Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 8), Art 228, pp. 1982 – 1989, August 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Exploring shuttle run test performance and adiposity indices among Italian high school students: a comparative analysis with European norms

ALESSANDRO GATTI[1*], ALESSANDRO CUDICIO[2], MATTEO GIURIATO[3], NICOLA LOVECCHIO[4]
[1,3]Laboratory of Adapted Motor Activity (LAMA), Department of Public Health, Experimental Medicine and Forensic Science, University of Pavia, 27100 Pavia, ITALY
[2,4]Sport Science Unit, Dpt. of Human and Social Sciences, University of Bergamo, ITALY

Published online: August 31, 2023
(Accepted for publication August 15, 2023)
DOI:10.7752/jpes.2023.08228

Abstract
Despite the recent decline in physical fitness, only a few studies were conducted on speed-agility (SA) trends and they have contrasting results about the trend of SA. Therefore, the aim of this study was to evaluate the SA performance of Italian high school students and to compare the results with European normative data. Furthermore, we analyzed how the adiposity indices were related to SA performance in adolescents to help coaches and physical education teachers to better tailor their activities. A total of 627 high school students aged between 14 to 18 years were recruited in 2019 from a single high school in Northern Italy. To assess SA we used the 10x5m shuttle run test, while to evaluate anthropometric characteristics we assessed weight, height, waist circumference, BMI, Waist-to-height ratio, TMI and fat mass. SA performance was found higher only for 15 years old males and for 14 and 15 years old female groups, while no differences were found for other age groups. Age-related performance shows no differences between male and female students. The correlation between the anthropometric indices and SA performance showed a poor relation (p<0.01) for males but not for females. We found that the SA seems poorly related to anthropometric characteristics and age (ranging from 14 to 18). In addition, our results showed that the SA performance of Italian adolescents is similar to, or even better than, the normative data from Europe. These results provide crucial information for physical education teachers to promote and evaluate SA in high school students.
Key words: Speed-agility; adolescents; anthropometric; 10x5 shuttle run.

introduction

The World Health Organization new guidelines on physical activity (PA) (Bull et al., 2020), recommend that children and adolescents engage in at least 60 minutes of moderate to vigorous PA daily. This amount of PA is associated with substantial health benefits. Indeed, it can reduce the risk of overweight, obesity, cardiorespiratory diseases and metabolic disorders in young people (Calcaterra et al., 2022, 2023; Lona et al., 2021; Saunders et al., 2016) and, also, promotes physical and mental health (Rodriguez-Ayllon et al., 2019). Another key improvement in children and adolescents associated with an increased level of PA is augmented physical fitness (PF). PF, defined as "a set of physical attributes that people have or achieve" (Caspersen et al., 1985), is divided in different macro areas (Cardiovascular fitness; muscular strength; body composition, flexibility, and motor skills) and each is associated with different health domains. For example, one of the motor skills, speed-agility (SA, ability to run quickly and change direction while maintaining control and balance), even if some authors reported it as only a performance indicator (Di Domenico & D'isanto, 2019; Dos'Santos et al., 2016; Haugen et al., 2014), it has been shown to be related to bone health in children and adolescents (Howley, 2001). Despite the clear benefits of PA in children and adolescents, as reported by Guthold et al. (Guthold et al., 2020), more than 80% of children and adolescents worldwide are insufficiently active.

This lack of PA contributes to the recent decline in PF (Giuriato et al., 2023; Lovecchio et al., 2020, 2022; Vandoni et al., 2022), which poses a threat to the health of children and adolescents. Indeed, several studies (Fühner et al., 2021; Moliner-Urdiales et al., 2010; Venckunas et al., 2017) tried to analyze the recent trends in PF, describing reduced performance in cardiorespiratory fitness tests. Indeed, Lovecchio et al. (Lovecchio et al., 2022) found a decline in endurance performance, using the Cooper run test and the 1000m run test, among middle school Italian children from 1984 to 2009. Moreover, muscular fitness seems to follow this negative trend, as reported by Đurić et al. (Đurić et al., 2021), who found a decrease in lower and upper limb strength in Slovenian children between 1983 to 2014. Also Giuriato et al. (Giuriato et al., 2022), when analyzing the PF performance of 13 and 14 years Italian pre-adolescents from 2005 to 2011, found a slight decline in lower limb strength, cardiorespiratory endurance and flexibility. However, the studies investigating SA showed contrasting results. Indeed, some authors described a decline trend (Matton et al., 2007; Tambalis et al., 2011), and vice versa, others reported an increase or a stagnation (Fühner et al., 2021; Moliner-Urdiales et al., 2010; Venckunas et al., 2017). However, to the authors' knowledge, only three studies have analyzed the data

Corresponding Author: ALESSANDRO GATTI, E-mail: alessandro.gatti08@universitadipavia.it

regarding the Italian situation, and these data were reported only up to 2013 (Lovecchio et al., 2020; G. R. Tomkinson et al., 2003; Vandoni et al., 2022). Moreover, the results of these studies were not consistent: while Vandoni et al. (Vandoni et al., 2022) found a trend of reduction of SA in both boys and girls from 1984 to 2009, Tomkinson et al. (G. R. Tomkinson et al., 2003) found a decreased performance only in girls from 1980 to 2000, while Lovecchio et al. (Lovecchio et al., 2020), has not found any changes in SA performance from 2004 to 2013. One of the possible causes of these contrasting results could be attributed to the different tests used to evaluate SA in these populations.

