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ORIGINAL ARTICLE

Associations of higher TV viewing and low levels of cardiorespiratory fitness with cardiometabolic risk in children and adolescents

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Abstract

Background A higher cardiometabolic risk has been associated with low cardiorespiratory fitness (CRF) levels and sedentary behaviours. However, most studies have focused predominantly on isolated behavioural, or CRF exposures.

Aim The present study aimed to evaluate the joint association of self-reported, sedentary TV viewing and CRF with cardio-metabolic risk in schoolchildren.

Methods Cross-sectional study with 2152 students (6–17 years old) from southern Brazil. Self-reported TV viewing and CRF were combined into a lifestyle-related exposure variable. Waist circumference, systolic blood pressure, glucose, and blood lipoprotein–lipids were determined and a clustered cardio-metabolic risk score (cCRS) was derived using internationally age and sex standardized *Z*-scores.

Results In boys and girls, the median values of cCRS were significantly ($p < 0.05$) higher among those with unfit levels of CRF, independent of TV viewing. The higher cardio-metabolic risk status was 18.0% more prevalent in participants classified as unfit, regardless of TV viewing. However, the higher cCRS associated with poor fitness was attenuated following adjustments for the confounding effect of adiposity, pubertal status, and sociodemographic factors.

Conclusion A higher cCRS prevalence was associated with low CRF levels, regardless of TV viewing. The association between higher CRF and the cardio-metabolic risk appeared to be attenuated by confounders, particularly adiposity.

Keywords Adolescent · Cardiorespiratory fitness · Child · Metabolic syndrome · Sedentary behavior

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Introduction

In the last few years, accumulating evidence has shown adverse levels of cardio-metabolic risk factors and cardio-metabolic clustering in schoolchildren, especially associated with higher levels of adiposity [1, 2]. An unhealthy cardio-metabolic profile in childhood and adolescence can reduce life expectancy and increase the risk of Type 2 diabetes and cardiovascular diseases [3]. The identification of evolving cardio-metabolic risk factors from early childhood appears crucial to promote changes in lifestyle and behavioural habits that may prevent the development of premature cardio-metabolic disorders [4, 5].

The literature also shows the preventive role of higher levels of moderate-to-vigorous-intensity physical activities (MVPA), and its arguably more objective biomarker cardiorespiratory fitness (CRF), in the reduction of these risk factors and cardio-metabolic clustering throughout childhood and adolescence [1, 6–10]. Despite the fact that physical activity (PA) and CRF are important indicators of health risk [11, 12], some authors caution that the adoption of prolonged sedentary behaviours (SB) of screen time (ST), especially the passive time in front of a TV further increases the propensity to develop cardio-metabolic abnormalities [13, 14]. Within the population-based, European Youth Heart Study (EYHS), amongst 9- to 10- and 15- to 16-year-old boys and girls from three regions of Europe, Ekelund et al. [15] showed significant separate and independent associations between both CRF and time spent in SB with clustered cardiometabolic risk scores (cCRS). Within separate reports from this cohort, the associations observed for both CRF (maximal cycle work capacity) and TV viewing (hours per day) with cCRS appeared partly mediated, or confounded by adiposity. However, the main study findings did not appear to be influenced by sex, or age group.

Andaki et al. [16] reported that SB (ST > 2 h/day) was positively associated with the metabolic syndrome (MetS) in younger (6–10 years) schoolchildren. Furthermore, findings from the nationwide, school-based Study of Cardiovascular Risk in Adolescents (ERICA), conducted in over 30,000 Brazilian adolescents, showed a dose–response association between total self-reported ST and MetS prevalence, even following adjustment for PA and total energy intake [17]. However, MetS definition has no consensus for childhood and youth populations, and its different diagnostic criteria are not concordant [18]. From this perspective, the use of cCRS variables seems to provide a better measure on MetS risk amongst children and adolescents [1].

