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ORIGINAL ARTICLE

Health-related physical fitness and weight status in 13- to 15-year-old Latino adolescents. A pooled analysis☆

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KEYWORDS
20-m shuttle run;
Muscular strength;
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Weight status;
Body mass index

Abstract
Objective: The aim of this study was to investigate the relation between health-related physical fitness and weight status in 13- to 15-year-old Latino adolescents.
Method: The final sample consisted of 73,561 adolescents aged 13−15 years (35,175 girls) from Chile (n = 48,771) and Colombia (n = 24,790). Cardiorespiratory and musculoskeletal fitness were measured using 20-m shuttle run (relative peak oxygen uptake − VO_{2peak}) and standing broad jump test (lower body explosive strength), respectively. The International Obesity Task Force definition was used to define weight status (i.e., underweight, normal weight, overweight, and obese).
Results: The present study found an inverted J-shape relationship between body mass index, cardiorespiratory fitness, and musculoskeletal fitness in both genders and all age groups ($p < 0.01$). Results also suggest that underweight adolescents, and not just overweight and obese adolescents, have lower odds of having a healthy cardiorespiratory fitness (based on new international criterion-referenced standards) profile when compared with their normal weight peers, except in girls aged 14 ($p = 0.268$) and 15 years ($p = 0.280$).

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Conclusions: The present results indicate low cardiorespiratory fitness and musculoskeletal fitness levels in underweight, overweight, and obese adolescents when compared with their normal weight peers. The findings appear to suggest that exercise programs should to decrease fat mass in overweight/obese adolescents and increase muscle mass in underweight adolescents.

PALAVRAS-CHAVE
Corrida vai-e-vem de 20 metros;
Força muscular;
Aptidão aeróbica;
Status do peso;
Índice de massa corporal

Aptidão física relacionada à saúde e status do peso em adolescentes latinos de 13 a 15 anos de idade. Uma análise em conjunto

Resumo

Objetivo: Investigar a relação entre a aptidão física relacionada à saúde e o status do peso em adolescentes latinos de 13 a 15 anos.
Método: A amostra final consistiu em 73.561 adolescentes entre 13 e 15 anos (35.175 meninas) do Chile (n = 48.771) e da Colômbia (n = 24.790). As aptidões cardiorrespiratória e musculoesquelética foram medidas com a corrida vaivém de 20 m (consumo máximo de oxigênio relativo – $VO_{2máx.}$) e o teste de impulso horizontal (menor força explosiva do corpo), respectivamente. A definição Força-Tarefa Internacional de Obesidade foi usada para definir o status do peso (ou seja, abaixo do peso, peso normal, sobrepeso e obeso).
Resultados: O presente estudo encontrou uma relação na forma de J invertido entre o índice de massa corporal, a aptidão cardiorrespiratória e a aptidão musculoesquelética em ambos os sexos e em todas as faixas etárias ($p < 0,01$). Os resultados também sugerem que os adolescentes abaixo do peso e não somente os adolescentes acima do peso e obesos têm menor chance de ter um perfil de aptidão cardiorrespiratória saudável (com base em novos padrões internacionais referenciados a critério) em comparação com os pares com peso normal, exceto em meninas com idade de 14 ($p = 0,268$) e 15 anos ($p = 0,280$).
Conclusões: Nossos resultados mostram baixos níveis de aptidão cardiorrespiratória e aptidão musculoesquelética em adolescentes abaixo do peso, acima do peso e obesos em comparação aos pares com peso normal. Os achados parecem sugerir que os programas de exercícios devam ser voltados para reduzir a massa gorda em adolescentes com sobrepeso/obesos e aumentar a massa muscular em adolescentes abaixo do peso.

Introduction

Physical fitness is a good summative measure of the body's ability to perform physical activity and exercise and is widely considered to be an important indicator of good health.[1] To date, much of the literature examining the link between fitness and health has focused on cardiorespiratory fitness (CRF), which in adolescents is associated with inflammation,[2] cardiometabolic health,[3] and academic achievement.[4] Furthermore, musculoskeletal fitness (MSF) is strongly associated with mortality from all causes, including cardiovascular disease and cancer in healthy and ill adults.[5] In children and adolescents, favorable associations have been reported linking CRF and MSF to cardiometabolic disease risk, excess weight, mental health, and cognition, as well as linking MSF to bone health.[6] Direct evidence shows that low CRF and MSF in adolescence is significantly linked to all-cause mortality in adulthood.[7]

