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Analysis of the effect size of overweight in speed-agility test among adolescents Reference values according to sex, age and BMI

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Abstract. The objective of the present cross-sectional study was to quantify the effect size of overweight on the results of speed-agility in adolescents and to report percentile tables based on sex, age and BMI. Was hypothesized that the effect size obtained from the difference between normal-weight and overweight youth would be equal to or greater than the differences between sexes within the same age group. A total of 10.439 Spanish adolescents aged 13.72 ± 1.42 years from 42 secondary schools participated in the research. Speed-agility was evaluated using the 4x10 m test. The effect size was analysed using the adjusted Hedges' ð. The findings regarding sex show that 92.74% and 86.98% of normal-weight and overweight girls, respectively, attained lower speed-agility than boys. With regard to body composition, the percentages are also high, but they are a bit lower than those for sex. So, 77.26% and 70.52% of overweight boys and girls, respectively, showed lower speed-agility than their normal-weight peers. The differential effect size between boys and girls is higher than between normal-weight and overweight adolescents in speed-agility. In spite of this, the results suggest that BMI should be taken into account in assessing the speed-agility of young people.
Keywords: speed; fitness; obesity; adolescent; physical education.

Resumen. El objetivo de este estudio transversal fue cuantificar el tamaño del efecto del sobrepeso en los resultados de velocidad-agilidad en adolescentes e informar las tablas de percentiles en función del sexo, la edad y el IMC. Se planteó la hipótesis de que el tamaño del efecto obtenido entre los jóvenes con sobrepeso y normopeso sería igual o mayor que las diferencias entre los sexos dentro del mismo grupo de edad. Un total de 10.439 adolescentes españoles de 13.72 ± 1.42 años de 42 centros de educación secundaria participaron en la investigación. Se evaluó la velocidad-agilidad utilizando la prueba de 4x10 m. El tamaño del efecto se analizó ajustando por la prueba ð de Hedges. Los resultados con respecto al sexo muestran que el 92.74% y el 86.98% de las niñas con sobrepeso y normopeso, respectivamente, alcanzaron una velocidad-agilidad menor que los niños. Con respecto a la composición corporal, los porcentajes también son altos, pero son un poco más bajos que los del sexo. El 77.26% y 70.52% de los niños y niñas con sobrepeso, respectivamente, mostraron menor velocidad-agilidad que sus pares de peso normal. Como conclusión, el tamaño del efecto diferencial entre niños y niñas es mayor que entre adolescentes con normopeso y sobrepeso en velocidad-agilidad. A pesar de esto, los resultados sugieren que se debe tener en cuenta el IMC al evaluar la velocidad-agilidad de los jóvenes.
Palabras clave: velocidad; actividad física; obesidad; adolescentes; educación física.

Introduction

Speed-agility comprises speed of movement, agility and coordination (Ramos-Sepúlveda et al., 2016). This physical fitness component has been associated to better motor coordination, motor ability and sports performance (Alesi et al., 2016; Lennemann et al., 2013). In addition, speed-agility has shown a positive association with skeletal health (Ortega et al., 2008), and with other key variables related to integral development in young people such as cognitive and academic performance at school (Ruiz-Ariza et al., 2017).

The most common way to assess speed-agility in young people is through field tests due to their validity, easy execution, lack of technical equipment and the possibility of assessing a large number of participants in a short time (Castro-Piñero et al., 2010). One of the speed-agility tests most used worldwide is the 4x10 m test from the ALPHA-Fitness battery (Ruiz et al., 2011). Currently, there are many valid and reliable battery tests where this physical fitness variable appears (Botelho et al., 2013; Gulías-González et al., 2014; Ruiz-Ariza et al., 2017). In these tests, normative reference values are mostly shown based on sex and age parameters, because it has been widely demonstrated that boys usually obtain higher physical fitness scores than girls and this variable changes significantly in both sexes as age advances (Castro-Piñero et al., 2010; Ruiz et al., 2011; Santos et al., 2014; Vanhelst et al., 2016).

