) children aged 8-9 years (Okkio alla Salute, 2023). Unhealthy body composition and weight were associated with poor levels of daily physical activity, with less than 19.9% of children being sufficiently physically active (Steene-Johannessen et al., 2020): the percentage of children engaged in active playing 2 or 3 days a week was 21.7% or 15.6%, respectively (Okkio alla Salute, 2023).

Previous studies conducted in Apulia Region have confirmed the inverse association between BMI and motor performance, revealing a modest and worrying decline in physical fitness development over recent decades (Monacis, Colella & Kolimechkov, 2023; Monacis, Haisan & Colella, 2024). Despite remarking the value of physical fitness components, particularly cardiorespiratory fitness, and the achievement of recommended daily physical activity levels for promoting and maintaining optimal health (Monacis, Sannicandro & Colella, 2025), these studies have been conducted exclusively at provincial level, thereby underscoring the need to establish regional and provincial reference values.

To address this gap and respond to the alarming health data concerning children in Southern Italy, the present study aims to (i) provide norm-referenced values of physical fitness components in Apulian children participating in the SBAM! project, (ii) evaluate differences based on sex, age group (8–9 yrs) and province, and (iii) explore the latent structure of physical fitness across subgroups.

Materials and methods

Study context: SBAM! Project

The present study uses data collected within the SBAM! Project (Health, Wellbeing, Food Education and Movement at School), a regional health-promotion project involving third and fourth grade classes (8-9 yrs children) across the Apulia Region (Southern Italy). The project provides multiple and complementary areas of interventions, including the promotion of quality of physical education, active transport and healthy eating habits, providing a regional framework for an interdisciplinary and cross-sectoral health-related approach through physical activity, nutrition and the prevention of sedentary lifestyles.

SBAM! was developed to provide a concrete, school-based response to the growing increase in overweight and obesity in Southern Italy. The initiative aligns with the WHO's 2020-2025 action plan "Health promoting schools" (Bartelink & Bessems, 2019). It is supported by the "Department of Health Promotion, Social Well-Being, and Sports for all" of the Apulia Region, and coordinated by Apulian Regional School Office, Apulian Regional Committee for Sport (CONI), Apulian Regional Paralympic Committee (CIP) and local Universities.

Furthermore, the SBAM! Project serves as a regional, complementary initiative to a broader National Research project "Okkio alla SALUTE" (Okkio alla Salute, 2019; Okkio alla Salute, 2023) While this project's systematically monitors the evolution of children's nutritional status (aged ~8 yrs) and outlies the epidemiological framework (Okkio alla Salute, 2019; Okkio alla Salute, 2023), the SBAM! Project translates this need for intervention into active practice by providing a structured environment for physical fitness assessment and the promotion of active lifestyles among primary school children.

Participants and design

This study involved schoolchildren aged 8-9 years old who attended the SBAM! Project. A total of 130 schools and 623 primary school classes were engaged in the experimental activities. The objective of the project was to emphasize the psycho-pedagogical framework under best practices in physical education and for physical education teacher's training. The initiative was designed to collect regionally representative cross-sectional data on health in children aged 8-9 years old, living in six Apulian provinces [Foggia, Barletta-Andria-Trani (BAT), Bari, Brindisi, Lecce and Taranto]. The aim is to provide the state of art about physical fitness, guiding policies for the adoption of healthy lifestyles, improve physical fitness and nutritional habits among Apulian children. Activities were carried out from November 2024 to June 2025 across all six Apulian provinces, encompassing a total of 10330 primary school children, grouped by age range (8.00–8.99 yrs and 9.00–9.99 yrs). However, the sample included in the present study was made of 9777 participants. A total of 553 children (5,35% of the total sample) were excluded following a rigorous data cleaning procedure, accounting for both missing data (children who did not complete the whole assessment procedure) and outliers' removal (BMI=1.49%, SLJ=0.84%, 6MWT=3.55%, 4x10m SR=0.91%, referred to the total sample). As suggested by G*Power (Faul et al., 2009), adequate sample size should be made of approximately 396 children, thereby ensuring adequate statistical power at f2(V)=0.0625 and α level at 0.05, which is consistent with the analysis conducted in the present study. Informed consent was obtained from all children involved in the project before data collection. The investigation was approved by the local university ethics board (approval number: 2181-205-02-05-19-0020).

Physical fitness assessment

In this study, authors evaluated both components of HRPF and SKPF, assessing body mass index and six-minute walking distance, and standing long jump and 4 x 10m shuttle run, respectively. These tests have been widely applied in research involving children in schools setting, demonstrating acceptable levels of validity and reliability (Ortega et al., 2008; Ruiz et al., 2011).

