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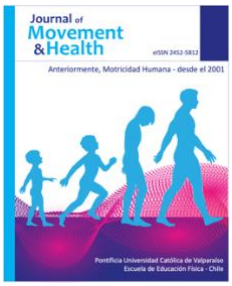

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Original article

Metabolically healthy versus unhealthy obesity in adolescents: is there a difference in cardiorespiratory fitness, physical activity, and active commuting?

Obesidad metabólicamente saludable *versus* no saludable en adolescentes: ¿existe una diferencia en la aptitud cardiorrespiratoria, la actividad física y los desplazamientos activos?

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Abstract

Aim: To identify the relationship between physical activity, cardiorespiratory fitness (CRF), and active commuting in adolescents with metabolically healthy obesity (MHO) and metabolically unhealthy obesity (MUO). **Methods:** This cross-sectional study included 274 adolescents from schools in Southern Brazil. Body mass index, waist circumference, blood pressure, and lipid profile were evaluated. The 6-minute run/walk test was used to determine CRF. Physical activity, active commuting, and stretching/muscle strength were assessed using a self-report questionnaire. MHO was defined as the presence of overweight/obesity and up to one cardiometabolic risk factor, while MUO was defined as overweight/obesity plus at least two of these risk factors. Poisson regression analyses were used and adjusted for sex, age, skin color, living area and maturational stage. **Results:** The MUO profile was observed in 47.5% of the boys and 55.6% of the girls. Low levels of CRF (crude: PR=1.19, 95%CI= 1.07-1.32; adjusted: PR=1.17, 95%CI=1.05-1.31) and passive commuting (crude: PR=1.08, 95%CI=1.00-1.17; adjusted: PR=1.09, 95%CI=1.01-1.18) were associated with the MUO group. **Conclusions:** MUO adolescents presented lower levels of CRF and passive commuting than their MHO counterparts.

Keywords: metabolic syndrome; cardiorespiratory fitness; exercise; adolescent

Resumen

Objetivo: identificar la relación entre actividad física, aptitud cardiorrespiratoria (ACR) y desplazamiento activo en adolescentes con obesidad metabólicamente saludable (OMS) y obesidad metabólicamente no saludable (OMN). **Métodos**: estudio transversal realizado con 274 adolescentes de escuelas del sur de Brasil. Se evaluaron el índice de masa corporal, la circunferencia de la cintura, la presión arterial y el perfil lipídico. La prueba de carrera/caminata de 6 minutos determinó la ACR. La actividad física, el desplazamiento activo y el estiramiento/fortaleza muscular se evaluaron mediante un cuestionario autoinformado. Consideramos OMS como la presencia de sobrepeso/obesidad y hasta un factor de riesgo cardiometabólico, y OMN como sobrepeso/obesidad más al menos dos de estos factores de riesgo. Se utilizaron análisis de regresión de Poisson, ajustados por sexo, edad, color de piel, área de residencia y estadio de maduración (Tanner). **Resultados**: El perfil OMN se observó en un 47,5% de los adolescentes varones y un 55,6% de las adolescentes mujeres. Los niveles bajos de ACR (Bruto: RP=1,19, IC del 95%=1,07-1,32; ajustado: RP=1,17, IC95%=1,05-1,31) y el desplazamiento pasivo (Bruto: RP=1,08, IC del 95%=1,00-1,17; ajustado: RP=1,09, IC95%=1,01-1,18) se asociaron con el grupo OMN. **Conclusiones:** Los adolescentes con OMN presentaron niveles más bajos de ACR y desplazamiento inactivo en comparación con sus contrapartes con OMS.

Palabras clave: síndrome metabólico; aptitud cardiorrespiratoria; ejercicio; adolescente

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Key Points

- Lifestyle and cardiorespiratory fitness in metabolically healthy versus unhealthy obesity was investigated.
- A metabolically unhealthy profile was observed in 47.5% of boys and 55.6% of girls.
- Cardiorespiratory fitness and passive commuting were associated with the MUO group.
- Lifestyle habits and physical fitness are related to less favorable metabolic health.

Introduction

Obesity is associated with a high risk of metabolic and cardiovascular changes. In recent years, there has been a significant increase in studies involving individuals with metabolically healthy obesity (MHO), which suggests that excess fat storage is not the only determinant risk factor for the development of metabolic disorders [1,2].