These suggest the need to provide data about the SA performance with validated tests. In literature, EUROFIT battery (Sport, 1983) has been used as an evaluation tool to assess PF. The EUROFIT battery includes several tests, such as the 10x5m Shuttle Run Test, which has been used to assess SA. Using the EUROFIT test, Tomkinson et al. (G. Tomkinson et al., 2017) established normative values for the 10x5m Shuttle Run Test for European children and adolescents. Due to the crucial role of SA for health and performance (Dos'Santos et al., 2016; Haugen et al., 2014; Howley, 2001), a comparison between the Italian data and the European normative values could be an essential starting point for trainers and teachers to tailor PA promotion in children and adolescents. In addition, it is essential to understand if SA performance in Italian adolescents is related to anthropometric characteristics, since it is clear that the trend of PA practice is decreasing, while the trends of adiposity index (i.e. body mass index (BMI)) are increasing (Gatti et al., 2022; Giuriato et al., 2023; Ogden et al., 2014; Vandoni et al., 2022). Therefore, and due to the lack of studies on this topic, the aim of this study was to evaluate the SA performance of Italian high school students using the 10x5m shuttle run test and to compare the results with European normative data to verify discrepancies or critical gaps between Italian adolescents and their European counterparts. Furthermore, we wanted to understand the adiposity indices related to SA performance in adolescents in order to help physical education teachers to better tailor their activities.

Material and Methods

Participants

A total of 627 high school students (male = 52.5%; female = 47.5%) aged between 14 to 18 years were recruited in 2019 from a single high school in Northern Italy. Students of both sexes, who did not have any contraindications to the practice of PA and who did not have any known orthopaedical, neurological, or cardiovascular diseases were considered eligible and included in the study. After hearing the explanation of the study protocol, parents or legal guardians provided written consent. Every student gave verbal absence for participation, and they could withdraw from the study at any moment without any consequence. The students did not receive any academic credit or benefit from their participation in the study. This study was approved by the dean of the school and conducted in accordance with the Declaration of Helsinki (World Medical Association, 2013).

Procedures

The data were collected between January 2019 and March 2019, during curricular classes of PE. The data were collected by Sports scientists, which were preventively instructed about all procedures and protocol instructions. Anthropometric characteristics and the 10x5m Shuttle Run Test were assessed as follows.

Standing height was measured with a stadiometer (Seca 213, Seca GmbH & Co., Hamburg, Germany) to the closest 1 cm, with students standing upright and with their heads in the Frankfurt plane. Weight was evaluated using a balance scale (Seca 864, Seca GmbH & Co., Hamburg, Germany) to the nearest 0.1 kg. These anthropometric characteristics were assessed following the guidelines provided by the International Society for the Advancement of Kinanthropometry (Clarys et al., 2006). BMI was calculated using standing height and weight data. Then, BMI was computed following this formula: body mass (kg) divided by squared height (m^2). WC was measured in the standing position, at the end of a quiet expiration, at the midpoint between the edge of the rib cage and the iliac crest (Calcaterra et al., 2017). Then, adiposity indices including Waist to Height Ratio (WtHR), Triponderal Mass Index (TMI), and fat mass were calculated as follows:

- WtHR = Waist circumference (m) / Height (m);
- TMI = Weight (kg)/Height $(m)^3$ (Leone et al., 2020);
- Fat Mass = Weight - exp[0.3073 × $Height^2$ - 10.0155 × $Weight^{-1}$ + 0.004571 × Weight- 0.9180 × ln(age) + 0.6488 × $age^{0.5}$ + 0.04723 × male + 2.8055] (Hudda et al., 2019).

(exp = exponential function, ln = natural log transformation, male = 1, female = 0).

For the 10x5m Shuttle Run test, in brief, the participant starts with a foot on one marker and, when instructed, runs to the opposite marker, turns and come back to the starting line. At each shuttle, the feet must fully cross the line before running back. Subjects are asked to run back and forth over the 5 meters without stopping, ten times, covering 50 meters in total. The operator records the total time taken to complete the ten shuttles, where a lower time indicated a better performance.