Anthropometric profile was assessed reporting height, weight and BMI. According to the WHO (2008), digital portable stadiometers were used to assess height (m) and weight (kg), with an accuracy of ~0.1 mm and ~0.1 kg, respectively. Body mass index (BMI) was calculated with the following formula "weight (kg) / squared height (m2)". Despite there's a lack of consensus about the validity of BMI as sole parameter for obesity diagnosis (Marković-Jovanović et al., 2015), it has been recognized worldwide as a reliable, widely applicable, cost effective and non-invasive method for screening for overweight and obesity, especially in children (Hampl et al., 2023).

Cardiorespiratory endurance was assessed with the 6-minute walking test (6MWT). Before the assessment, children were instructed to walk (not run) for 6 minutes, and they were asked to cover as much distance as possible (6MWD) on a course with two aligned cones placed 30 meters apart and other cones spaced 3 meters apart (Kasović, Štefan & Petrić, 2021; Lammers et al., 2008). This protocol was administered according to studies and findings in literature.

Children performed test one a time to prevent competition during the assessment. During each lap, they were notified and updated of their time. A final signal was given during the last 30 seconds. The number of laps completed by each student was reported. Once the test finished (after 6 minutes), students stopped at the spot to measure the exact distance they covered in meters (Kasović, Štefan & Petrić, 2021; Lammers et al., 2008). Due to the physical demands of the 6MWT, it was performed once to prevent fatigue in primary schoolchildren.

Lower limbs strength was assessed with standing long jump (SLJ). Children were asked to position themselves behind the starting line marked on the mat in the gym. From this initial position, teachers asked them to jump as far as possible by using their arm swing, landing back onto the mat. Distance was gauged from the starting line to the closest mark left on the mat by feet (or any other body part), noting the contact of heels with the mat (Ortega et al., 2008; Ruiz et al., 2011). The 10x4 shuttle run test (4x10 m SR) was used for evaluating children's agility and speed. In this test, children were asked to sprint over 10 m, moving back and forth two times (4x10 m). The beginning and finishing lines were outlined with a mark (1 m x 5 cm) on the ground. Children started upon the verbal signal from the teacher (3-2-1, go!). The test administration required that both feet cross the marked line for the attempt to be valid. Time was reported in hundredths of seconds with a manual stopwatch after the final lap. The assessment was conducted by one child per time (Ortega et al., 2008; Ruiz et al., 2011). Children performed two attempts of SLJ and 10x4 SR, respectively. Only the best result was considered for further analysis.

Statistics

Data were screened for missing values, outliers, and normality. In addition to mean and standard deviation, percentiles were reported for each continuous variable, while frequency were reported for categorical ones. To minimize the impact of severe data-entry errors and extreme performances, outliers were defined as values beyond ±2 SD and excluded based on the following thresholds: BMI (10.01–26.07 kg/m²), SLJ (0.55–1.62 m), 6MWD (231–850 m), and 4×10 m SR (10.59–18.62 s). All subsequent statistical analysis were performed after this data cleaning process.

After verifying all assumptions, multivariate analysis of variance (MANOVA) has been performed to assess main and interaction effects, assuming gender (girls and boys), age groups (8.00–8.99 yrs and 9.00–9.99 yrs) and province (Bari, BAT, Brindisi, Foggia, Lecce, and Taranto) as independent variables (IVs) and physical fitness components as dependent variables (DVs). The Pillai's Trace was chosen for its robustness against the violation of the assumption of homogeneity of covariance matrices, as confirmed by Box's M-Test ($p<0.01$). Subsequently, robust ANOVAs were carried out for each DVs to assess differences in physical fitness components scores according to provinces, age and gender, respectively. Effect size estimation has been reported and interpreted for ANOVA using omega squared ($\omega^2<0.01$ as very small, $0.01<\omega^2<0.06$ as small, $0.06<\omega^2<0.14$ as medium, and $\omega^2>0.14$ as large) with 95% confidence interval, respectively (Cohen, 2013).

Percentile curves were developed using the LMS method based on Box-Cox power exponential (BCPE), Box-Cox t (BCT) and Box-Cox Cole and Green (BCCG) modelling of three parameters: Lambda (L), Median (M) and the coefficient of variation (S). To achieve an optimal balance between model fit and smoothness, the parameters' curves L(t), M(t) and (S)t were controlled after adjusting them by the degrees of freedom. Optimal model was identified by estimating the degrees of freedom using the Generalized Akaike Information Criterion (GAIC). Model adequacy was assessed through visual inspection of quantile residuals, density plots, and Q-Q plots. Separate models were developed for boys and girls for each variable considered. Based on these models, percentiles (1st, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 99th) were estimated.