The presence of MHO has been observed in 21.5% to 31.5% of children and adolescents aged 8 to 17 years with a body mass index (BMI) above the 87th percentile. Thus, one in three children may present MHO, depending on their lifestyle and body fat. Moreover, the prevalence of MHO is higher in females, ranging from 7% to 28%, compared to 2% to 19% in males [3,4]. Muñoz-Garach establishes that MHO is only the absence of metabolic and cardiovascular alterations, without considering orthopedic problems, pulmonary complications, and other physiological conditions associated with higher BMI, especially in obese individuals [5].

In this sense, an active lifestyle and high levels of physical fitness have been associated with maintaining a healthy metabolism [6,7]. It's observed that physical activity (PA) and cardiorespiratory fitness (CRF) seem to interfere in the metabolically healthy and unhealthy profile of children and adolescents, in which physically active adolescents but with sedentary behavior are more likely to present cardiometabolic alterations [8]. Also, the literature indicates that individuals who are more active [9–11] and those with higher CRF levels are often associated with MHO [9–12]. Another lifestyle factor connected to metabolic health is active commuting, in which the adolescents that present this behavior have better physical fitness levels and lower cardiometabolic risk factors [13]. In addition, it has been observed that engaging in active commuting is associated with MHO [14]. Active commuting appears to have a positive impact on the health of children and adolescents, contributing to increased PA levels[13,15]. Indeed, studies highlight the importance of active commuting as a strategic public policy to promote an active lifestyle [16,17].

Despite the importance of maintaining high physical fitness levels as a predictor of a healthier metabolic profile, few studies seek to investigate the relationship with the MHO standard [6]. It is crucial to comprehend how lifestyle habits, particularly active commuting, may be associated with MHO and metabolically unhealthy obesity (MUO) among children and adolescents. This area remains under-researched in the literature, especially concerning South American schoolchildren. The hypothesis is that PA and CRF may play a protective role against the development of these phenotypes. Understanding these associations is vital for designing interventions aimed at reducing metabolic complications and their long-term effects. Consequently, this study seeks to investigate the relationship between PA, CRF, and active commuting with MHO and MUO in adolescents. Therefore, this study aims to identify the relationship between PA, CRF, and active commuting with MHO and MUO in adolescents.

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Methods

Population

The participants of this cross-sectional study were selected from 25 public and private schools in the rural and urban areas of a city in southern Brazil. The data from the students evaluated are part of "Health of Schoolchildren - phase IV" research, carried out between 2016 and 2017, which included 2594 students aged six to 17 years. The sample calculation was based on the estimated prevalence of overweight and obesity among the students, assuming that a maximum of 50% would have MHO and MUO. The error considered was 5%, with a 95% confidence interval, resulting in a required sample of 197 students.

The inclusion criteria included parental/guardians' consent and informed assent by the adolescent, being aged between 12 and 17 years, and presenting a BMI between overweight (≥85th percentile) and obesity (≥97th percentile). Students who did not agree with blood and urine collection and those who did not participate/complete the 6-minute run/walk test, or who had not completed the lifestyle questionnaire were excluded. At the end of the application of the inclusion and exclusion criteria, a total of 274 adolescents were included in the study (Figure 1).