Statistical analysis

Data were collected anonymously and stratified by sex and age. Mean and standard deviation were calculated for all variables and used to describe the data. We tested for normality by Shapiro–Wilk tests and graphically checked for linearity. The significance level was set at 0.05. To compare males and females of the same age we used a test T of Student or a test U of Mann-Whitney, respectively if the variable were distributed normally or not. To assess how SA performance changed between different ages, we used an ANOVA of Welch with a post-hoc procedure of Bonferroni. The Z-score was used to compare the Italian results with European reference (G. Tomkinson et al., 2017): deviations of ± 1.645 were considered statistically significant and used to discriminate differences between the two groups. The negative value of the Z-score for the Italian group indicates a lower time of the 10x5m Shuttle Run Test than the European group, which indicates a better performance. To assess the relationship between anthropometric indices and SA performance we used a Pearson or a Spearman correlation, if the data were respectively normally or not normally distributed. The correlation coefficient (r) was interpreted as reported by Chan (Chan, 2003). Statistical analyses were performed using "The Jamovi project (2021). Jamovi Version 1.6 for Mac [Computer Software], Sydney, Australia; retrieved from https://www.jamovi.org.

Results

The characteristics of the participants were thoroughly examined and are displayed in Table 1. These descriptive features encompass age, number of subjects, weight, height, waist circumference, waist-to-height ratio, absolute fat mass, body mass index, triponderal mass index, and the shuttle run test results. The data is presented in the form of mean ± standard deviation to provide a comprehensive understanding of the measurements.

Table 1. Descriptive characteristics of the total sample divided by sex and age.

	Age (years)	n	Weight (kg)	Height (m)	Waist (m)	WtHR index	Fat Mass (kg)	BMI (kg/m^2)	TMI (kg/m^3)	10x5m SRT (s)
Males	14	51	57.81 ± 8.53	1.69 ± 0.07	0.69 ± 0.06	0.41 ± 0.04	13.49 ± 4.66	20.02 ± 2.39	11.82 ± 1.44	19.69 ± 1.64
	15	78	61.09 ± 10.02	1.73 ± 0.08	0.72 ± 0.07	0.42 ± 0.04	12.82 ± 5.16	20.30 ± 2.73	11.73 ± 2.73	19.16 ± 1.46
	16	95	67.02 ± 11.32	1.75 ± 0.07	0.74 ± 0.07	0.42 ± 0.04	14.36 ± 6.40	21.73 ± 3.24	12.40 ± 1.90	19.34 ± 1.43
	17	92	68.58 ± 12.03	1.76 ± 0.06	0.74 ± 0.08	0.42 ± 0.05	13.53 ± 6.62	22.01 ± 3.40	12.49 ± 1.96	19.44 ± 1.51
	18	99	69.56 ± 11.21	1.77 ± 0.06	0.75 ± 0.07	0.43± 0.04	12.33 ± 6.28	22.16 ± 3.18	12.53 ± 1.84	19.27 ± 1.91
Females	14	51	52.09 ± 7.58	1.62 ± 0.07	0.67 ± 0.06	0.41 ± 0.04	11.22 ± 5.13	19.95 ± 3.14	12.38 ± 2.26	20.94 ± 1.72
	15	63	55.37 ± 7.59	1.64 ± 0.06	0.68 ± 0.05	0.42 ± 0.03	11.41 ± 4.08	20.52 ± 2.34	12.51 ± 1.51	21.10 ± 1.73
	16	86	57.34 ± 8.32	1.64 ± 0.05	0.70 ± 0.05	0.42 ± 0.03	11.65 ± 4.50	21.20 ± 2.54	12.91 ± 1.53	21.38 ± 2.13
	17	90	59.10 ± 8.63	1.65 ± 0.06	0.72 ± 0.12	0.44 ± 0.07	11.42 ± 4.76	21.77 ± 2.69	13.28 ± 1.70	21.59 ± 1.42
	18	86	58.42 ± 0.07	1.65 ± 0.06	0.69 ± 0.06	0.42 ± 0.04	9.80 ± 5.38	21.55 ± 3.01	13.11 ± 1.92	21.46 ± 1.48

Note: kg=kilograms; m=meters; s=seconds; n=numerosity; WtHR=Waist to Height Ratio; BMI=Body Mass Index; TMI=Triponderal Mass Index; SRT= Shuttle Run Test.

In Table 2, changes in SA performance across different age groups are reported for both males and females. However, within each age group, there were no significant differences in performance observed among male and female students.

Table 2. Age-related differences for the 10x5m Shuttle Run Test in males and females.

