Differences in Physical Fitness Between Adolescents According to Sex Adjusting by the Active Tissue Ratio

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Abstract

This study aims to analyze the differences in physical fitness between adolescents according to sex, adjusting for the active tissue ratio (ATR), computed dividing the lean and fat mass. In this way, the motor performance was evaluated considering the active (lean mass) and non-active (fat mass) body tissue. Forty-six secondary school students were evaluated using the ALPHA-Fitness battery. The raw data yielded significantly better results in boys in all tests ($p<0.001$; $d>0.8$), but when the ATR was considered (which was higher in boys by 2.66 units of active tissue; $p<0.001$), the data balanced out and even in some cases suggested better efficiency in girls. Concretely in the horizontal jump, the adjusted value in boys was 3.46 cm per unit of active tissue and in girls 3.84 cm per unit of active tissue ($p<0.001$; $r=0.55$) and in the 4x10 meters agility test, girls completed the course at 1.67 km/h more per unit of active tissue ($p<0.001$; $r=0.62$). When adjusting the data according to active tissue, physical performance among adolescents of different sexes tends to balance, and in some cases even favors girls. It would be worthwhile to analyze the causes of girls' higher adjusted performance in certain fitness variables, especially those related to lower limb strength/power.

Keywords: *adolescence, body composition, functional assessment, relative indicators, muscle-fat ratio, motor efficiency*

Introduction

Despite the methodological rigor of fitness assessment batteries, such as the Alpha Fitness Battery (Ruiz et al., 2011), many of them are based on raw performance data and do not take into account the structural differences between sexes. Classic body composition models divide total body weight into fat mass and fat-free mass. Fat-free mass contains skeletal muscle mass, visceral tissue, extracellular fluids, and bone (Visser et al., 1998), representing the principal active body tissue, useful for motion. Fat tissue has important functions such as energy storage, thermogenesis regulation, immune responses, or lactation (Colaianni et al., 2014). However, body fat does not play a direct role in movement and if there is an excess, it can be a ballast (Browning, 2012) or reduce the range of motion and mobility (Tsiros et al., 2020). Actually, body fat in children is negatively related to motor skills and physical fitness (Nobre et al., 2022; Saraiva et al., 2025). For biological reasons, girls have more fat mass than boys, especially in the gluteal and femoral area, and boys have a higher fat-free mass than girls. In this way, girls would have a lower percentage of tissue implied in motion. These structural differences explain why boys are able to develop greater peak strength. But what happens if we adjust physical test results based on body composition? In this regard, different authors have analyzed the differences in strength between young male and female athletes,

in relation to different body composition variables. For example, in some lower limb strength test no differences were found between sexes after adjusting by the lean mass (Bartolomei et al., 2021; Perez-Gomez et al., 2008).

In addition to adjusting for lean mass (active tissue) as usually done, it would be very interesting to also take into account fat mass (inactive tissue). In this regard, the lean mass-to-fat or active tissue ratio (ATR), could allow the motor efficiency to be corrected, providing a more objective perspective of relative physical performance. A person with a lower ATR, which achieves better results than another, can be considered more efficient from a functional point of view. Although the relationship between lean and fat mass has been used in clinical and metabolic studies (Ezeh et al., 2014; Gamboa-Gómez et al., 2019; Lee et al., 2018; Nishikori & Fujita, 2024; Padua et al., 2023; Xue et al., 2022) and although there are studies that consider body fat when analyzing physical performance variables in adults (Pérez et al., 2024) we haven´t find any investigation which use ATR in adolescents to normalize the physical performance results.

The present study aims to compare the performance between sexes in different physical fitness tests, adjusting according to the active tissue ratio (ATR). It is hypothesized that, the differences between female and male adolescents in physical condition will be attenuated when the results are adjusted based on the ATR.

Methods

Sample

The sample consisted of a heterogeneous sample of 46 adolescents (21 girls) with a mean age of 16.8±0.6 years (boys) and 16.19±0.56 years (girls). All the participants and their tutors were informed about the nature, risks and benefits of the study prior to any data collection and then signed an institutionally approved informed consent document. The study was accepted by the Bioethics Committee of Comillas (decision 088/24-25) and complies with the standards of the Declaration of Helsinki. Body composition data for boys and girls are presented in table 1. All the boys and girls belonged to the same class groups, so they had a similar socioeconomic status and lifestyle.