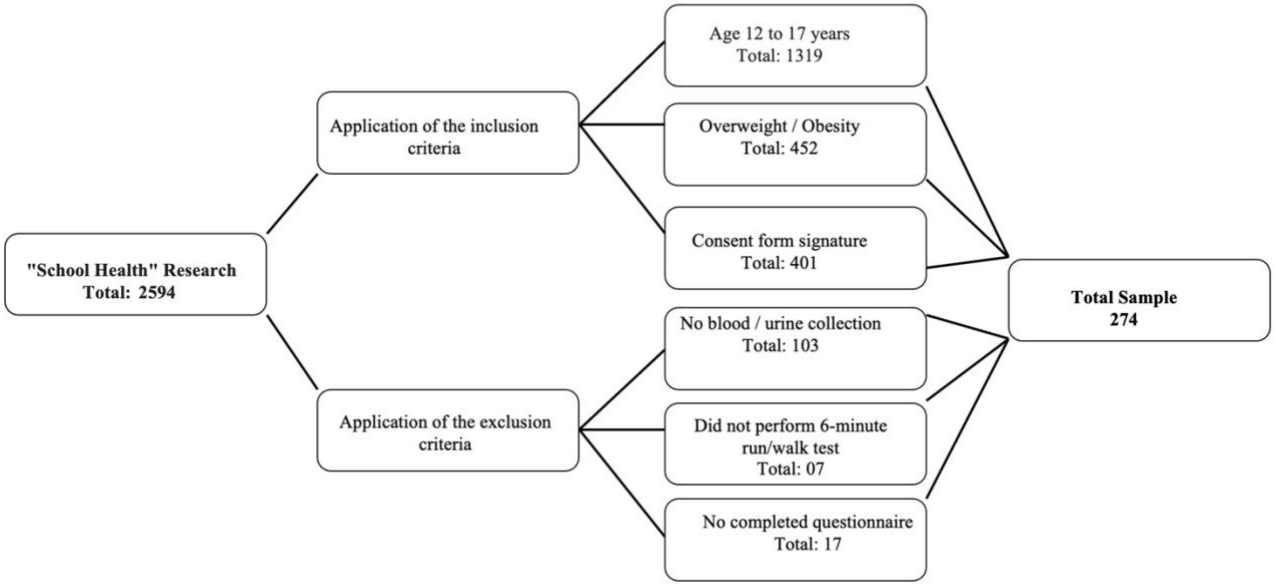

Figure 1. Selection flowchart of participating subjects

Ethical Considerations

This study was conducted at the University of Santa Cruz do Sul (UNISC) and was approved by the Ethics Committee (nº: 1.498.305). The parents or guardians signed the consent form and the students signed the informed assent agreement to participate in the study.

Data collection

BMI was used for nutritional status evaluation. The World Health Organization (2007) percentile curves were used to classify BMI by age and sex, being overweight (percentile ≥85), and obesity (percentile ≥ p97) [18]. Waist circumference (WC) was classified according to Fernández et al.[19],

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considering abdominal obesity> 75th percentile, according to age and sex, being measured in the narrower part of the trunk between the ribs and the iliac crest (Cardiomed ®, Brazil). Blood pressure (BP) was measured using a sphygmomanometer and a stethoscope (Premium ®, China). The adolescents were instructed to rest for five minutes before the evaluation. It was classified according to the percentiles suggested by the VII Brazilian Society of Cardiology, Hypertension and Nephrology Guidelines, considering 90th and 95th percentiles for borderline and hypertension, respectively [20].

For CRF assessment, the 6-minute run/walk test was used, which involved running or walking as many laps as possible on a sports court. The number of laps completed, plus the additional distance achieved by adolescents unable to complete a full lap at the end of the test, were calculated. The estimation of CRF was obtained by multiplying the number of laps by the length of one lap. The results were categorized into a health zone (equal to or above the cutoff point) and a risk zone (below the cutoff point), taking sex and age into account, according to the cutoff points established by Projeto Esporte Brasil - PROESP-BR [21].

PA, active commuting and stretching/muscle strength were assessed according to an adaptation of Nahas, Barros, and Francalacci's "Well-being pentacle" [22]. The questionnaire was self-reported by the students, containing three questions related to the practice of PA, considering: 1) practice of 30 minutes of moderate-intense PA, five or more days a week; 2) performing, twice a week, stretching exercises and muscular strength, and 3) walking/ cycling on a day-to-day basis as a means of transportation.

The lipid profile was assessed based on serum high-density lipoprotein cholesterol (HDL-c), considering normal values (>50 mg/dL), and triglycerides (TG) (<100 mg/dL). Glucose values were considered normal up to 110 mg/dL. Lipid and glycemic profiles were collected in the morning after a previous 12-hour fast. All dosages were performed after a previous 12-hour fast in the Miura One automated equipment (I.S.E., Rome, Italy) using commercial DiaSys kits (DiaSys Diagnostic Systems, Germany), and were classified according to Ferranti et al. [23], for evaluation of metabolic syndrome (MetS).