Comparison					
	Age		**Age**	**Mean difference (s)**	***p*-value**
	14	-	15	-0.1544	>0.05
		-	16	-0.4373	>0.05
		-	17	-0.6437	>0.05
		-	18	-0.5171	>0.05
Males	15	-	16	-0.2829	>0.05
		-	17	-0.4894	>0.05
		-	18	-0.3627	>0.05

Comparison					
	Age		**Age**	**Mean difference (s)**	***p*-value**
	16	-	17	-0.2064	>0.05
		-	18	-0.0798	>0.05
	17	-	18	0.1267	>0.05
Females	14	-	15	-0.1544	>0.05
		-	16	-0.4373	>0.05
		-	17	-0.6437	>0.05
		-	18	-0.5171	>0.05
	15	-	16	-0.2829	>0.05
		-	17	-0.1544	>0.05
		-	18	-0.4373	>0.05
	16	-	17	-0.6437	>0.05
		-	18	-0.5171	>0.05
	17	-	18	-0.2829	>0.05

Upon comparing our data with the European data (G. Tomkinson et al., 2017) , intriguing non-linear trends emerged (see Table 3). Specifically, SA performance was notably higher for 15-year-old males (z-score = -1.90); and 14 (z-score = -2.04) and 15 (z-score = -1.86) year-old females, while no differences were found for other age groups (-1.65 > z-score <1.65).

Table 3: Z-score analysis between Italian data and European references. S: statistical significative differences; N: no significative differences

	Age	Z-score	Significance (N/S)
Males	14	-1.54	N
	15	-1.90	S
	16	-0.85	N
	17	-0.03	N
	18	-0.38	N
Males	14	-2.04	S
	15	-1,86	S
	16	-1.20	N
	17	-0.73	N
	18	-1.14	N

Note: S=statistical significative differences; N=no significative difference.

The correlation between the anthropometric indices and SA performance showed a not random relationship (*p*<0.01) for males but not for females. Although exists a relationship for males, for all the indices, the relationship is considered as poor (0.00 > r < 0.20).

Table 4. Correlations between anthropometric indices and 10x5m Shuttle Run Test in males and females.

	5x10m Shuttle Run test	
	Males	Females
WtHR	0.13**	0.03
Fat Mass	0.15**	0.04
BMI	0.13**	0.07
TMI	0.14**	0.11*

Note: All data are presented as r. *p<0.05;**p<0.01. WtHR=Waist to Height Ratio, BMI=Body Mass Index; TMI=Triponderal Mass Index; SRT= Shuttle Run Test.

Fig.1 Linear relation between anthropometric indices and 10x5m Shuttle Run Test in males.

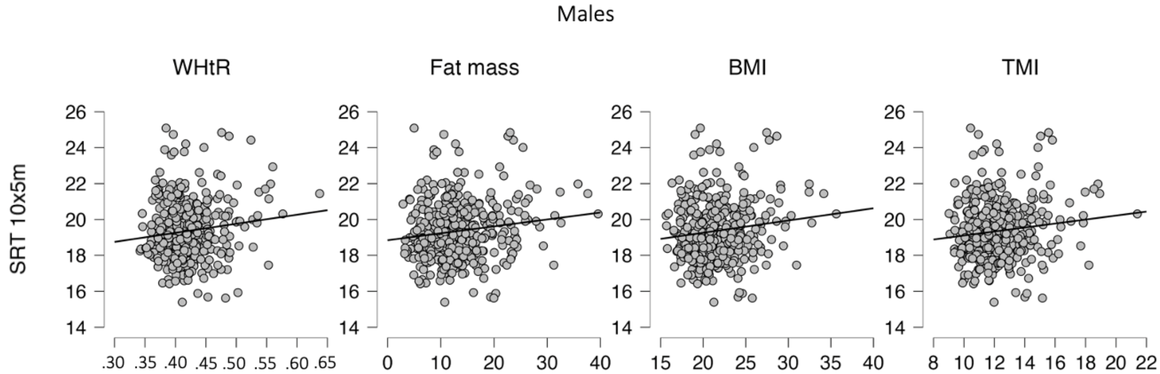
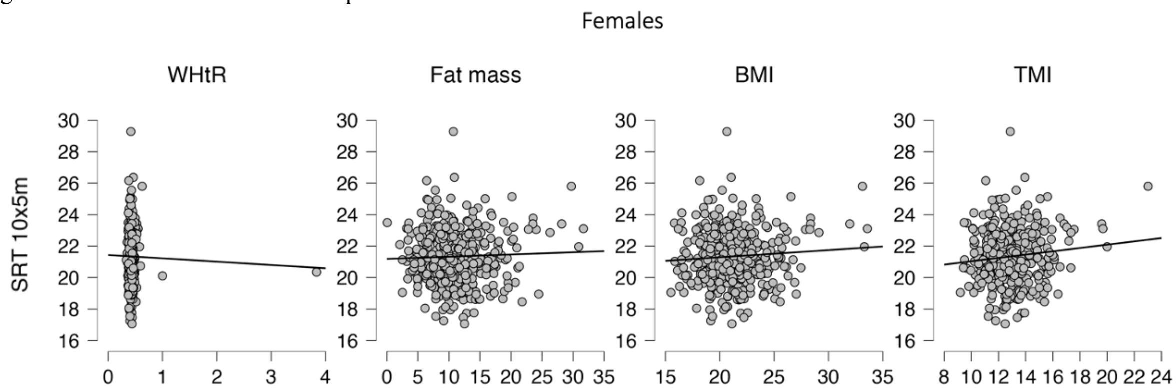


Fig.2 Linear relation between anthropometric indices and 10x5m Shuttle Run Test in females.