Principal component analysis (PCA) has been performed dividing participants into twenty-four groups (sex * age group * province), including physical fitness components in the analysis. Before running the analysis, all variables were standardized and converted into z-scores to ensure better comparability of the scales, multiplying 4x10 SR values by -1 to ensure better consistency in the interpretation of principal component loading and coefficient in PCA. Moreover, correlation matrix and Bartlett's test of sphericity were conducted to evaluate the adequacy of intercorrelation among variables. Only principal components with Eigenvalues greater than 1 and explaining more variance than a single variable was considered and retained in the analysis. For all the statistical analysis, a pairwise deletion was used, including all valid cases for each variable to maximize statistical power. All analyses were performed using SPSS (v.26) and R (GAMLSS package), with statistical significance set at $p<0.05$.

Results

Anthropometric and physical fitness descriptive statistics are presented in Table 1 according to sex differences. Our findings indicate that boys and girls showed comparable physical fitness profile. While sex differences were statistically significant for SLJ, the effect sizes were small, suggesting no meaningful practical differences in physical fitness tests and BMI.

Table 1. Participants anthropometric and physical fitness profile

	Girls = 4679					Boys = 5098					Total = 9777				
	M	SD	Min	Max	Range	M	SD	Min	Max	Range	M	SD	Min	Max	Range
Age (yrs)	9.32	0.31	8.12	9.95	1.83	9.28	0.32	8.09	9.93	1.84	9.30	0.32	8.09	9.95	1.86
Height (m)	1.31	0.06	1.14	1.49	0.35	1.32	0.06	1.14	1.49	0.35	1.31	0.06	1.14	1.49	0.35
Weight (Kg)	31.17	6.38	22.00	50.40	28.40	31.59	6.40	22.00	50.30	28.30	31.39	6.39	22.00	50.40	28.40
BMI (kg/m2)	18.06	2.93	10.14	26.07	15.93	18.06	2.89	10.01	26.04	16.03	18.06	2.91	10.01	26.07	16.06
SLJ (m)	1.09	0.21	0.55	1.62	1.07	1.08	0.20	0.55	1.62	1.07	1.09	0.20	0.55	1.62	1.07
6MWD (m)	541.15	116.21	231.00	850.00	619.00	539.62	117.05	231.00	850.00	619.00	540.36	116.65	231.00	850.00	619.00
4x10 SR (s)	14.63	1.47	10.59	18.62	8.03	14.64	1.50	10.59	18.61	8.02	14.64	1.49	10.59	18.62	8.03

Note. M = mean, SD = standard deviation, Min = minimum, Max = maximum, Range = Max – Min; BMI = Body Mass Index; SLJ = Standing Long Jump; 6MWD = 6-Minutes Walking Distance; 4x10 SR = 4x10m Shuttle Run.

Figure 1 shows sex- and age-referenced derived smoothed centiles curves (P1, P5, P10, P25, P50, P75, P90, P95, P99) values for both HRPF and SRPF variables for all Apulian provinces.