Pubertal maturation was determined according to Tanner´s criteria. The evaluator explained the pictures with the different stages, and the adolescents indicated the picture according to their current stage, considering genital development for boys), breast development for girls, and pubic hair for both. Thus, five stages of sexual maturation were considered: prepubertal (stage I), initial development (stage II), continuous maturation (stages III and IV), and matured (stage V) [24]. Skin color was evaluated by a self-reported questionnaire, in which the adolescents should indicate their skin color according to the following options: White, black, brown/mulatto, indigenous or yellow. These options were then recategorized into two categories: White and Non-white (including black, brown/mulatto, indigenous, or yellow in this category).

Obesity Metabolically Healthy and Metabolically Unhealthy Classification

For MHO, the presence of overweight/obesity was used, up to one risk factor for MetS and two or more factors for MUO [25,26]. For BMI values, the classification of the World Health Organization was used [18]. For MetS it was considered an adaptation of Ferranti et al. 2004 from the National Cholesterol Education Program Adult Treatment Panel (NCEP-ATPIII) [23]. Figure 2 shows the cut-off points established for MetS.

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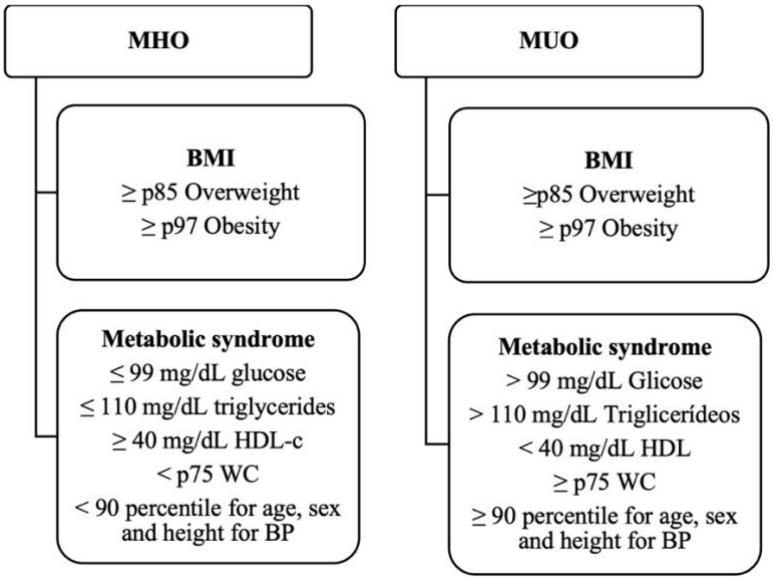

Figure 2. Cut-off points for MHO and MUO.
MUO: metabolically unhealthy obesity; MHO: metabolically healthy obesity; BMI: body mass index; HDL-c: High-density lipoprotein cholesterol; WC: waist circumference; BP: blood pressure.

Statistical analysis

Frequency and percentage were used to describe the variables. The Poisson regression test was crude and adjusted for sex, age, skin color, living area and maturational stage and the chi-square test for comparison between MHO and MUO students was applied. Data were expressed as prevalence ratio (PR) and 95% confidence intervals (95%CI). The probability value $p < 0.05$ was considered to be significant for all analyses. The analyses were performed in the Statistical Package for the Social Sciences (SPSS), version 23.0 (IBM, Armonk, NY, USA).

Results

Table 1 shows the descriptive characteristics of the adolescents. The majority of MUO adolescents were obese (68.1%), were in the risk zone for CRF (87.9%) and reported a high prevalence of passive commuting (59.6%). In addition, the MUO group presented a higher prevalence of WC (74.5%), HDL-C (66.7%), triglycerides (39.0%), systolic blood pressure (SBP) (44.0%) and diastolic blood pressure (DBP) (62.4%) altered, compared to the MHO group. Also, the MUO group presented a higher prevalence of low CRF levels (87.9%) and passive commuting (59.6%) compared to the MHO group. The mean age for boys was 13.64 ± 1.47, and for girls was 13.56 ± 1.38 (data not presented in the table).