Discussion

The aim of this study was to analyze the correlation between anthropometric indices and age with SA performance in Italian adolescents and to evaluate the Italian adolescents' SA performance. Moreover, to the best of our knowledge, our study is the first that compared the Italian adolescents' SA performance with the European normative data. Our study results showed that Italian adolescents' SA performance was similar to the performance of European peers, and for some age groups of males (15 years) and females (14 and 15 years), SA performance is even better than European norms. Our results were in contrast with the data about PA levels of the Italian population. Indeed, Loyen et al. (Loyen et al., 2016) demonstrated that the Italian population, when comparing European nations for % meeting PA recommendations and mean METs-min per week, belongs consistently to the lowest tertile. Moreover, our data were in contrast with the study conducted by Vandoni et al. (Vandoni et al., 2022), which showed a decline in SA performance in Italian middle school youths. While Lovecchio et al. (Lovecchio et al., 2020), confirming our results, showed a stagnation of SA performance in Italian adolescents. One possible explanation for these divergent results is the years in which the studies were conducted. While Vandoni et al. (Vandoni et al., 2022) assessed SA performance until 2009, Lovecchio et al. (Lovecchio et al., 2020) assessed it until 2013 and our results until 2019. Therefore, since our results report equal or even better performance of Italian adolescents compared to European norms, this could mean a reversal of the trend, reporting an increase in the SA performance of Italian adolescents with time.

Regarding the correlation, our findings showed that all anthropometric indices are not randomly related to SA performance. Although we proved the existence of these relationships, SA performance, in our results, depended poorly on the anthropometric indices, suggesting that SA seems not to be greatly influenced by an increased fat mass. In contrast with our results, several studies (Pehar et al., 2018; Rinaldo et al., 2020) showed a direct medium-strong relationship between SA performance and anthropometric indices, demonstrating a higher performance in adolescents with lower fat mass and higher muscle mass.

These different results could be explained by the different populations used in the studies. Since they used a population of athletes, they had lower percentages of overweight and none of adolescents with obesity, on the contrary, our data used a sample of adolescents representing typical physical education classes in Italy. Certainly, future studies are needed to confirm our results and to explain the relationship between anthropometric indices and non-athlete adolescents.

Our results also showed that SA performance is not related to age in males and females. Our results are in line with the finding of other studies. For example, Vänttinen et al. (Vänttinen et al., 2011) and Büchel et al. (Büchel et al., 2019) showed that SA performance reached stagnation in 14 years old adolescents, and they did not observe a difference in SA performance of 14-years with 15-, 16- and 17-years adolescents. This stagnation in SA performance between 14- and 18-year-olds may be explained by the timing of agility growth spurts. Indeed, as shown in European youths by Pereira et al. (Pereira et al., 2022), identifying the timing, intensity, and sequences of PF spurts aligned by the age-at-peak of their mid-growth spurt, concluded that agility spurt occurred slightly after (6-to12 months) age-at-peak of their mid-growth spurt in their stature (approx. 8 years old). Our results showed that even if other motor abilities increase with age (Beunen & Thomis, 2000; Pate et al., 2006) SA did not improve with age. Based on this, our findings may be helpful to physical education teachers and coaches not to expect improvement in SA performance with age after reaching 14 years and without a specific type of training. Therefore, new studies are needed to understand the best type of training to improve SA ability in adolescents after the age of 14, in order to help physical education teachers and coaches develop SA performance in their students.

The great sample size of our study is a great strength point since it provides relevant information about the SA ability of Italian adolescents. However, this study presents some limitations. Firstly, we only assessed the SA performance and no other domains of the PF. Secondly, we used only one test to assess the SA performance and we did not assess the anthropometric characteristics with any direct method (i.e., BIA, DXA). Finally, we have no data about the ethnicity of the participants.

Conclusion

In conclusion, our results provide a relevant overview of the SA performance of Italian adolescents. We found that SA seems to be poorly related to anthropometric characteristics and age (ranging from 14 to 18). In addition, our results showed that the SA performance of Italian adolescents is similar to, or, for some age groups, even better than the normative data from Europe. Furthermore, our study has provided evidence indicating that while various other motor abilities in children and adolescents exhibit a consistent increase with age, this pattern of progression is not observed in the case of SA. These results provide crucial information for physical education teachers to promote and evaluate SA in high school students. Future studies should also investigate the trends of SA performance in Italian adolescents to confirm our results.