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However, in the last few decades, teenagers have increased their daily sedentary time, spending 33% of the whole day on non-physically active behaviours –watching television, video consoles, smartphones, tablets or computers– (Verloigne et al., 2016). Moreover, 81% of adolescents do not carry out the recommended daily amount of 60 minutes of moderate to vigorous physical activity [MVPA] (WHO, 2016). Consequently, a progressive increase in the prevalence of overweight-obesity has appeared (Freedman et al., 2016). Overweight young people —including those with overweight + obesity— show less power in their legs (Gulías-González et al., 2014; Iglesias et al., 2019) and lower speed-agility scores than their normal-weight counterparts (Antunes et al., 2015; Botelho et al., 2013; Fogelholm et al., 2008). Thus, body mass index (BMI), the most standardized measure globally and clinically equal to, or even more reliable than, other measures of weight status (Martínez-López, Moreno-Cerceda, Suárez-Manzano, & Ruiz-Ariza, 2018; Ortega et al., 2016) could significantly and negatively influence speed-agility results. To the best of our knowledge, no study has yet quantified the magnitude of the difference analysing the effect size of a high BMI on adolescent speed-agility. Only one recent study has quantified the effect size of overweight on physical fitness results in adolescents, specifically on muscular strength. This research showed that, in spite of the fact that differential effect size between boys and girls is higher than between normal-weight and overweight adolescents, it is important to take into account BMI, in addition to sex and age (Martínez-López, De La Torre-Cruz, Suarez-Manzano, & Ruiz-Ariza, 2018; López-Serrano, de Loureiro, Suarez-Manzano, & de la Torre-Cruz, 2020).

Due to the previous evidence in other physical fitness components, and because overweight affects a greater number of young people, this study aimed to establish whether it is necessary to take BMI into account in assessing speed-agility in addition to sex and age. We hypothesize that the effect size obtained from the difference between normal-weight and overweight young people could be similar to, or higher than, the result obtained from the differences between sexes within the same age group. Therefore, the purpose of this study was to quantify the effect size of overweight on the results of the 4x10 m speed-agility test in adolescents. It was also intended to report percentile tables adapted to sex, age and BMI in a relatively large sample of Spanish girls and boys aged 12 to 16 years.

Material and Method

Participants

A total of 10.439 Spanish adolescents (49.1% girls) from 42 Andalusian secondary schools (4.87% of the total) were selected for convenience from among the 165 (19.2% among Andalusian secondary schools) schools that expressed interest in this study. The participants were categorized as normal-weight and overweight according to the International Obesity Taskforce criteria (Cole et al., 2000) and the specific cut-offs for each sex and age were in accordance by Cole and Lobstein (2012). Thus, 71.2% and 28.8% of the participants were found to be normal-weight and overweight + obesity, respectively. The anthropometric and 4x10 m speed-agility features of the study sample are detailed in Table 1. Participation was voluntary, authorized and unrewarded. The data were collected during 2013/14 and 2014/15. This study had the consent from parents and was approved by the Bioethical Committee of the University. The design complies with the Spanish regulations for clinical research with humans (Law 14/2007, 3rd July, of Biomedical Research), and with the principles of the Declaration of Helsinki (2013 version, Brazil).

Materials and testing

Weight was measured in underwear and without shoes using an electronic scale (ASIMED® Elegant type B – class III) to the nearest 0.1 kg, and height was measured barefoot in the Frankfort horizontal plane with a telescopic height-measuring instrument (SECA® 214) to the nearest 0.1 cm. BMI was calculated by Quetelec formule, as body weight in kilograms divided by the square of the height in meters. Time measurements were taken with an SL210 Oregon stopwatch.

We selected the 4x10 m test from the ALPHA-Fitness battery (Ruiz et al., 2011). Two parallel lines were drawn on the floor at a distance of 10 m apart. A slip-proof floor, four cones, a stopwatch and three sponges were used to perform the test. The objective was to carry sponges from one line to the other, crossing each line with both feet every time. The participants ran the distance four times at maximum speed, changing the sponge each time. The first time, participants picked up a sponge, and the second and third times, they exchanged the sponge they had for one that had been placed earlier behind the lines. The test was performed twice by each adolescent. The best result was recorded in seconds (s). The 4x10 m speed-agility test showed an excellent intra-class correlation (ICC = 0.902, 95% CI: 0.905–0.914).