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Table 1. Descriptive characteristics of adolescents

	Overall	MHO	MUO
	n (%)	n (%)	n (%)
Sex			
Male	133 (48.5)	73 (54.9)	66 (46.8)
Female	141 (51.5)	60 (45.1)	75 (53.2)
Skin color			
White	207 (76.4)	98 (74.2)	109 (78.4)
Non-white	64 (23.6)	34 (25.8)	30 (21.6)
Living area			
Urban	239 (87.2)	122 (91.7)	117 (83.0)*
Rural	35 (12.8)	11 (8.3)	24 (17.0)
Maturational stage			
Pre-pubertal (I)	7 (2.6)	1 (0.8)	6 (4.3)
Initial development (II)	32 (11.7)	20 (15.0)	12 (8.5)
Continuous maturation (III and IV)	193 (70.4)	91 (68.4)	102 (72.4)
Maturing (V)	42 (15.3)	21 (15.8)	21 (14.9)
Cardiorespiratory fitness			
Healthy zone	220 (80.3)	37 (27.8)	17 (12.1)*
Risk zone	54 (19.7)	96 (72.2)	124 (87.9)
Stretching and muscle strength			
Almost/Always	136 (49.6)	65 (48.9)	70 (49.9)
Never/Sometimes	138 (50.4)	68 (51.1)	71 (54.4)
Moderate/vigorous physical activity			
Never/Sometimes	158 (57.7)	72 (54.1)	86 (61.0)
Almost/Always	116 (42.3)	61 (45.9)	55 (39.0)
Active commuting			
Never/Sometimes	147 (53.6)	63 (47.4)	84 (59.6)*
Almost/Always	127 (46.4)	70 (52.6)	57 (40.4)
BMI			
Overweight	132 (48.2)	87 (65.4)	45 (31.9)*
Obesity	142 (51.8)	46 (34.6)	96 (68.1)
WC			
Normal	135 (49.3)	99 (74.4)	36 (25.5)*
Elevated	139 (50.7)	34 (26.6)	105 (74.5)
HDL-C			
Normal	157 (57.3)	110 (82.7)	47 (33.3)*
Altered	117 (42.7)	23 (17.3)	94 (66.7)
Triglycerides			
Normal	219 (79.9)	133 (100.0)	86 (61.0)*
Altered	55 (20.1)	0 (0.0)	55 (39.0)
Glucose			
Normal	274 (100.0)	133 (100.0)	141 (100.0)
Altered	0 (0.0)	0 (0.0)	0 (0.0)
SBP			
Normotensive	195 (71.2)	116 (87.2)	79 (56.0)*
Hypertensive	79 (28.8)	17 (12.8)	62 (44.0)
DBP			
Normotensive	155 (55.1)	98 (73.7)	53 (37.6)*
Hypertensive	123 (44.9)	35 (26.3)	88 (62.4)

MUO: *metabolically unhealthy obesity*; MHO: *metabolically healthy obesity*; BMI: body mass index; WC. Waist circumference; HDL-C: high-density lipoprotein cholesterol; SBP: Systolic blood pressure; DBP: Diastolic blood pressure.
* Indicates a statistically significant difference between MHO and MUO.

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Table 2 presents CRF, PA, and active commuting related to metabolically unhealthy obesity. Results indicated that low levels of CRF (Crude: PR=1.19, 95%CI= 1.07-1.32; adjusted: PR=1.17, 95%CI=1.05-1.31) and passive commuting (Crude: PR=1.08, 95%CI=1.00-1.17; adjusted: PR=1.09, 95%CI=1.01-1.18) were associated with the MUO group. PA was not associated with the MUO group.

Table 2. Cardiorespiratory fitness, physical activity, and active commuting related to metabolically unhealthy obesity.

	MUO*			
	PR (95% CI) Crude	**p**	**PR (95% CI) Adjusted**	**p**
Cardiorespiratory fitness				
Healthy zone	1		1	
Risk zone	1.19 (1.07-1.32)	0.001	1.17 (1.05-1.31)	0.004
Moderate/vigorous physical activity				
Almost/Always	1		1	
Never/sometimes	1.05 (0.97-1.13)	0.252	1.04 (0.96-1.13)	0.289
Stretching and muscle strength				
Almost/Always	1		1	
Never/sometimes	1.01 (0.93-1.09)	0.806	1.01 (0.93-1.09)	0.810
Active commuting				
Almost/Always	1		1	
Never/sometimes	1.08 (1.00-1.17)	0.042	1.09 (1.01-1.18)	0.025

Poisson regression; adjusted for sex, age, skin color, living area and maturational stage; *versus MHO; PR: prevalence ratio; CI: 95% confidence interval; MUO: metabolically unhealthy obesity; MHO: metabolically healthy obesity.