Given that the prevalence of overweight and obesity is rapidly increasing among Latin American children and adolescents,[8] there is interest in the relationship between excess weight and physical fitness. Overall, excess body fat as indicated by the body mass index (BMI) has a negative influence on physical fitness levels[9–13] or appears to be a potential covariate of physical fitness.[2] Most studies reported a linear relationship between BMI and fitness,[10,14] and several of them tested its nonlinear relationship.[12,13] Although fitness and excess weight may be correlated, they are not synonymous and indicate different disease and mortality risks. In adults, the risk of cardiovascular events and all-cause and cardiovascular mortality have been shown to be lower in aerobically fit individuals with high adiposity when compared with individuals with normal adiposity and low CRF, although some studies support the inverse conclusion.[15]

Despite the rise of excess weight, worldwide there are more underweight children and adolescents than obese.[16] However, underweight usually does not receive as much attention as overweight and obesity. Results about the relationship between underweight and fitness are inconsistent.[17] It has been reported that underweight adolescents scored better than their lean peers,[11] but in contrast, poorer fitness[9,14,18] as well as null findings[10] have been reported by others.

To the best of the authors' knowledge, only one study has examined the full BMI variability spectrum (i.e., from underweight to obesity) and physical fitness among South American adolescents.[13] This recent study showed a meaningfully large linear and nonlinear quadratic relationship between BMI and physical fitness (using the Yo-Yo test, standing long jump, seated 2-kg medicine ball throw, and 20-m dash) in Brazilian children and adolescents.[13] In the absence of other pertinent information in this population, the purpose of this study was to examine the relationship of health-related physical fitness with weight status (underweight, normal, overweight, and obese) among Latino adolescents.

Methods

Study sample and design

This study was based on secondary data analysis from two separate and independent samples drawn from two different countries that have contrasting levels of affluence, socioeconomic status, nutrition, and genetic factors, which may well explain the differences in CRF: Chile (n = 48,771; System for the Assessment of Educational Quality [Sistema de Medición de la Calidad de la Educación — SIMCE]) and Colombia (n = 24,790; Prueba SER Survey). All parents/caregivers signed an informed consent. In both cases, institutional ethics approval and written informed consent were obtained prior to data collection. The complete methodology of both studies are described in detail elsewhere.[4]

Sample 1 comprised data taken from the SIMCE test, which is a standardized fitness and anthropometric test battery for use in physical education that has been administered annually in November from 2011 to 2015 by the Chilean Ministry of Education.[19] A team of trained Ministry of Education evaluators (n = five each year) conducted the tests in schools in partnership with physical educators. Testing took place in the school gymnasium or on another available hard surface.

Sample 2 consisted of data drawn from the combined Curriculum 40 × 40 and Prueba SER surveys administered by Bogotá's District Secretary of Education in November 2015. Data were collected in schools by 20 teams of trained researchers (n = six per team). Before data collection, researchers completed six theoretical and practical training sessions to standardize the assessment process and to minimize inter-observer variability.

Procedures

The procedures used for data collection in both samples were identical and adopted the same measurement techniques. For BMI calculation, body mass was measured using digital weighing scales to the nearest 0.1 kg (Seca 769 — Hamburg, Germany), and height was measured using a stadiometer to the nearest 0.1 cm (Seca 220 – Hamburg, Germany). Weight status was classified using the International Obesity Task Force (IOTF) age- and gender-specific thresholds.[20] Anthropometric measurements were made with students barefoot and in light clothing.

CRF was measured using the 20-m shuttle run test as previously described by Leger et al.[21] Participants were asked to run back and forth between two parallel lines spaced 20 m apart, following the pace of an audio signal that began at a speed of 8.5 km/h and increased by 0.5 km/h at 1-min intervals.[21] The last completed stage was recorded with estimated relative peak oxygen uptake (VO_{2peak} in mL/kg/min).[21] VO_{2peak} was used to estimate the percentage of individuals with healthy CRF based on new international reference standards of 41.8 and 34.6 mL/kg/min for boys and girls, respectively.[22]

Lower body explosive strength, a proxy for MSF, was measured using the standing broad jump test, in which participants performed a double-leg takeoff to jump horizontally for the greatest possible distance, swinging their arms and bending their knees when preparing to take off. The best score from two correctly performed jumps was used.