Table 1. Descriptive statistics (mean±sd) of body composition variables according to sex

Variable	Sex	
	Boys	**Girls**
Weight (kg)	67.61±10.06	57.84±9.24
Height (cm)	175.34±7.41	164.4±5.66
Bone mass (kg)	2.79±0.54	2.19±0.19
Body Water (%)	62.55±4.56	54.39±4.73
Waist circumference (cm)	76.17±4.76	70.21±6.04
Body mass index	21.92±2.36	21.34±2.72
Body Fat (%)	15.65±5.32	25.43±5.39
Lean mass (kg)	52.72±9.72	41.23±5.03

Procedures and instruments

To assess health-related physical fitness in adolescents, the Assessing Levels of Physical Activity and Fitness (Alpha-Fitness) battery was used, a tool that has proven to be reliable and safe in school settings and epidemiological studies (Ruiz et al., 2011). First, weight, height and body composition (including ATR) were measured, using a bioimpedance based scale (Tanita BC545, Tokyo, Japan) and a stadiometer (SECA 213, Hamburg, Germany). For descriptive purposes, maturity status was calculated using the formula developed by Moore et al. (2015). The ATR was calculated by dividing the fat-free (lean) mass by the fat mass. This measurement takes into account both active tissue (fat-free mass) and inactive tissue (fat mass), and has already been used in clinical and metabolic studies (Ezeh et al., 2014; Gamboa-Gómez et al., 2019; Lee et al., 2018; Nishikori & Fujita, 2024; Padua et al., 2023; Xue et al., 2022). Subsequently, jump, handgrip strength and 4x10 m agility circuit tests were performed. In the agil-

ity test the time was measured with a stopwatch (Tremblay, Gleizé, France) and results were expressed in km/h dividing the time by the total distance (40 m). In all these tests, each subject repeated the test twice and the best result was selected. Finally, cardiovascular endurance was assessed using the 20 m shuttle run test (Course Navette). The evaluator-subject ratio was one evaluator for fewer than 10 subjects, so that each evaluator could verify that the children actually crossed the line at each beep. This order of testing was followed to minimize the effects of fatigue on the results.

Statistical analysis

Statistical analysis was performed using Jamovi 2.04.14.0 software, and the significant p-value was set at p=0.05. Descriptive data were shown as mean ± standard deviation. For the statistical analysis, both the raw data from each of the physical fitness tests and the adjusted data, divided by the ATR, were used. After applying the Shapiro-Wilk normality test, the

means for boys and girls were compared using Student's t-test for independent samples and Cohen d values along with confidence intervals for effect size or the non-parametric equivalents (Mann Whitney U and biserial correlation).

Results

There were significant differences between boys and girls in the ATR (5.67±2.39 in boys vs. 3.01±0.95 in girls; p<0.001; r=-0.74) and in the maturity offset (2.50±0.66 in boys vs. 3.57±0.57 in girls; p<0.001; d=-1.75). When the raw condi-

tional results were compared, the Shapiro Wilk test showed normality in most cases. However, after applying the adjustment dividing by the ATR, there was no normality in any physical condition variable, so in these cases the Mann Whitney U test was applied (Table 2). In the unadjusted results, it was observed that boys achieve higher values (p<0.001) in all cases (Table 2; Figure 1). However, after adjusting by the ATR, the difference was reduced, and in some tests the female group performed better. This occurs specifically in the horizontal jump and in the 4x10 agility test, where the difference was significant (p<0.001) (Table 2; Figure 1).

Table 2. Means comparisons statistics of physical fitness tests without normalization and normalized by ATR

Test	Raw data					Normalized data by ATR			
	t	df	p	Cohen D (IC-95%)		U	df	p	r_bc
Right HG strength	9.77	45	<0.001	2.87	2.03-3.68	198	45	0.111	0.27
Left HG strength	8.6	45	<0.001	2.52	1.74-3.29	223	45	0.29	0.18
Horizontal jump	6.46	44	<0.001	1.91	1.2-2.61	118	44	0.001	0.55
Agility 4 x 10	6.88	41	<0.001	2.13	1.36-2.88	72	41	<0.001	0.72
Aerobic Capacity (CN)	5.62	44	<0.001	1.68	0.99-2.36	162	44	0.109	0.29