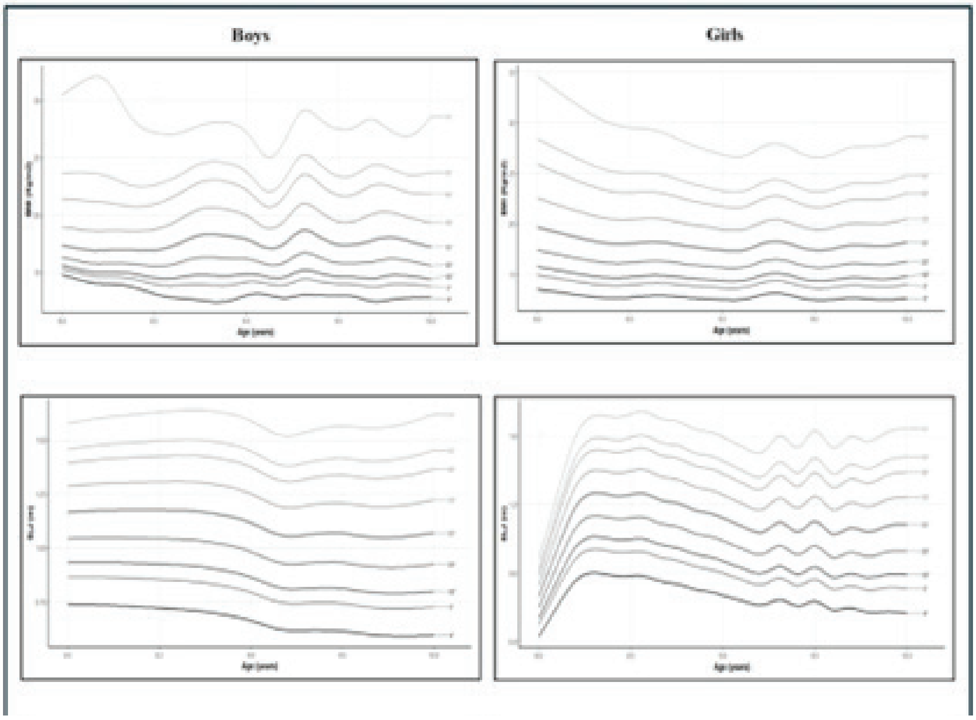

Figure 1. Smoothed centiles curves according to sex

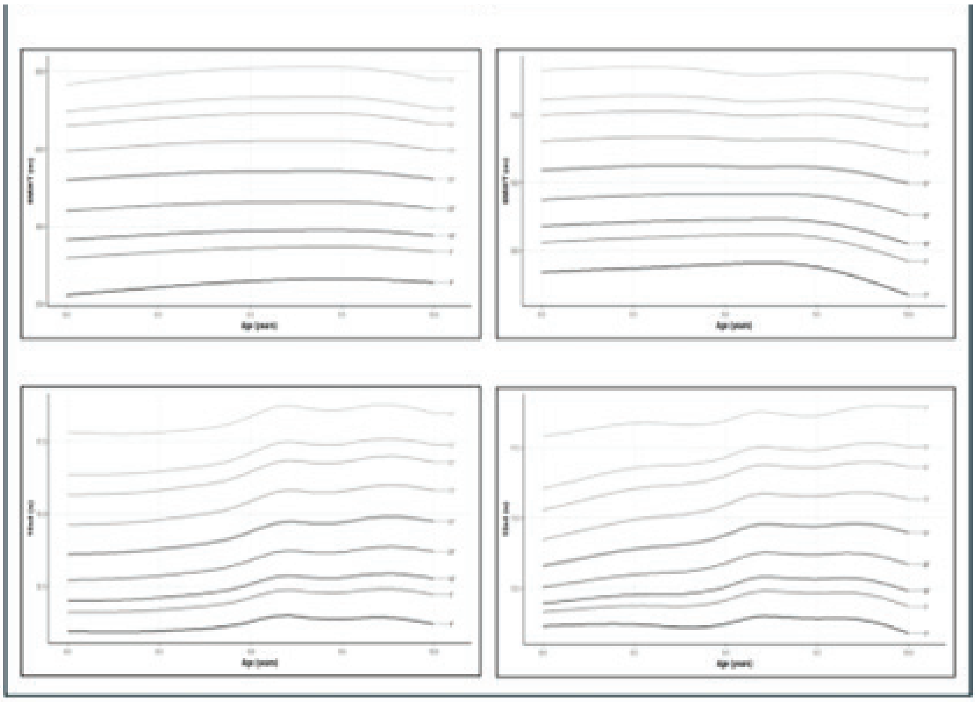

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Figure 1. Smoothed centiles curves according to sex

Factorial MANOVA and ANOVAs were performed to evaluate differences according to age group, sex and province. Analysis highlighted significant multivariate effect of age group ($p<0.01$) and age group*sex on dependent variables ($p<0.05$). ANOVAs results (Table 2) revealed that age group was a significant predictor of BMI [$F(1, 9753)=13.17$, $p<0.01$, $\omega^2=0.001$], SLJ [$F(1, 9753)=232.49$, $p<0.01$, $\omega^2=0.02$], 6MWT [$F(1, 9753)=5.28$, $p<0.05$, $\omega^2=0.001$], and 4 x 10m SR BM [$F(1, 9753)=97.40$, $p<0.01$, $\omega^2=0001$]. SLJ was influenced also by province [$F(5, 9753)=2.08$, $p<0.05$, $\omega^2=0.001$] and sex [$F(1, 9753)=3.64$, $p<0.05$, $\omega^2=0.001$]. There was a significant interaction effect between province and sex on BMI [$F(5, 9753)=2.28$, $p<0.05$, $\omega^2=0.001$], and between age and sex on SLJ [$F(1, 9753)=3.69$, $p<0.05$, $\omega^2=0.001$] and 6MWT [$F(1, 9753)=3.36$, $p<0.05$, $\omega^2=0.001$].