Socioeconomic status

In the SIMCE, socioeconomic status (SES) was defined by school type — public, private subsidized, and private non-subsidized — based on the decentralized Chilean educational system. Familial SES is highly predictive of school type; that is, low SES families tend to send their children to public schools, middle SES families to private subsidized schools, and high SES families to private non-subsidized schools, with few exceptions.[23] In the Prueba SER, SES was characterized as low, middle, and high according to family income (i.e., parental income data).

Statistical analysis

Results are presented as mean (SD) or relative frequency (%). Differences between the genders were tested using the *t*-test or the Chi-squared test for unadjusted means or frequencies, respectively. The normality of the distribution of the variables was tested using the Kolmogorov–Smirnov test procedure. Because of their skewed distribution, the following variables were log-transformed before analysis: BMI, CRF, and MSF.

For comparison of the dependent variables, an F test was performed to verify the assumption of homogeneity of regression slopes for the interactions between the independent variable (e.g., weight status groups) and the covariates (age and gender). Because there were no interactions, linear and nonlinear analysis of covariance (ANCOVA) with polynomial contrast were used to compare the primary physical fitness variables across weight status categories. This method examines both linear and quadratic trends. Furthermore, pairwise *post hoc* hypotheses were tested using the Bonferroni correction for multiple comparisons.

The proportions of unhealthy CRF performers (%) were compared across categories of weight status. Finally, logistic regression models were employed to compare the prevalence of individuals with healthy CRF using international cutoffs[22] and weight status categories using normal weight as reference. All analyses were adjusted by country and SES, and were performed using SPSS 21 (IBM – Armonk, New York, United States). The level of statistical significance was set as $p < 0.05$.

Table 1 Sample characteristics by gender.

	Total ($n = 73{,}561$)	Boys ($n = 38{,}386$)	Girls ($n = 35{,}175$)
Country			
Chile, *n* (%)	48,771 (66.3)	26,314 (68.6)	22,457 (63.8)
Colombia, *n* (%)	24,790 (33.7)	12,072 (31.4)	12,718 (36.2)
Physical characteristics			
Age, years	14.02 (0.68)	14.04 (0.68)	13.99 (0.68)
Weight, kg	56.17 (10.45)	57.35 (10.94)	54.87 (9.72)[a]
Height, cm	160.71 (7.94)	164.34 (7.82)	156.75 (5.92)[a]
Body mass index, kg/m^2	21.72 (3.61)	21.28 (3.50)	22.31 (3.63)[b]
Underweight, *n* (%)	3033 (4.1)	1790 (4.7)	1243 (3.5)
Normal weight, *n* (%)	48,883 (66.5)	26,300 (68.5)	22,583 (64.2)
Overweight, *n* (%)	17,280 (23.5)	8,097 (21.1)	9,183 (26.1)
Obese, *n* (%)	4,365 (5.9)	2,199 (5.7)	2,166 (6.2)
Physical fitness			
Cardiorespiratory fitness,[c] speed	10.59 (1.19)	11.21 (1.10)	9.89 (0.85)[a]
Cardiorespiratory fitness, mL/kg/min	42.28 (6.71)	45.68 (6.25)	38.56 (5.01)[a]
Unhealthy, *n* (%)[c]	16,549 (22.5)	9,202 (24.0)	7,347 (20.9)[a]
Musculoskeletal fitness, cm	147.57 (32.55)	166.44 (28.12)	126.97 (23.22)[a]
Socioeconomic status			
Low, %	32,283 (43.9)	17,158 (44.7)	15,125 (43.0)
Medium, %	35,179 (47.8)	18,119 (47.2)	17,060 (48.5)
High, %	6,099 (8.3)	3,109 (8.1)	2,990 (8.5)

Values are expressed as means ± SD, except for categorical data *n* (%).
The *t*-test or Chi-squared were applied to compare unadjusted means on frequencies by gender:
[a] $p < 0.001$.
[b] $p < 0.05$.
[c] Cardiorespiratory fitness categories were computed using the cut points established by Ruiz et al.[22]

Results

Table 1 shows the demographic descriptive statistics of the adolescents. No differences were found between both samples (data not shown). The final sample had a mean age (SD) of 14.02 years (0.68) and 47.81% were girls. Girls had lower weight, height, CRF, MSF, and unhealthy CRF prevalence than boys ($p < 0.001$).