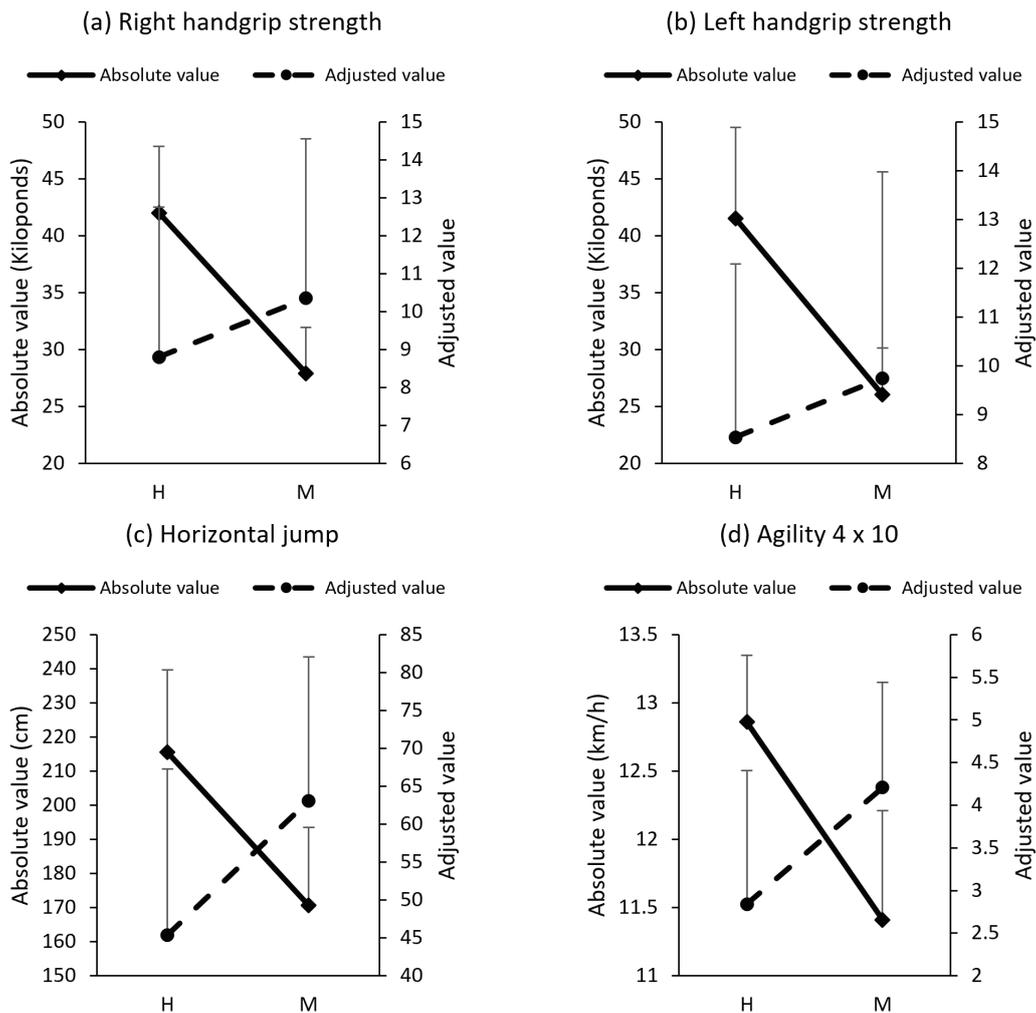*Note. r_bc biserial correlation coefficient*

Figure 1. Sexes comparison of the physical test included in the Alpha Fitness Battery, including the raw data (solid lines) and the data adjusted by the Active Tissue Ratio (ATR) (dashed lines)
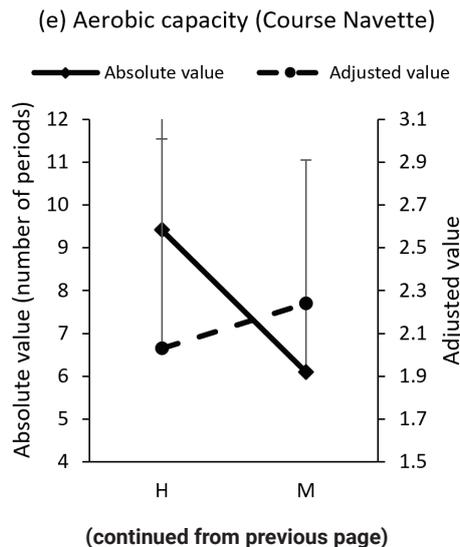
(e) Aerobic capacity (Course Navette)

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Figure 1. Sexes comparison of the physical test included in the Alpha Fitness Battery, including the raw data (solid lines) and the data adjusted by the Active Tissue Ratio (ATR) (dashed lines)

Discussion

When physical fitness data were adjusted by the ATR, the physical condition differences between boys and girls were smaller, and in the jump and agility test, girls even obtained a better adjusted value. In this discussion, some hypotheses are proposed to explain the best performance of girls after adjusting by the ATR.

In the CMJ and the 4x10 agility test, when data was adjusted using the ATR, girls achieved significantly better results, suggesting that girls are more efficient. Both tests have high coordination requirements and maybe boys included in the sample, being less mature than girls, had not yet achieved full coordinative control. On the other hand, girls reach their maximum relative leg power at around 15-16 years of age and then improve little, while boys reach their maximum relative leg power close to 18 years old (Praagh, 2000) so boys in the study still have margin for improvement in these tests where power plays an important role. On the other hand, differences in lower limb strength between adolescent boys and girls are smaller than between upper limbs, favored by a lower center of mass and a more efficient pelvic structure in the case of the girls (Wall-Scheffler, 2024). All those factors combined could cause the results to even out when adjusting by ATR. The results of the present study are consistent with those of Comfort et al. (2024), who found no differences between men and women when power data were expressed in terms of relative maximum strength. The authors point out that when attempting to compare force production capabilities between women and men, ratio scaling data should be considered essential.