The undertaking of regular PA, especially MVPA and less time spent in SB during childhood and adolescence are factors that are strongly associated with the reduction of cardiometabolic risk [13, 19, 20]. Within recent large observational studies from different regions of Brazil, investigators have reported that 50–80% of Brazilian adolescents, particularly females, were classified as minimally physically active, and over 70–80% of adolescents self-reported over 2 h daily on sedentary screen-based devices [21–23]. Cross-sectional findings emphasized increasing total PA and decreasing ST and other SB to reduce cardio-metabolic risk among children aged 6–8 years [24]. Likewise, the combined effect of PA and SB with cCRS was reported within a large sub-sample from the Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA) study [25]. Therefore, one can assume that the development of cardio-metabolic risk is higher when children and adolescents have concurrent low levels of CRF and high levels of SB [26], especially TV viewing. Despite these statements, few studies have actually demonstrated the relationship between ST and CRF with the presence of cardio-metabolic risk (defined by higher cCRS) [27], especially stratified by sex. From this perspective, it is necessary to understand the combined mechanisms of behaviours associated with the presence of cardio-metabolic risk at this stage of life [28]. The present study aimed to evaluate the association between self-reported TV viewing/measured CRF and cardio-metabolic risk in a representative, cross-sectional sample of southern Brazilian boys and girls.

Methods

This was a cross-sectional study using a sample composed of 2152 children and adolescents (927 males), aged 6–17 years, from public and private schools of Santa Cruz do Sul, Rio Grande do Sul, Brazil. The samples were derived predominately from the public school network, stratified by location and from urban and rural areas (Fig. 1). The G*Power 3.1 program (Heinrich-Heine-Universität -Düsseldorf, Germany) was used to calculate the required sample size. Based on the Poisson regression, we used the following parameters to achieve 85% statistical power: a one-tailed outcome (presence versus absence of cardio-metabolic risk); a relative rate of $\text{Exp}(\beta) = 1.15$; the significance level of $\alpha = 0.05$; a base rate estimation of 0.85; and X was assumed to be binomially distributed with $\pi = 0.25$ (equal numbers of participants for each group). The established sample was 2138 participants.

The TV viewing level was measured by self-report using an adapted questionnaire [29]. The participants reported how much time they spent per day in front of the TV. The estimate of CRF followed the six-minute running and walking test established by the Projeto Esporte Brasil [30] and subsequent conversion into peak oxygen uptake (VO_{2peak}) with the following equation: 6-min test → $VO_{2peak} = 41.946 + 0.022 \times (\text{test}) - 0.875 \times (\text{BMI}) + 2.107 \times (\text{sex})$; [31] where test is the value of meters performed by the adolescent; BMI is the body mass index; and *sex* equals to 1 and 0 for boys and girls, respectively. The test was performed on athletics track and the schoolchildren were instructed to run as long as possible during six minutes with subsequent quantification of the total distance covered by the participant. The upper tertile of TV viewing in minutes was considered as high TV viewing (across most age groups in both sexes, the upper tertile corresponded to two hours of TV viewing) and the lower tertile of CRF was considered as unfit. The tertiles were defined according to age and sex. Subsequently, the measures of TV viewing and CRF were unified into a single categorical variable and classified as low TV/fit, low TV/unfit, high TV/fit or high TV/unfit.

The skin color was self-reported by the participants using a questionnaire. The pubertal status assessment was also performed via self-evaluation questions, in which the participant filled the image corresponding to their current pubertal status considering genital and pubic hair [32]. Five stages of pubertal status for each sex were presented according to Tanner's criteria: prepubertal (stage I), initial development