Table 2. ANOVA results

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Table 2. ANOVA Results

Test	Sex	Age group 8.00 – 8.99 M ± SD	Age group 8.00 – 8.99 95% C.I.	Age group 9.00 – 9.99 M ± SD	Age group 9.00 – 9.99 95% C.I.	ANOVA p-value (ω²) Province	Age	Sex	Province* Age	Province* Sex	Age*Sex	Province *Age *Sex
BMI	Boys	18.94±3.98	18.65 - 19.22	18.40±3.54	18.29 - 18.50	>0.05	<0.01 (0.001)	>0.05	>0.05	<0.05 (0.001)	>0.05	>0.05
	Girls	18.66±3.89	18.36 - 18.95	18.40±3.49	18.30 - 18.51							
SLJ	Boys	1.16±0.22	1.15 - 1.18	1.07±0.21	1.07 - 1.08	<0.05 (0.001)	<0.01 (0.02)	<0.05 (0.001)	>0.05	>0.05	<0.05 (0.001)	>0.05
	Girls	1.19±0.22	1.18 - 1.21	1.07±0.22	1.06 - 1.08							
6MWT	Boys	547.62±149.99	533.97 - 553.74	547.81±143.72	540.53 - 548.47	>0.05	<0.05 (0.001)	>0.05	>0.05	>0.05	<0.05 (0.001)	>0.05
	Girls	564.92±163.80	547.79 - 568.30	545.87±141.69	539.02 - 547.30							
4x10 SR	Boys	14.40±2.14	14.25 - 14.55	15.05±2.29	14.98 - 15.11	>0.05	<0.01 (0.001)	>0.05	>0.05	>0.05	>0.05	>0.05
	Girls	14.25±1.88	14.11 - 14.39	15.08±2.38	15.01 - 15.16							

Note. M = mean, SD = standard deviation, 95% C.I. = 95% Confidence Interval, ω² = omega squared effect size.

Principal component analysis was conducted independently for 8 and 9-year-old on full dataset, and also separately for boys and girls within each of each Apulian Provinces.

The results of the analysis conducted on the total sample (Table 3) showed two principal components. The first (PC1) demonstrated strong positive loadings on SLJ, 6MWD and 4x10m SR, while the second (PC2) was related to BMI. These results accounted for 61.37% of the total variance. The Kaiser-Meyer-Olkin (KMO) value was 0.601, suggesting fair-to-moderate sampling adequacy. Bartlett's tests of sphericity yielded significant results ($p<0.01$), indicating sufficient intercorrelation among variables to perform PCA.

Table 3. Principal Component Analysis on Full Dataset

Total Sample								
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 9.99	BMI	0.012	0.996	36.34	25.03	61.37	0.601	<0.01
	SLJ	0.776	-0.058					
	6MWD	0.489	0.082					
	4x10 SR	0.783	-0.009					

Note. PC1 = first principal component, PC2 = second principal component, %PC1 = f variance explained by PC1, %PC2 = variance explained by PC2, %TOT = variance explained by PC1 and PC2, KMO = Kaiser-Meyer-Olkin test.

For every subgroup, two factors (eigenvalues >1) were kept, accounting for the 59.7% and 68.4% of the total variance (Table 4). In many instances, the first principal component (PC1) exhibited strong positive loadings on SLJ, 6MWD and 4x10m SR, suggesting an underlying factor associated with overall physical fitness. This trend has been verified both in boys and girls, independently of sex and age group. The second principal component analysis (PC2) displayed significant loadings for body mass index (BMI), highlighting an anthropometric factor, particularly among girls and in the 8-year-old groups. In some cases (i.e., Taranto and Lecce), BMI contributed less to explain variance in the first component for boys, while in other cases it demonstrated significant loading on PC2, highlighting its unique importance.