The second hypothesis is based on cultural (maybe phenotypic) factors, on the application of force in everyday tasks. Unlike in primitive societies, where the division of labour between men and women was conditioned by physical strength (Wood & Eagly, 2002), in contemporary society, environmental stimuli are quite similar for both men and women. It is possible, then, that in relative terms, women have greater physical demands, considering that their muscle mass is lower. This may be more important in the case of the lower limbs, where previous studies have found smaller differences between men and women than in the case of the upper limbs (Miller et al., 1993). Locomotive tasks, such as walking or climbing stairs, in which the action of the lower limbs predominates, are conducted with roughly the same intensity intensity/volume by both sexes. Thus, girls would have greater relative training than boys, since they must develop similar strength with less muscle mass. In this regard, no studies have been found that explore this hypothesis. However, there are studies that confirm that although boys take more diary steps than girls, the effect sizes reported are small in some cases (Groffik et al., 2020). Furthermore the difference in the number of steps between boys and girls tends to decrease throughout adolescence (Beets et al., 2010; Jussila et al., 2022). Regarding daily physical activity, measured with accelerometry, there is some contradictory data that is difficult to interpret. For example, girls had significantly more light physical activity than boys between 9 and 11 years but significant between-sex differences disappeared when they have 13-15 years and boys had more moderate-to-vigorous physical activity than girls in every age group (Jussila et al., 2022). On the other hand sedentary behavior increased significantly with age, and boys were, on average, more sedentary than the girls (Jussila et al., 2022).

The data from this study differ from those of other similar studies that show differences in favour of boys, even after applying some form of standardization to the physical fitness tests. For example, Bartolomei et al. (2021) or Pérez-Gómez et al. (2008), in young athletes, after normalizing some strength data by lean mass or total mass, continue finding higher values in males. Mayhew and Salm (1990) conclude that men perform better than women in tests of strength, power, and neuromuscular activation, and that these differences remain even after adjusting for lean mass, relative leg strength, and neuromuscular activation, but to a lesser extent. These au-

thors argue that variables such as neuromuscular efficiency, running biomechanics, and technical control also influence sex differences, which are not solely due to structural factors (Pérez-Gómez et al., 2008). Given these disparities, further research should be conducted on this topic, expanding the sample size and including a more heterogeneous sample (especially with a wider age range). Considering its cross-sectional design preventing causal interpretation it would be interesting to measure physical condition variables even longitudinally in time. Another limitation of the study is that it did not include measures of motor coordination, which could perhaps have explained why, when adjusting by the ATR, the differences between boys and girls were equalized and girls even obtained better results than boys. Objective or subjective measures of children's physical activity levels (i.e., accelerometry or questionnaires) should also have been included to allow for a better understanding of the physical characteristics of the selected sample. Furthermore, the gold standard was not used to measure body composition. Although bioimpedance is a valid and reliable tool for measuring fat mass, there are other more accurate methods such as DEXA. Finally, it would be interesting to compare alternative normalization approaches, such as lean mass, muscular section or allometric scaling, included in previous research studies.

Conclusions

Teenage boys performed better in all conditional tests of the Alpha Fitness battery in absolute terms. However, when the results were adjusted based on the lean mass to fat mass ratio, the differences were reduced in handgrip strength and endurance tests. In tests involving the lower limbs (jumping and 4x10 agility), girls performed better when the data was adjusted by the ATR. It is hypothesized that girls in this study had better coordination than the boys, and that the "environmental loads" are similar for boys and girls, so girls have more trained muscles in relative terms (as they are less hypertrophied). These hypotheses should be analyzed in depth, by increasing the sample size, including precise measurements of coordination and body composition, and in longitudinal studies. Finally, ATR is suggested as a normalization measure for futures studies that aim to compare the physical condition between sexes.

Practical Applications

The ratio of active tissue could improve the interpretation of physical performance, adjusting to the structural reality of each individual and allowing the identification of differences that do not depend exclusively on sex, but on the efficiency with which active tissue is used. Several authors have discussed the importance of considering body composition when comparing fitness test results in adolescent boys and girls, and this is the first research study to consider both fat-free mass and fat-free mass. Considering that this is a simple measure, coaches, physical education teachers, or clinicians, could implement ATR in assessment protocols, as it can provide more information about mechanical efficiency than if only absolute values are provided.

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