Procedure

Prior to the testing session, the adolescents performed a typical warm-up consisting of five minutes of low-intensity running and five minutes of general exercise (i.e. skipping, lateral running and front-to-behind arm rotations). After that, the 4x10 m test was performed. The participants also performed some familiarization trials. The research team conducted a demonstration. The adolescents were encouraged to achieve the best possible time. A week later, 121 participants were randomly selected to carry out the same test (retest). The data were registered during PE classes. All adolescents in a standard class group were included in the study, except those with muscle or joint pathologies or any other physical impairment that militated against PA practice.

Statistical analysis

Anthropometric and physical fitness characteristics of the study sample are presented as means (SD), unless otherwise indicated. The normality and homoscedasticity of the data were verified using the Kolmogorov–Smirnov and Levene tests, respectively. Percentile values were identified and smoothed using the Lambda-Mu-Sigma (LMS) method, which adjusts for the asymmetry of the percentile distribution (L = symmetry coefficient, M = median, and S = variation coefficient) (Cole & Green, 1992). For this, the software TLMS chartmaker Light (version 2.54) was used (Pan & Cole, 1997). We analysed sex and age-group differences in the anthropometric and physical fitness variables through two-way analysis of variance. To analyse the differences in the speed-agility test according to sex (boy and girl) and weight status (normal-weight and overweight + obesity) in each age group, we used the Student's t-test. Due to the practical interest of this kind of work, the effect size was calculated. Although there are several procedures for estimating effect size, such as the coefficient of determination, h^2, w^2 or ö (Sink & Stroh, 2006), this study used the standardized difference of mean obtained by the adjusted Hedges' ð (Ledesma, Macbeth & Cortada de Kohan, 2008). The Hedges' ð estimates the difference between the means of the groups and expresses a typified value that allows it to be inferred from the table of the normal curve of the percentage of cases that one group is below the average of the another group. This decision was based on three favourable criteria: (1) accurate and unbiased estimation; (2) simplicity of calculation; and (3) easy interpretation of the results (Greenwald et al., 1996). In addition, we calculated the value of the probability of each difference using the standardized normal distribution table (Vincent, 2005). A Pearson correlation analysis and a multiple linear regression analysis were performed between the 4x10 m speed-agility test and anthropometric variables. The reliability of the 4x10 m test was analysed using a pre-post test through the intra-class correlation coefficient (ICC). The accepted level of significance was $p < 0.05$. The data were analysed using the Statistical Package for the Social Sciences (SPSS, version 22.0), except for the adjusted Hedges' ð, which was carried out on an Excel spreadsheet provided by Microsoft.

Results

Anthropometric characteristics and speed-agility parameters of the study sample are shown by sex in Table 1. The analysis of the results also shows that boys had a higher weight, height, BMI and speed-agility than girls ($p < 0.05$). All anthropometric variables tend to increase in both sexes as age advances except for the waist-hip index.

Table 1
Anthropometric characteristics and speed-agility parameters of the study sample according to sex.

	All (n= 10439)	Boys (n= 5313)	Girls (n= 5126)	Sex differences	Age trend
Age (years)	13.72 (1.42)	13.75 (1.42)	13.68 (1.42)	=	-
Weight (kg)	59.62 (13.72)	63.01 (14.96)	56.20 (11.37)	>	>
Height (meters)	1.64 (0.09)	1.68 (0.09)	1.60 (0.06)	>	>
Body mass index (kg/m^2)	22.02 (4.12)	22.14 (4.29)	21.89 (3.94)	=	>
Waist-hip index (meters)	0.79 (0.06)	0.82 (0.06)	0.75 (0.05)	>	<
Speed 4x10m (seconds)	12.31 (1.32)	11.60 (0.09)	13.06 (1.11)	<	<

The > symbol in the sex differences column means that the variable is significantly higher in boys than in girls ($p < 0.05$), and the < symbol means the opposite. The > symbol in the age trend column refers to the variable tends to increase as the age increases, and the < symbol means the opposite. The = symbol means that there are no significant differences, and the - symbol means that it is not applicable. In the 4x10 m speed-agility test, a lower time means a higher score in speed-agility.