Table 4. Principal component analysis according to sex, age group and Province
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Table 4. Principal component analysis according to sex, age group and Province

								Foggia							
		Boys							**Girls**						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 8.99	BMI	-0.200	0.201	32.88	28.18	61.06	0.400	<0.01	-0.265	0.822	40.04	23.31	63.35	0.548	<0.01
	SLJ	0.870	0.036						0.771	0.301					
	6MWD	0.529	-0.699						0.545	-0.450					
	4x10 SR	0.489	0.773						0.800	0.288					
9.00 - 9.99	BMI	-0.052	0.970	35.02	25.22	60.24	0.529	<0.01	0.013	0.825	35.61	26.38	61.99	0.518	<0.01
	SLJ	0.779	-0.119						0.808	-0.085					
	6MWD	0.433	0.224						0.361	0.577					
	4x10 SR	0.777	0.060						0.801	-0.187					
								BAT							
		Boys							**Girls**						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 8.99	BMI	0.137	0.888	39.29	27-Sep	66.38	0.564	<0.01	0.452	-0.493	37.14	26.48	63.62	0.512	<0.05
	SLJ	0.658	0.427						0.772	0.291					
	6MWD	0.750	-0.276						0.023	0.855					
	4x10 SR	0.746	-0.262						0.827	-0.026					
9.00 - 9.99	BMI	0.074	0.850	35.49	26.51	62	0.532	<0.01	-0.287		37.01		37.01	0.557	<0.01
	SLJ	0.785	0.043						0.760						
	6MWD	0.437	-0.550						0.458						
	4x10 SR	0.779	0.185						0.781						
								Bari							
		Boys							**Girls**						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 8.99	BMI	0.051	-0.676	34.39	25.44	59.83	0.497	<0.01	0.075	0.935	34.29	25.45	59.74	0.553	<0.01
	SLJ	0.828	0.076						0.674	-0.224					
	6MWD	-0.012	0.745						0.589	0.284					
	4x10 SR	0.829	-0.023						0.752	-0.115					
9.00 - 9.99	BMI	-0.015	0.966	35.81	25.21	61.02	0.550	<0.01	0.008	0.998	36.57	25-Jan	61.58	0.552	<0.01
	SLJ	0.755	-0.119						0.777	-0.006					
	6MWD	0.510	0.246						0.502	0.056					
	4x10 SR	0.776	-0.027						0.780	-0.041					
8.00 - 8.99	BMI														
								Brindisi							
		Boys							**Girls**						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**

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Table 4. Principal component analysis according to sex, age group and Province

8.00 - 8.99	BMI	-0.283	0.912	39.09	25.77	64.86	0.551	<0.01	0.078	-0.607	35.74	30.38	66.12	0.397	<0.01
	SLJ	0.704	0.263						0.852	0.287					
	6MWD	0.589	0.329						0.072	0.818					
	4x10 SR	0.801	-0.150						0.833	-0.308					
9.00 - 9.99	BMI	-0.046	0.929	37.95	25-Jun	63.55	0.548	<0.01	-0.020	0.913	36.83	25.71	62.54	0.543	<0.01
	SLJ	0.757	-0.187						0.790	-0.064					
	6MWD	0.533	0.356						0.477	0.408					
	4x10 SR	0.812	-0.007						0.790	-0.159					

Taranto

		Boys							Girls						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 8.99	BMI	0.085	0.946	42.31	26-Jan	68.41	0.602	<0.01	0.307		44.32		44.32	0.612	<0.01
	SLJ	0.792	-0.113						0.792						
	6MWD	0.669	0.285						0.624						
	4x10 SR	0.781	-0.233						0.814						
9.00 - 9.99	BMI	-0.087	0.981	35.76	25-Feb	60.78	0.535	<0.01	0.069	0.921	36.99	25.78	62.77	0.541	<0.01
	SLJ	0.739	-0.063						0.733	-0.3					
	6MWD	0.494	0.175						0.544	0.306					
	4x10 SR	0.796	0.058						0.801	-0.013					

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		Boys							Girls						
Age group	**Test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**	**PC1**	**PC2**	**%PC1**	**%PC2**	**% TOT**	**KMO**	**Bartlett's test**
8.00 - 8.99	BMI	0.483		45.22		45.22	0.653	<0.01	0.123	0.865	40.46	26.81	67.27	0.526	<0.01
	SLJ	0.704							0.783	-0.357					
	6MWD	0.717							0.519	0.444					
	4x10 SR	0.753							0.849	-0.068					
9.00 - 9.99	BMI	-0.037	0.995	35.26	25-May	60.31	0.554	<0.01	0.082	0.885	35.38	25.61	60.99	0.535	<0.01
	SLJ	0.769	-0.031						0.780	0.089					
	6MWD	0.554	-0.024						0.426	-0.476					
	4x10 SR	0.715	0.103						0.787	0.078					

Note. PC1 = first principal component, PC2 = second principal component, %PC1 = f variance explained by PC1, %PC2 = variance explained by PC2, %TOT = variance explained by PC1 and PC2, KMO = Kaiser-Meyer-Olkin test.