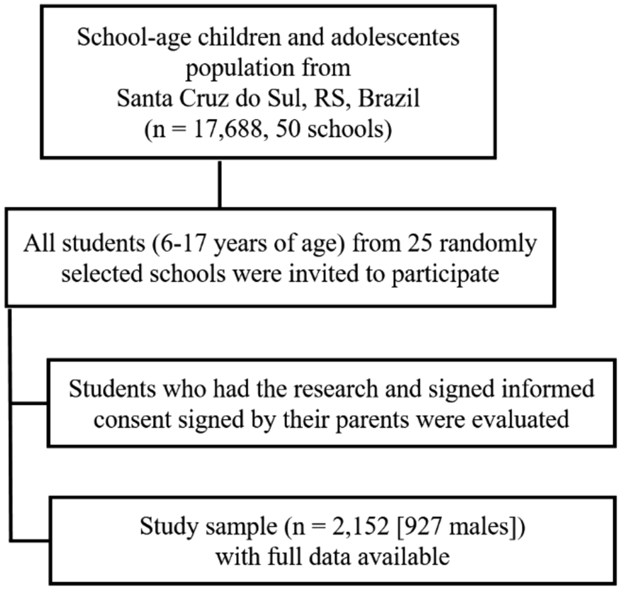

Fig. 1 Study design and sampling

(stage II), continuous maturation (stages III and IV), and matured (stage V). The body mass index (BMI) was calculated by the ratio between body mass in kilograms and the height squared in meters (weight/[height]^2) and classified into normal weight, overweight, or obesity according to the cutoff points for children and adolescents [33]. Levels of fasting (12 h) glucose, triglycerides, total cholesterol (TC), and high-density lipoprotein cholesterol (HDL-C) were carried out utilizing automated equipment Miura 200 (I.S.E., Rome, Italy) using commercial DiaSys (DiaSysDiagnostic Systems, Germany) kits. The systolic blood pressure (SBP) was measured with the students sitting a rest, using a sphygmomanometer (B-D®, aneroid, Germany) with cuff suitable for the student's arm circumference and stethoscope (Premium, Rappaport, China), in accordance with guidelines for blood pressure (BP) measurement in children and adolescents [34]. The waist circumference (WC) was evaluated using a plastic tape measure, using as reference the narrowest part between the ribs and the iliac crest [35].

The cCRS was calculated using standardized values (*Z*-scores) for each continuous cardio-metabolic variable, namely glucose, SBP, TC/HDL-C ratio, triglycerides, and WC. The *Z*-score of each variable was calculated using the following formula: $Z\text{-score} = (X_{\text{Brazilian}} - X_{\text{International reference}})/\text{SD}_{\text{International reference}}$, according to age and sex-specific international reference values calculated from regression equations [36]. All *Z*-scores were summed and divided by five. The cCRS values higher than 0.85 standard deviations were considered as indicating higher cardiometabolic risk [1].

The Statistical Package for the Social Sciences (SPPS) software version 23.0 (IBM, Armonk, NY) was used for statistical analysis. The Shapiro–Wilk test was used to test data normality. A descriptive analysis was performed to describe the participants. Data were expressed as median (interquartile range) for continuous variables or as absolute and relative frequency for categorical variables. The Mann–Whitney *U* test was used to verify differences between sexes. The comparison of the median values of cCRS with the TV viewing/CRF relationship was performed by the Kruskal–Wallis test, both with post hoc of Dunn–Bonferroni. The association between the cardiometabolic risk presence and TV viewing/CRF relationship was tested by Poisson regression, using prevalence ratio and 95% confidence interval. Each model was adjusted for confounders related both with the independent and dependent variables in preliminary analyses. The *p* values of $p < 0.05$ were considered significant in all analyses.

Results

Table 1 presents comprehensive descriptive data on all the children and adolescents within the sample. Overall, 90.7% of the sample were from public schools, 55.4% lived in outskirts areas, 25.8% were categorized with a stage III of pubertal development, and the distribution of ethnic groups was predominantly (80.0%) Caucasian. In terms of overall levels of adiposity (BMI categories), 22.0% and 8.8% of the samples were classified overweight and obesity, respectively, and there was no difference between the girls and boys (median BMI 19.58 kg/m^2). Boys presented more favorable levels of TC/HDL-C ratio and triglycerides, whereas, girls presented more favorable levels of glucose and WC ($p < 0.05$).

With respect to the descriptive data on the combined lifestyle-related variables of TV viewing habits and CRF, 8.8% of the samples were classified within the high behavioral risk group, namely high TV/unfit. Boys presented more favorable levels of TV viewing and higher levels of CRF ($p < 0.05$). The prevalence of children and adolescents defined with higher cardiometabolic risk was 7.1% (boys: 6.1%; and girls: 7.8%).

Tables 2 presents the comparison of cCRS between different TV/CRF categories. In boys and girls, the median values of cCRS were significantly higher among those with unfit CRF levels, independent of TV viewing.

Table 3 demonstrates that the cardiometabolic risk prevalence was associated with lower levels of CRF. Moreover, the cardiometabolic risk was 18.0% more prevalent within the whole sample with unfit CRF levels, regardless of TV viewing. However, these risks were attenuated following the methods of adjustment for covariates (adjusted models).