The results obtained in the speed-agility test are presented in Table 2. At all ages, boys and girls in the overweight sample had lower values for speed-agility than their normal-weight peers (all $p < 0.001$). The analysis of effect size showed that 72.2% of boys and 68.4% of girls aged 12 in the overweight group had lower-than-the-average speed-agility scores of their normal-weight peers (12.45 ± 1.18 vs. 11.93 ± 0.98 cm, ð = 0.496, effect magnitude (M) = 0.722, and 13.47 ± 1.16 vs. 12.94 ± 1.07 cm, ð = 0.481, M = 0.684, respectively). Similar effect sizes were obtained for the other ages (ð = 0.899, M = 0.813 and ð = 0.451, M = 0.673 for the highest and the lowest, respectively). With regard to sex, between 84.6% and 96.4% (highest and

Table 2
Results for 4x10 m speed-agility according to age (12–16 years), sex (boys vs. girls) and weight status (normal-weight and overweight [overweight + obesity]). g = adjusted Hedges' g. Effect magnitude (M), shown in brackets, represents the probability for each of the typified differences using the standardized normal distribution table. This value is also expressed in the text as a percentage.

4x10 meters speed-agility												
	Boys (n= 5313)				Girls (n= 5126)				Normal-weight (Boys vs. girls)		Overweight (Boys vs. girls)	
Age	Normalweight n=3890 Mean (SD) n	Overweight n=1423 Mean (SD) n	p	g (M)	Normalweight n=3642 Mean (SD) n	Overweight n=1484 Mean (SD) n	p	g (M)	p	g (M)	p	g (M)
12	11.93 (0.98) 1007	12.45 (1.18) 468	<.001	0.496 (0.722)	12.94 (1.07) 1101	13.47 (1.16) 581	<.001	0.481 (0.684)	<.001	1.012 (0.846)	<.001	0.812 (0.791)
13	11.55 (0.96) 744	12.19 (1.04) 316	<.001	0.650 (0.745)	12.90 (1.11) 632	13.54 (1.30) 276	<.001	0.542 (0.705)	<.001	1.308 (0.910)	<.001	1.155 (0.874)
14	11.15 (0.90) 751	12.02 (1.12) 296	<.001	0.899 (0.813)	12.86 (1.06) 804	13.36 (0.84) 208	<.001	0.756 (0.773)	<.001	1.747 (0.959)	<.001	1.321 (0.904)
15	11.10 (0.84) 684	11.92 (1.15) 212	<.001	0.889 (0.810)	12.75 (1.02) 692	13.27 (1.07) 192	<.001	0.504 (0.691)	<.001	1.813 (0.964)	<.001	1.212 (0.886)
16	11.03 (0.87) 704	11.74 (1.27) 131	<.001	0.752 (0.773)	12.66 (1.02) 574	13.11 (0.91) 154	<.001	451 (0.673)	<.001	1.733 (0.958)	<.001	1.255 (0.894)

lowest values, respectively) of normal-weight girls had speed-agility scores lower than the average for boys (ð = 1.012, M = 0.846 and ð = 1.813, M = 0.964). Similarly, the speed-agility scores for overweight girls were between 79.1% and 90.4% (lowest and highest values, respectively), lower than the boys' average (ð = 0.812, M = 0.791 and ð = 1.321, M = 0.904).

Figure 1 shows the average of the magnitudes of means obtained for those aged 12–16 years in the speed-agility test. The results show higher percentages for effect magnitude between boys and girls than between the normal-weight and overweight groups. In all, 92.74% and 86.98% of normal-weight and overweight girls, respectively, attained a speed-agility lower than boys with a similar weight status. However, only 77.26% and 70.52% of the overweight boys and girls, respectively, attained a speed-agility lower than normal-weight boys and girls.

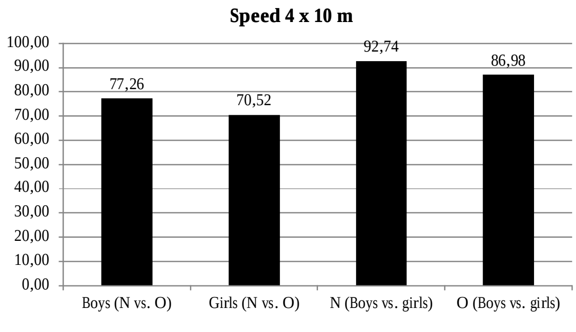

Figure 1. Average magnitude of effect size obtained by adolescents aged 12–16 in speed-agility test. The values for boys and girls indicate the percentage of overweight young people with results equal to or lower than the average for their normal-weight peers (50%). The values for normal-weight (N) and overweight (O) groups indicate the percentage of girls with scores equal to or lower than the boys' average (50%).