The Kaiser-Meyer-Olkin (KMO) values across subgroups ranged from 0.397 to 0.653. While the full sample demonstrated moderate sampling adequacy (KMO=0.601), several subgroups presented KMO below the acceptable threshold of 0.50. Bartlett's test of sphericity yielded significant results ($p<0.01$) in all analysis, suggesting adequate intercorrelation among variables to perform PCA. These findings suggest two underlying dimensions in children's physical fitness: motor performance (SLJ, 6MWD, 4x10m SR) and anthropometric characteristics (BMI).

However, the factorial structure showed strong consistency among all provinces and groups, reflecting a robust and reliable pattern in the dimensions of children's physical fitness-related variables.

Discussion

The current research aimed to establish norm-referenced age- and-sex-specific reference values for physical fitness in children aged 8-9 yrs participating in the SBAM! project from all of the six Apulian provinces, evaluating differences based on sex, age and province.

Findings supported both international and national trends in existing research, including the inverse relationship between body mass index and physical fitness development. In line with developmental expectations and similar previous studies in Italian youngest population (Fiori et a., 2020; Galvani et al., 2024; Vaccari et al., 2021), this study demonstrated both sex- and age-associated decline in SLJ, 6MWT and 4x10m SR. Regarding sex differences, although a statistically significant effect was observed for SLJ, the effect size was small, and performance levels in all other physical fitness tests and BMI were largely similar between boys and girls. This suggests that early childhood may represent a fundamental stage of homogeneous physical development before the more significant sex disparities typically emerge in adolescence (Fiori et al., 2020; Vaccari et al., 2021).

A striking characteristic of the research is the geographical distribution of data throughout the six Apulian provinces. While our analysis highlighted statistically significant main and interaction effects linked to provincial differences, it is important to recognize that these could be largely driven by large sample size. The actual magnitude of these provincial effect was very small ($\omega^2=0.001$), indicating that physical fitness outcomes are practically homogeneous across the Apulian Region. Nevertheless, providing regional normative data is crucial: national standards frequently overlook micro-territorial variations, potentially limiting an accurate assessment of health risk and the resulting design of targeted interventions (Ke et al., 2022).The percentile curves obtained in this study fill this significant knowledge gap providing teachers, healthcare professionals, and policy decision-makers with relevant regional standards for assessing and fostering children's physical development.

The norm-referenced values obtained in the current study were approximately almost similar to those previously reported in both European (Kolimechkov, Petrov & Alexandrova, 2019; Ortega et al., 2023; Tomkinson et al., 2018) and non-European countries (Ma et al., 2022; Vasquez, Salazar & Vasquez, 2024). The reference standards offered by this study seem to be closely aligned with other European studies, revealing that Italian children have similar levels of physical fitness compared to other European ones.

When comparing the results of the present study with other research conducted in Italy, several interesting observations emerge, particularly when examining data from different regions. Data of the SLJ and 6MWT are in align with to those reported in a study conducted in Veneto region (Toscani & Pedersen, 2024). Comparable findings also emerged when comparing our results with those of Galvani et al. (2024) assessing SLJ, 6MWT and 4x10m SR in Lombardy (Galvani et al., 2024). Additionally, similar SLJ results were observed in the study by Vaccari et al. (2021) carried out in Friuli Venezia-Giulia region.

Furthermore, exploring the latent structure of physical fitness, the principal component analysis (PCA) revealed a two-factor solution among total sample and subgroups, differentiating a so called "physical fitness factor", (including SLJ, 6MWD and 4x10m SR), from an "anthropometric" one (BMI). This distinction is consistent with the multidimensional perspective of physical fitness endorsed by both traditional and modern frameworks.

The Physical Fitness factor probably indicates the interplay of musculoskeletal, cardiorespiratory endurance, and neuromotor systems, whereas the anthropometric factor highlights structural components related to body composition. Notably, the second factor (BMI) exhibited a stronger loading among girls and 8yrs old group, suggesting that body composition might significantly influence overall physical fitness in these groups. However, findings from PCA should be interpreted with caution and as exploratory, particularly in those specific strata where sampling adequacy was weaker.