Results of the trend analysis revealed a significant positive linear ($p_{linear} < 0.001$) and quadratic trend (inverted J-shape) across weight status categories for both CRF and MSF ($p_{quadratic} < 0.01$) in all age group and genders (Fig. 1).

The Supplementary Table 1 provides the mean values of the CRF and MSF test according to weight status and gender. Significant differences in both fitness performances were found among weight status groups ($p < 0.001$). Overall, adolescents of both genders with underweight, overweight, and obesity presented better performance in both tests than their normal weight and underweight peers, except for MSF in girls in all age groups.

Fig. 2 illustrates the proportions of all adolescents (boys and girls) who had unhealthy CRF across weight status categories. Underweight adolescents had poor CRF performance more often than their normal weight peers, although the difference was weaker than the difference between normal weight and obese adolescents ($p < 0.01$).

Finally, Table 2 shows the odds ratio of the relationship between healthy CRF prevalence and weight status categories (underweight, overweight, and obese) using normal weight as a reference. Overall, regardless of age and gender, underweight, overweight, and obese adolescents have lower odds of having a healthy CRF profile (all $p < 0.001$) when compared with normal weight adolescents, except in girls aged 14 ($p = 0.268$) and 15 years ($p = 0.280$).

Discussion

The present study found an inverted J-shape relationship between BMI and physical fitness parameters (CRF and MSF) in Chilean and Colombian adolescents, but the peaks of the parabola are sharper in boys than girls. The present findings also appear to suggest that underweight adolescents, not just overweight and obese adolescents, have lower odds of having a healthy CRF profile when compared with normal weight peers. Therefore, this study provides valuable insight into health-related physical fitness across weight status categories in young South Americans, for which data are scarce.

High BMI is a factor that significantly affects the physical fitness of children, adolescents, and adults.[12] As in previous studies,[9–13] the present findings show that overweight and obese adolescents of both genders scored worse than their normal weight peers in both fitness tests, probably due to obese children require larger muscle contractions to maintain similar gait patterns[24] and therefore for propulsion or lifting of the body. It was also observed that normal