Pearson correlation analysis showed a significant correlation between 4x10 m speed-agility and age (-0.179, $p < 0.01$), sex (-0.553, $p < 0.001$), weight (-0.028, $p < 0.01$), height (-0.346, $p < 0.001$), BMI (0.175, $p < 0.001$) and waist-hip index (-0.155, $p < 0.001$). A multiple linear regression analysis between 4x10 m speed-agility and the above variables was conducted (Table 3). Age, sex and waist-hip index are predictor variables for the 4x10 m speed-agility test. Table 4 exhibits percentiles of the 4x10 m speed-agility test by weight status (normal-weight and overweight [overweight + obesity]) and sex (boys vs. girls).

Table 3
Multiple linear regression analyses between 4x10 m speed-agility test and age, sex and anthropometric variables. SE = Standard error. BMI = Body mass index. Sex: boys = 1.

Model	β	EE	t	p-value	95% confidence interval Lower limit	95% confidence interval Higher limit
Constant	13.365	0.898	14.875	0.000	11.604	15.127
Age	-0.157	0.008	-20.696	0.000	-0.172	-0.142
Sex	-1.142	0.028	-40.297	0.000	-1.197	-1.086
Weight	-0.011	0.007	-1.546	0.122	-0.025	0.003
Height	-0.165	0.539	-0.306	0.760	-1.222	0.892
BMI	0.009	0.020	0.434	0.664	-0.030	0.047
Waist-hip index	0.979	0.173	5.663	0.000	0.640	1.317

Table 4
4x10 m speed-agility test percentiles in adolescents based on sex, age and weight status (with focus on overweight).

Years	P_{10}	P_{20}	P_{30}	P_{40}	P_{50}	P_{60}	P_{70}	P_{80}	P_{90}	P_{100}
Normalweight girls										
12	11.8	12.0	12.3	12.6	12.8	13.1	13.4	13.7	14.4	16.7
13	11.7	12.0	12.3	12.6	12.8	13.0	13.5	13.9	14.2	16.0
14	11.5	11.9	12.3	12.5	12.8	13.0	13.4	13.7	14.4	15.7
15	11.8	12.0	12.4	12.6	12.9	13.1	13.4	13.9	14.1	15.4
16	11.6	11.9	12.2	12.5	12.6	12.9	13.3	13.6	14.0	15.2
Overweight girls										
12	12.2	12.5	12.8	13.0	13.3	13.6	13.9	14.6	15.3	16.4
13	12.1	12.3	12.5	12.9	13.2	13.7	14.3	14.8	15.2	16.8
14	12.7	12.8	13.0	13.1	13.2	13.3	13.8	14.3	14.8	15.8
15	12.2	12.5	12.8	13.0	13.0	13.4	13.7	14.4	15.0	15.5
16	12.0	12.3	12.4	12.8	13.1	13.4	13.9	14.0	14.7	15.4
Normalweight boys										
12	10.8	11.1	11.3	11.5	11.8	12.1	12.4	12.7	13.3	14.8
13	10.5	10.8	11.0	11.2	11.5	11.7	11.9	12.1	12.7	15.5
14	10.1	10.4	10.5	10.8	11.1	11.3	11.6	11.9	12.3	14.2
15	10.1	10.4	10.6	10.8	10.9	11.3	11.6	11.8	12.3	13.8
16	10.2	10.4	10.5	10.8	10.9	11.1	11.3	11.6	12.1	13.6
Overweight boys										
12	11.2	11.6	11.8	12.1	12.3	12.5	12.8	13.3	14.1	16.0
13	10.6	11.0	11.4	11.7	12.0	12.2	12.5	12.9	13.6	15.6
14	10.7	10.9	11.3	11.4	11.7	12.0	12.2	12.9	13.4	15.3
15	10.7	11.3	11.2	11.2	12.0	12.3	12.4	12.7	14.1	15.0
16	10.6	10.9	11.1	11.3	11.6	11.9	12.0	12.3	13.5	14.8

Discussion

This paper quantifies the effect size of overweight status on the results of the 4x10 m speed-agility test in adolescents and reports percentile tables based on sex, age and BMI in a relatively large sample of Spanish girls and boys aged 12 to 16. At all ages, boys attain greater speed-agility than girls in the normal-weight and overweight categories. Overweight boys and girls obtain lower values for the speed-agility test than those in the normal-weight group. Nevertheless, contrary to our hypothesis, the magnitude of the differential effect size between boys and girls is higher than that between normal-weight and overweight adolescents. Despite the above, 77.26% and 70.52% of boys and girls, respectively, in the overweight category obtain a speed-agility score lower than the average scores for normal-weight boys and girls. These results suggest that it is necessary to take BMI into account when assessing speed-agility during adolescence, in addition to sex and age.