Ultimately, practical implications lie in the application of the normative data itself, which provides tangible percentile scores to guide interventions regardless of small statistical group differences. Data from this study can be a powerful resource for large-scale planning evaluation for health authorities and policy makers at the provincial or regional level. Given the sample's high representativeness, the established reference values can be used by provinces and schools as starting point to benchmark children's physical fitness levels in Apulia region. By comparing data, it could be possible to highlight areas with a higher prevalence of children with poor performance, helping to direct resources and intervention programs where they are needed most. For example, children with results below the 10th percentile could imply a need for further assessment by schools or physical education teachers (including daily practice of physical activity, eating habits, sports facilities, etc.) or suggest specific interventions to enhance physical fitness components. On the other hand, results above the 90th percentile can translate into interventions that encourage and support maintaining active lifestyles and an excellent level of physical fitness.

Study limitations

Despite the strengths and possible application of the present study, some limitations need to be discussed. First, the cross-sectional design approach and the unbalanced size of each province's subgroups limit the potential to draw causal conclusions or assess time-related changes in children's physical activity (i.e., longitudinal study design or randomized controlled trials), affecting the stability of province-specific percentiles. Longitudinal data would be better suited to assess changes over time and uncover possible predictors of fitness paths.

The research acknowledges that the number of participants for each age groups and province was not equally distributed, as detailed in participants' flow diagram. While the study found no significant differences by province and low effect size, the observed data highlight the potential impact on the representativeness of overall regional findings, underscoring the need to establish specific provincial and regional fitness standards. However, further studies will be necessary to extend the sample, aiming for a more comprehensive and balanced normative dataset.

A further methodological limitation concerns the outlier handling strategy. The application of ±2 SD cut-off was performed to filter out possible data-entry errors typical of large-scale filed evaluations. Consequently, the estimation of extreme normative percentiles (P1 and P99) might be slightly biased or underestimated, and should be interpreted with appropriate caution.

Moreover, although participant's different geographical location improves the applicability of findings in Apulia region, the analysis didn't consider other potential confounding and/or influencing variables (covariates) across provinces, such as socio-economic status, urban or rural living areas, sports facilities, parental education, etc. An important methodological limitation concerns the Principal Component Analysis (PCA). Some variables in the analysis presented a KMO value below the recommended threshold of 0.5, which undermines data's suitability for robust factorability and PCA. Therefore, interpretations from these specific subgroups are inherently unstable and should be viewed purely as exploratory. Another important limitation concerns children's motivation during assessment. In fact, despite the validity and reliability of the proposed physical fitness test are well recognized, children's motivation could have played a significant role in determining outcomes. Finally, the assessment focused only on three physical fitness tests and BMI, omitting the evaluation of other components of physical fitness (i.e., as upper-body strength, flexibility, and balance, etc.) that could have further enriched the understanding of Apulian children's fitness levels.

Future studies should aim to implement longitudinal assessment and cohort design to evaluate trends in physical fitness over time, integrating more comprehensive measures of body composition and physical fitness tests. In addition, psychosocial, behavioural and environmental factors previously mentioned would allow for a more holistic and comprehensive understanding of determinants of children's physical fitness. Despite our results, it's important to recognize that the data presented represent a starting point for assessing physical fitness in Apulian children. Further studies are needed to improve the methodological quality of the research framework. Specifically, future research should aim to extend to scope of this study to different age groups, including younger and older children/adolescents, to create a more comprehensive dataset to guide health policies in Apulia.

Conclusions

The findings of this study have significant implications for public health and educational practices. Firstly, the development of regional and provincial reference values facilitates the early identification of children at health risk issues associated with low fitness levels or excessive adiposity. This is particularly pertinent in Apulia, a region that consistently reports high prevalence rates of childhood overweight and obesity.

Additionally, the SBAM! project and the obtained norm-referenced provincial regional percentile values could act as a model for an effective inter-institutional health-promoting strategy by integrating structured and systematic assessment of health determinants in a sustainable way. The obtained data could represent the starting point to develop concrete action health-oriented, guiding professionals and institutions. They can be used to identify emerging trends, optimize strategies, and predict future outcomes by health authorities, political decision-makers and school principals at provincial or regional level. For instance, physical education teachers can use this data to estimate student fitness levels against regional or provincial percentiles and design high-quality physical education interventions to improve physical fitness.

Moreover, the project strengthens the regional cooperation and collaboration between Universities, CONI, CIP and schools, fostering the overall effect of these interventions. Finally, schools' valence is emphasized as an ideal setting for regular fitness assessment. Their organized and inclusive environment facilitates population-wide data gathering, long-term monitoring, and specific interventions.

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Conflicts of Interest
The authors declare no conflict of interest.

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