Conflict of interest: The authors declare no conflict of interest.

References

Beunen, G., & Thomis, M. (2000). Muscular Strength Development in Children and Adolescents. *Pediatric Exercise Science*, *12*(2), 174–197. https://doi.org/10.1123/pes.12.2.174

Büchel, D., Lehmann, T., & Baumeister, J. (2019). *Effect of Age on Reactive Multidirectional Speed in Highly Trained Young Soccer Players*.

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., … Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Calcaterra, V., De Giuseppe, R., Biino, G., Mantelli, M., Marchini, S., Bendotti, G., Madè, A., Avanzini, M. A., Montalbano, C., & Cossellu, G. (2017). Relation between circulating oxidized-LDL and metabolic syndrome in children with obesity: The role of hypertriglyceridemic waist phenotype. *Journal of Pediatric Endocrinology and Metabolism*, *30*(12), 1257–1263.

Calcaterra, V., Vandoni, M., Marin, L., Carnevale Pellino, V., Rossi, V., Gatti, A., Patanè, P., Cavallo, C., Re, F., Albanese, I., Silvestri, D., De Nunzio, A., & Zuccotti, G. (2023). Exergames to Limit Weight Gain and to Fight Sedentarism in Children and Adolescents with Obesity. *Children*, *10*(6), Article 6. https://doi.org/10.3390/children10060928

Calcaterra, V., Verduci, E., Vandoni, M., Rossi, V., Fiore, G., Massini, G., Berardo, C., Gatti, A., Baldassarre, P., Bianchi, A., Cordaro, E., Cavallo, C., Cereda, C., Bosetti, A., & Zuccotti, G. (2022). The Effect of Healthy Lifestyle Strategies on the Management of Insulin Resistance in Children and Adolescents with Obesity: A Narrative Review. *Nutrients*, *14*(21), 4692. https://doi.org/10.3390/nu14214692

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports (Washington, D.C.: 1974)*, *100*(2), 126–131.

Chan, Y. H. (2003). Biostatistics 104: Correlational analysis. *Singapore Medical Journal*, *44*(12), 614–619.

Clarys, J. P., Provyn, S., Marfell-Jones, M., & Van Roy, P. (2006). Morphological and constitutional comparison of age-matched in-vivo and post-mortem populations. *Morphologie*, *90*(291). https://doi.org/10.1016/S1286-0115(06)74505-2

Di Domenico, F., & D'isanto, T. (2019). Role of speed and agility in the effectiveness of motor performance. *Journal of Physical Education and Sport*, *19*, 1836–1842.

Dos'Santos, T., Thomas, C., Jones, P., & Comfort, P. (2016). Mechanical Determinants of Faster Change of Direction Speed Performance in Male Athletes. *Journal of Strength and Conditioning Research*, *31*, 1. https://doi.org/10.1519/JSC.0000000000001535

Đurić, S., Sember, V., Starc, G., Sorić, M., Kovač, M., & Jurak, G. (2021). Secular trends in muscular fitness from 1983 to 2014 among Slovenian children and adolescents. *Scandinavian Journal of Medicine & Science in Sports*, *31*(9), 1853–1861. https://doi.org/10.1111/sms.13981

Fühner, T., Kliegl, R., Arntz, F., Kriemler, S., & Granacher, U. (2021). An Update on Secular Trends in Physical Fitness of Children and Adolescents from 1972 to 2015: A Systematic Review. *Sports Medicine (Auckland, N.Z.)*, *51*(2), 303–320. https://doi.org/10.1007/s40279-020-01373-x

Gatti, A., Pugliese, L., Carnevale Pellino, V., Del Bianco, M., Vandoni, M., & Lovecchio, N. (2022). Self-Declared Physical Activity Levels and Self-Reported Physical Fitness in a Sample of Italian Adolescents during the COVID-19 Pandemic. *European Journal of Investigation in Health, Psychology and Education*, *12*(6), 655–665. https://doi.org/10.3390/ejihpe12060049

Giuriato, M., Carnevale Pellino, V., Cavallo, C., Farronato, L., Pirazzi, A., Beghetto, A., Gross, F., Del Bianco, M., Gatti, A., Vandoni, M., & Lovecchio, N. (2023). Physical fitness trend after COVID-19 restrictions in Italian school-aged children: A cross-sectional study. *The Journal of Sports Medicine and Physical Fitness*. https://doi.org/10.23736/S0022-4707.23.14943-7

Giuriato, M., Pirletti, C., Pellino, V. C., & Lovecchio, N. (2022). Regression of physical fitness in pre-adolescent: Is it a real trend? *Journal of Physical Education and Sport*, *22*(2), 402–407. Scopus. https://doi.org/10.7752/jpes.2022.02050