Our findings are similar to those of other international studies examining speed-agility in adolescents from Australia (Catley & Tomkinson, 2013), Colombia (Ramos-Sepúlveda et al., 2016), Portugal (Santos et al., 2014), France (Vanhelst et al., 2016) and Spain (Ruiz et al., 2011). Most of the studies show speed-agility classifications according to sex and age and they only consider BMI as a possible modulating element of the test results (Castro-Piñero et al., 2010). Similarly to this study, the weight status (with a focus on overweight + obesity) has tended to be determined by applying the criteria of the International Obesity Task Force (Cole & Lobstein, 2012). Other studies have used the criteria of the Centers for Disease Control and Prevention (Hubbard et al., 2016), the criteria of the World Health Organization (Nhantumbo et al., 2013) or their own criteria classifications (Gajewska et al., 2015). In spite of this, to the best of the authors knowledge, there are no other researches that use BMI to create speed-agility scales adapted to overweight adolescents, or that have quantified and compared the effect size of BMI with regard to sex.

Our results reveal that seven out of ten and almost eight out of ten overweight adolescents, girls and boys respectively, attain a speed-agility equal to or less than the average for their normal-weight peers. This evidence has also been shown in the majority of studies carried out among adolescents, which point out that overweight is related to a lower performance in motor fitness (Castro-Piñero et al., 2010; Gontarev & Ruzdija, 2014; Nhantumbo et al., 2013). For example, previous researches in this line showed that the normal-weight group performed significantly better than their overweight counterparts in six running speed tests (Castro-Piñero et al., 2010). Botelho et al. (2008) showed that obese adolescents were slower in speed tests (40 m maximal sprint). For their part, Antunes et al. (2015) showed that normal-weight participants scored significantly better than their obese peers in all gross motor coordination tests –assessed by the *Körperkoordinations Test für Kinder (KTK)*–. Likewise, Carcamo-Oyarzun, Estevan & Herrmann (2020) found that overweight and obesity are negatively related to motor competences, particularly regarding the self-movement factor of the MOBAK test battery. In addition, Fogelholmm et al. (2008) showed that overweight is related to impaired performance in some tests such as speed-agility.

Only one recent study has quantified the effect size of overweight on physical fitness results in adolescents and has reported percentile tables based on sex, age and BMI. The results showed that approximately 70% of overweight adolescents obtained a muscular strength equal to or less than the normal-weight average. But, in spite of this high percentage, the differential effect size between boys and girls is still higher than between normal-weight and overweight adolescents (Martínez-López et al., 2018, 2019, 2020). Our results are in consonance with the above, and both suggest that sex is still more important than BMI; however, it is necessary to consider BMI, in addition to sex and age, in physical fitness assessment.

This research has some limitations. The cross-sectional design does not allow causal relationships. In addition, the normative values of speed-agility should be obtained from longitudinal studies that provide the possibility of evaluating natural changes in individual growth and development. However, in the absence of these data, the cross-sectional information in this study was accurately evaluated through harmonized and standardized procedures and using appropriate statistical methods. As additional data, this study found that the waist-hip index was shown to be a predictor of the 4x10m speed-agility test. We believe that this result may be the basis for future studies within this line of research.

It is concluded that the performance of approximately 74% of overweight adolescents in the 4x10 m speed-agility test is lower than that of normal-weight peers. The differential effect size magnitude is higher between boys and girls (H» 90%) than between normal-weight and overweight adolescents (H» 74%). These findings suggest that sex continues to be more important, but BMI is another important variable when we want to assess speed-agility in adolescents. The percentile values by sex, age and BMI are also reported for the 4x10 m speed-agility test in a large random sample of Spanish adolescents. These values will allow accurate and equitable assessment of speed-agility during adolescence and would allow physical education teachers and coaches to adapt the level of speed-agility tests according to BMI, in addition to sex and age.

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