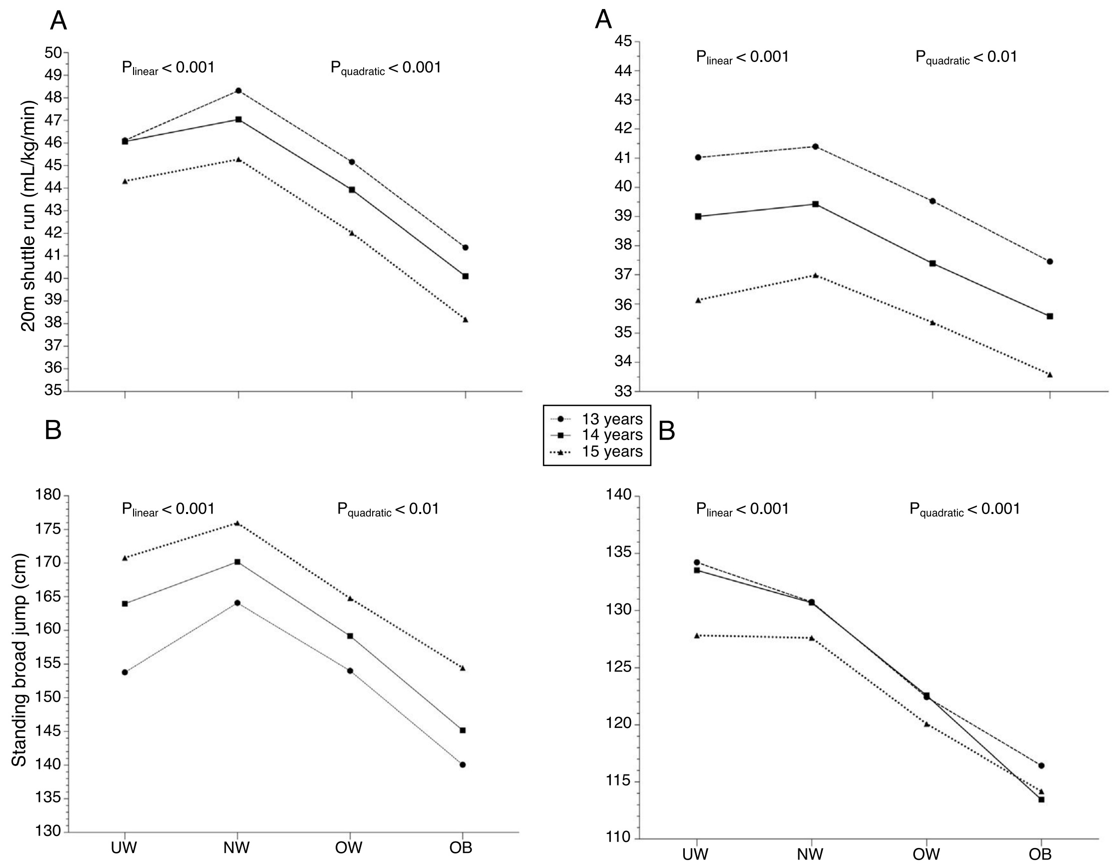

Figure 1 Associations of cardiorespiratory fitness and musculoskeletal fitness in boys (A) and girls (B) across weight status categories in adolescents. p_{linear} and $p_{quadratic}$ refer to p-values obtained from the ANCOVA analysis for linear and quadratic terms, respectively, and adjusted for country and socioeconomic status. UW, underweight; NW, normal weight; OW, overweight; OB, obese.

weight Latin American adolescents generally had better CRF and MSF than their underweight, overweight, and obese peers, in an inverted J-shape relationship (nonlinear relationship). Such an inverted J-shape association has been previously observed.[9] Another study in Brazilian children and adolescents confirmed this parabola shape in several physical fitness parameters (Yo-Yo test, standing long jump, seated 2-kg medicine ball throw, and 20-m dash).[13] Also, Huang and Malina[12] studied the relationship between BMI and fitness in 102,765 Taiwanese youth (9–18 years of age) using a quadratic regression model and found that this curvilinear relationship fits the four physical fitness components (sit and reach, standing broad jump, sit-ups, and 800/1600 m run/walk) and all age groups.

Similarly to CRF, MSF declines in a curvilinear manner with increasing BMIs in both genders and all age groups. The relationship is especially parabolic in boys aged 13–15 years, and best performances were observed in the normal weight categories. These results are consistent with other studies in Taiwanese youth[12] and Brazilian children and adolescents.[13] Excess weight probably has a negative influence on the standing broad jump due to the necessity of propelling the body (i.e., greater weight having to be moved by overweight and obese adolescents).[25] However, Artero et al.[14] stated that these differences appear to attenuate or even disappear after adjusting for body fat.

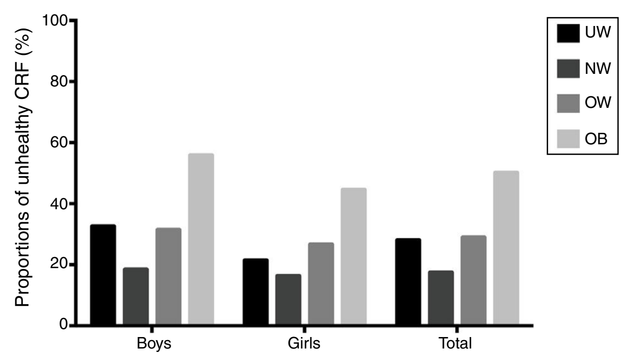

Figure 2 Proportion of adolescents with unhealthy cardiorespiratory fitness performance by body weight categories. Cardiorespiratory fitness categories were computed using the cut points established by Ruiz et al.[22] The difference between underweight, overweight, or obese *vs*. normal weight was statistically significant for both genders and the whole sample ($p < 0.01$). UW, underweight; NW, normal weight; OW, overweight; OB, obese.

As in previous research[9,13] the present study suggests significant differences between underweight and normal weight adolescents in the standing broad jump test. The study of Bovet et al.[9] reported a trend toward lower

Table 2 Odds ratio for healthy cardiorespiratory fitness for each weight status category, by age and gender.