Guthold, R., Stevens, G. A., Riley, L. M., & Bull, F. C. (2020). Global trends in insufficient physical activity among adolescents: A pooled analysis of 298 population-based surveys with 1·6 million participants. *The Lancet Child & Adolescent Health*, *4*(1), 23–35. https://doi.org/10.1016/S2352-4642(19)30323-2

Haugen, T., Tønnessen, E., Hisdal, J., & Seiler, S. (2014). The role and development of sprinting speed in soccer. *International Journal of Sports Physiology and Performance*, *9*(3), 432–441. https://doi.org/10.1123/ijspp.2013-0121

Howley, E. T. (2001). Type of activity: Resistance, aerobic and leisure versus occupational physical activity. *Medicine and Science in Sports and Exercise*, *33*(6 Suppl), S364-369; discussion S419-420. https://doi.org/10.1097/00005768-200106001-00005

Hudda, M. T., Fewtrell, M. S., Haroun, D., Lum, S., Williams, J. E., Wells, J. C. K., Riley, R. D., Owen, C. G., Cook, D. G., Rudnicka, A. R., Whincup, P. H., & Nightingale, C. M. (2019). Development and validation of a prediction model for fat mass in children and adolescents: Meta-analysis using individual participant data. *BMJ (Clinical Research Ed.)*, *366*, l4293. https://doi.org/10.1136/bmj.l4293

Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S., & Verduci, E. (2020). Evaluation of Different Adiposity Indices and Association with Metabolic Syndrome Risk in Obese Children: Is there a Winner? *International Journal of Molecular Sciences*, *21*(11), 4083. https://doi.org/10.3390/ijms21114083

Lona, G., Hauser, C., Köchli, S., Infanger, D., Endes, K., Faude, O., & Hanssen, H. (2021). Changes in physical activity behavior and development of cardiovascular risk in children. *Scandinavian Journal of Medicine & Science in Sports*, *31*(6), 1313–1323. https://doi.org/10.1111/sms.13931

Lovecchio, N., Giuriato, M., Carnevale Pellino, V., Valarani, F., Codella, R., & Vandoni, M. (2020). Italian Physical Fitness Decline: A True Fact or a Mindset? A 10-Year Observational Perspective Study. *International Journal of Environmental Research and Public Health*, *17*(21), E8008. https://doi.org/10.3390/ijerph17218008

Lovecchio, N., Vandoni, M., Codella, R., Rovida, A., Carnevale Pellino, V., Giuriato, M., Klug, M. G., & Tomkinson, G. R. (2022). Trends in means and distributional characteristics of cardiorespiratory endurance performance for Italian children (1984-2010). *Journal of Sports Sciences*, *40*(22), 2484–2490. https://doi.org/10.1080/02640414.2023.2165007

Loyen, A., Van Hecke, L., Verloigne, M., Hendriksen, I., Lakerveld, J., Steene-Johannessen, J., Vuillemin, A., Koster, A., Donnelly, A., Ekelund, U., Deforche, B., De Bourdeaudhuij, I., Brug, J., van der Ploeg, H. P., & on behalf of the DEDIPAC consortium. (2016). Variation in population levels of physical activity in European adults according to cross-European studies: A systematic literature review within DEDIPAC. *International Journal of Behavioral Nutrition and Physical Activity*, *13*(1), 72. https://doi.org/10.1186/s12966-016-0398-2

Matton, L., Duvigneaud, N., Wijndaele, K., Philippaerts, R., Duquet, W., Beunen, G., Claessens, A. L., Thomis, M., & Lefevre, J. (2007). Secular trends in anthropometric characteristics, physical fitness, physical activity, and biological maturation in Flemish adolescents between 1969 and 2005. *American Journal of Human Biology: The Official Journal of the Human Biology Council*, *19*(3), 345–357. https://doi.org/10.1002/ajhb.20592

Moliner-Urdiales, D., Ruiz, J. R., Ortega, F. B., Jiménez-Pavón, D., Vicente-Rodriguez, G., Rey-López, J. P., Martínez-Gómez, D., Casajús, J. A., Mesana, M. I., Marcos, A., Noriega-Borge, M. J., Sjöström, M., Castillo, M. J., & Moreno, L. A. (2010). Secular trends in health-related physical fitness in Spanish adolescents: The AVENA and HELENA Studies. *Journal of Science and Medicine in Sport*, *13*(6), 584–588. https://doi.org/10.1016/j.jsams.2010.03.004

Ogden, C. L., Carroll, M. D., Kit, B. K., & Flegal, K. M. (2014). Prevalence of childhood and adult obesity in the United States, 2011-2012. *JAMA*, *311*(8), 806–814. https://doi.org/10.1001/jama.2014.732

Pate, R. R., Wang, C.-Y., Dowda, M., Farrell, S. W., & O'Neill, J. R. (2006). Cardiorespiratory Fitness Levels Among US Youth 12 to 19 Years of Age: Findings From the 1999-2002 National Health and Nutrition Examination Survey. *Archives of Pediatrics & Adolescent Medicine*, *160*(10), 1005–1012. https://doi.org/10.1001/archpedi.160.10.1005