Discussion

The main findings of the present study indicate that adolescents with low CRF levels, classified in the risk zone, and with passive commuting presented a higher prevalence in the MUO metabolic group (17% and 9%, respectively), indicating that lifestyle aspects and physical fitness could be related to a less favorable metabolic health. Thus, monitoring these lifestyle factors is crucial for enhancing metabolic health and decreasing the likelihood of developing multiple health issues in adulthood[27,28].

CRF is considered an important health indicator in youth [29], and different studies have indicated its positive impact on metabolic health [30,31]. Indeed, our data demonstrated that low CRF was associated with the MUO group. The literature regarding this topic is still contradictory, while Cadenas-Sanchez et al. [9] showed that CRF (measured by a 20-m shuttle run test) did not differ between MHO and MUO adolescents, Lee & Arslanian [12] indicated that the MHO phenotype is associated with high CRF (evaluated by a treadmill test). These discrepancies may be explained by the different methods used to evaluate CRF, and also the criteria used to the definitions of MHO. Also, while the MHO phenotype does not appear to be a protective factor against the progression to MUO or cardiovascular diseases, this link could be mitigated by higher levels of CRF[32].

A meta-analysis by Ortega et al. [11], pointed out that MHO individuals were more active, had less sedentary time, and had a higher level of CRF than subjects with MUO, suggesting that the healthier metabolic profile could be, at least in part, due to healthier lifestyle factors. Moon et al. [33] found that sedentary MHO subjects had an increased risk of cardiovascular diseases compared to physically active metabolically healthy non-obese (MHNO) participants, while physically active MHO participants did not present the same risk. In addition, moderate to vigorous PA levels seem to be higher in MHO than in MUO adolescents [9]. Surprisingly, in our data, physical inactivity was not associated with the MUO profile.

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Although there is evidence that PA level is not associated with MHO [34], we highlight that our findings should be cautiously interpreted due to the reliance on self-reported PA, through questionnaires.

In adolescents, several aspects have been described as determinants of a healthy lifestyle, including active commuting. This behavior is associated with a healthier lipid profile, a lower prevalence of metabolic syndrome, as well as better physical fitness [13,15]. Regarding the MHO and MUO phenotypes, active commuting has been poorly investigated. Thus, our data brings an important contribution indicating that passive commuting is associated with the MUO profile in adolescents. There is evidence that active commuting (walking or cycling to school) increases the odds of children being MHO [14], although more studies are needed to confirm this hypothesis. Active commuting is a simple way of increasing PA levels and should be incorporated into the adolescent's routine due to the health benefits related.

Lifestyle intervention activities have been shown to play a significant role for the MUO group, but in MHO subjects, the effects focused only on weight loss [35]. In this sense, it is observed that individuals with different metabolic phenotypes of obesity are benefited from the intervention program [36,37]. Thus, health promotion and preventive actions should focus on an active lifestyle [37], especially encouraging the children and adolescent population to actively commute and increase CRF levels, which seem to influence the presence of MUO and cardiometabolic alterations.

Our study makes important contributions when evaluating two groups of obese adolescents with different metabolic profiles. These data are scarce in the Brazilian youth population. We emphasize that adolescents who present excess body fat, still without metabolic alterations, should be seen as an "at-risk" population. MHO should not be considered a harmless condition. Also, the study that addresses this topic in the pediatric population is still lacking, mainly regarding active commuting. Our study also has limitations, which should be highlighted. Although the maturational stage has been evaluated, the age group may interfere with the results obtained since the Tanner instrument is not the best evaluation criterion for the pubertal stage. The use of self-reported questionnaires to evaluate PA may underestimate or super estimate PA levels. Considering that this study is cross-sectional, it is suggested that a follow-up focusing on this population be carried out.

Conclusion

Adolescents with the MUO profile demonstrate low CRF levels and passive commuting compared to MHO adolescents. These findings emphasize the need for public health strategies to increase positive lifestyle behavior habits early in life. As practical recommendations, we reinforce the relevance of moderate to vigorous PA practice and encourage active commuting to increase CRF levels and, consequently, achieve benefits for metabolic health.

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