	Boys			Girls		
	OR	95% CI	*p*	OR	95% CI	*p*
13 years						
Underweight	0.243	0.180–0.328	<0.001	0.153	0.105–0.222	<0.001
Overweight	0.373	0.331–0.421	<0.001	0.539	0.446–0.651	<0.001
Obese	0.117	0.099–0.139	<0.001	0.202	0.162–0.252	<0.001
14 years						
Underweight	0.603	0.512–0.710	<0.001	0.897	0.740–1.087	0.268
Overweight	0.393	0.361–0.428	<0.001	0.455	0.422–0.490	<0.001
Obese	0.134	0.118–0.153	<0.001	0.186	0.164–0.212	<0.001
15 years						
Underweight	0.648	0.552–0.759	<0.001	0.871	0.677–1.119	0.280
Overweight	0.342	0.302–0.387	<0.001	0.556	0.490–0.630	<0.001
Obese	0.106	0.082–0.137	<0.001	0.197	0.155–0.251	<0.001

Reference group (odds ratio = 1.0): normal-weight adolescents.
Analysis adjusted by country and socio-economic status.

performance in underweight adolescents when compared with students with normal weight for all fitness tests. As suggested by these authors,[9] the lower performance in underweight adolescents is likely to be consistent with a proportionate ratio of muscular mass to total body weight that may be less favorable in lean youths compared to average weight youths. Therefore, in an underweight population, BMI should not be interpreted only as a measure of excess weight, but rather as an indicator of muscle mass.[26] The relationship between muscular strength and risk of mortality in adulthood[5] emphasizes the importance of these findings in both underweight and overweight/obese students. In contrast, several studies showed no significant differences between underweight and normal weight students in the standing broad jump test.[10,14] Thus, it is necessary to interpret these results with caution due to differences in the studies regarding geographic characteristics, population, and criteria to establish weight status. Nevertheless, the categorization of adolescents by their BMI may have had an effect on sample size, which, as such, may have contributed to the lack of differences for the underweight category.

The findings from the 20-m shuttle run are of particular interest, as this test has been validated to assess cardiovascular fitness and could be used as a population health indicator to compare the health of children and adolescents worldwide.[3] Consistent with previous literature, the present results indicated worse outcomes in underweight individuals when compared with normal weight individuals in CRF,[9,18] but not all studies reported these differences.[10,14] In the present study, around 28.0% of the underweight adolescents presented unhealthy performance in CRF using the international cutoff,[22] which was higher than 17.4% among normal weight peers (OR = 0.243–0.648 and 0.153 in boys and girls, respectively). Furthermore, overweight and obese adolescents showed poorer CRF performance than their lean peers. Both underweight and overweight/obese adolescents have been reported to have decreased physical activity and reduced health-related physical fitness.[14] Empowering youth with this information may encourage maintenance of physical activity, the adoption of additional healthy lifestyles, and counteract the negative social stigma of their elevated adiposity.[27]

Limitations and strengths

As with any cross-sectional study, it is not possible discern the direction of the observed associations between CRF or MSF and weight status, which may indeed be reciprocal. Adolescents with healthy body composition and healthy physical fitness may be more likely to engage in physical activity, which may lead to healthier CRF and MSF and contribute to the prevention of obesity.[2] Furthermore, the maintenance of muscle mass as indicated by healthy MSF can contribute to a higher resting metabolic rate and, consequently, have a preventive effect on fat mass accumulation.[28] A second limitation is the potential for unmeasured confounding.

Conversely, the decision to categorize CRF according to health predictive value instead of using continuous variables can be considered a strength of the study, as it allowed greater public health interpretability.[22] A final strength of the study is its large sample size, allowing the analysis to meaningfully explore various cross-categories of fitness and weight status at the population level to better characterize Latino adolescents.

In conclusion, the present large study found an inverted J-shape relationship between BMI, CRF, and MSF in Latino adolescents aged 13–15 years. Results also suggest that underweight adolescents, not just overweight and obese adolescents, have lower odds of having a healthy CRF profile when compared with their normal weight peers. Locally, it provides Chilean and Colombian policymakers a nuanced understanding of the cardiometabolic health risk status of their adolescent population in the school setting.

Considering the present results together with the abovementioned studies, The present findings appear to suggest that intervention programs should be directed on decreasing fat mass for overweight/obese adolescents and increasing muscle mass for underweight adolescents. Studies have suggested that concurrent exercise training may increase muscle mass in lean subjects[29] and reduce fat mass in overweight/obese youths,[30] suggesting this approach as a possible intervention.

Conflicts of interest

The authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jped.2018.04.002.

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