Pehar, M., Sisic, N., Sekulic, D., Coh, M., Uljevic, O., Spasic, M., Krolo, A., & Idrizovic, K. (2018). Analyzing the relationship between anthropometric and motor indices with basketball specific pre-planned and non-planned agility performances. *The Journal of Sports Medicine and Physical Fitness*, *58*(7–8), 1037–1044. https://doi.org/10.23736/S0022-4707.17.07346-7

Pereira, S., Santos, C., Tani, G., Freitas, D., Garbeloto, F., Guimarães, E., Robinson, L. E., Baxter-Jones, A., Katzmarzyk, P. T., & Maia, J. (2022). Physical fitness spurts in pre-adolescent boys and girls: Timing, intensity and sequencing. *Journal of Sports Sciences*, *40*(6), 630–637. https://doi.org/10.1080/02640414.2021.2009201

Rinaldo, N., Toselli, S., Gualdi-Russo, E., Zedda, N., & Zaccagni, L. (2020). Effects of Anthropometric Growth and Basketball Experience on Physical Performance in Pre-Adolescent Male Players. *International Journal of Environmental Research and Public Health*, *17*(7), 2196. https://doi.org/10.3390/ijerph17072196

Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J., Migueles, J. H., Molina-García, P., Henriksson, H., Mena-Molina, A., Martínez-Vizcaíno, V., Catena, A., Löf, M., Erickson, K. I., Lubans, D. R., Ortega, F. B., & Esteban-Cornejo, I. (2019). Role of Physical Activity and Sedentary Behavior in the Mental Health of Preschoolers, Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine (Auckland, N.Z.)*, *49*(9), 1383–1410. https://doi.org/10.1007/s40279-019-01099-5

Saunders, T. J., Gray, C. E., Poitras, V. J., Chaput, J.-P., Janssen, I., Katzmarzyk, P. T., Olds, T., Connor Gorber, S., Kho, M. E., Sampson, M., Tremblay, M. S., & Carson, V. (2016). Combinations of physical activity, sedentary behaviour and sleep: Relationships with health indicators in school-aged children and youth. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition Et Metabolisme*, *41*(6 Suppl 3), S283-293. https://doi.org/10.1139/apnm-2015-0626

Sport, C. of E. C. for the D. of. (1983). *EUROFIT: Handbook for the EUROFIT Tests of Physical Fitness*. Strasbourg. https://books.google.it/books?id=9sGzngEACAAJ

Tambalis, K. D., Panagiotakos, D. B., Psarra, G., & Sidossis, L. S. (2011). Inverse but independent trends in obesity and fitness levels among Greek children: A time-series analysis from 1997 to 2007. *Obesity Facts*, *4*(2), 165–174. https://doi.org/10.1159/000327994

Tomkinson, G., Carver, K., Atkinson, F., Daniell, N., Lewis, L., Fitzgerald, J., Lang, J., & Ortega, F. (2017). European normative values for physical fitness in children and adolescents aged 9-17 years: Results from 2 779 165 Eurofit performances representing 30 countries. *British Journal of Sports Medicine*, *52*, bjsports-2017. https://doi.org/10.1136/bjsports-2017-098253

Tomkinson, G. R., Léger, L. A., Olds, T. S., & Cazorla, G. (2003). Secular trends in the performance of children and adolescents (1980-2000): An analysis of 55 studies of the 20m shuttle run test in 11 countries. *Sports Medicine (Auckland, N.Z.)*, *33*(4), 285–300. https://doi.org/10.2165/00007256-200333040-00003

Vandoni, M., Carnevale Pellino, V., De Silvestri, A., Lovecchio, N., Rovida, A., Gatti, A., Biagioli, V., Zuccotti, G., & Calcaterra, V. (2022). The Temporal Association between Body Characteristics and Speed Performance over Twenty-Five Years in Italian Adolescents. *Children (Basel, Switzerland)*, *9*(4), 521. https://doi.org/10.3390/children9040521

Vänttinen, T., Blomqvist, M., Nyman, K., & Häkkinen, K. (2011). Changes in body composition, hormonal status, and physical fitness in 11-, 13-, and 15-year-old Finnish regional youth soccer players during a two-year follow-up. *Journal of Strength and Conditioning Research*, *25*(12), 3342–3351. https://doi.org/10.1519/JSC.0b013e318236d0c2

Venckunas, T., Emeljanovas, A., Mieziene, B., & Volbekiene, V. (2017). Secular trends in physical fitness and body size in Lithuanian children and adolescents between 1992 and 2012. *Journal of Epidemiology and Community Health*, *71*(2), 181. https://doi.org/10.1136/jech-2016-207307

World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, *310*(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053