Table 1 Descriptive characteristics of the children and adolescents

	Boys $n = 927$	Girls $n = 1225$	All participants $n = 2152$
Median (Q1; Q3)			
Age (years)	11.95 (9.57 to 13.93)	12.05 (10.12 to 14.02)	12.01 (9.86 to 13.97)
Cardiorespiratory fitness (VO_{2peak}; mL/kg/min)	48.52 (44.23 to 52.09)	42.55 (38.86 to 45.67)	44.70 (40.44 to 48.83)[†]
TV viewing (min/day)	60.00 (20.00 to 120.00)	90.00 (30.00 to 180.00)	60.00 (30.00 to 180.00)[†]
Body mass index (kg/m^2)	19.37 (17.05 to 21.99)	19.74 (17.29 to 22.68)	19.58 (17.18 to 22.44)
Clustered cardio-metabolic risk score	− 0.189 (− 0.521 to 0.228)	− 0.070 (− 0.483 to 0.343)	− 0.127 (− 0.494 to 0.294)
Glucose (mmol/L)	4.94 (4.72 to 5.17)	4.83 (4.56 to 5.06)	4.89 (4.61 to 5.17)[†]
Systolic blood pressure (mmHg)	100.00 (95.00 to 111.00)	102.00 (100.00 to 110.00)	102.00 (96.00 to 110.00)
TC/HDL-C ratio	2.69 (2.36 to 3.10)	2.81 (2.43 to 3.28)	2.75 (2.40 to 3.20)[†]
Triglycerides (mmol/L)	0.64 (0.50 to 0.86)	0.76 (0.58 to 1.01)	0.71 (0.55 to 0.95)[†]
Waist circumference (cm)	65.80 (59.20 to 72.30)	64.30 (58.90 to 70.25)	65.00 (59.00 to 71.10)[†]
n (%)			
TV viewing/cardiorespiratory fitness relationship			
Low TV/fit	467 (50.4)	645 (52.7)	1112 (51.7)
Low TV/unfit	226 (24.4)	298 (24.3)	524 (24.3)
High TV/fit	153 (16.5)	173 (14.1)	326 (15.1)
High TV/unfit	81 (8.7)	109 (8.9)	190 (8.8)
Cardio-metabolic risk			
Lower	870 (93.9)	1130 (92.2)	2000 (92.9)
Higher	57 (6.1)	95 (7.8)	152 (7.1)
Body mass index			
Normal weight	641 (69.1)	848 (69.2)	1489 (69.2)
Overweight	199 (21.5)	275 (22.4)	474 (22.0)
Obesity	87 (9.4)	102 (8.3)	189 (8.8)
Housing area			
Downtown	277 (29.9)	378 (30.9)	655 (30.4)
Outskirts	502 (54.2)	690 (56.3)	1192 (55.4)
Rural	148 (16.0)	157 (12.8)	305 (14.2)
Pubertal status			
Stage I	264 (28.5)	201 (16.4)	465 (21.6)
Stage II	189 (20.4)	311 (25.4)	500 (23.2)
Stage III	165 (17.8)	390 (31.8)	555 (25.8)
Stage IV	221 (23.8)	234 (19.1)	455 (21.1)
Stage V	88 (9.5)	89 (7.3)	177 (8.2)
School network			
Municipal (public)	275 (29.7)	350 (28.6)	625 (29.0)
Private	102 (11.0)	98 (8.0)	200 (9.3)
State (public)	550 (59.3)	777 (63.4)	1327 (61.7)
Skin color			
Black	66 (7.1)	82 (6.7)	148 (6.9)
Indigenous	3 (0.3)	4 (0.3)	7 (0.3)
Mulatto	112 (12.1)	153 (12.5)	265 (12.3)
White	741 (79.9)	981 (80.1)	1722 (80.0)
Yellow	5 (0.5)	5 (0.4)	10 (0.5)

Data expressed as median (interquartile range) for continuous variables or as absolute and relative frequency for categorical variables

[†]Difference between sexes calculated using the Mann–Whitney *U* test ($p < 0.05$)

Discussion

The present study adopted an internationally recognized MetS scoring methodology that defined 7.1% of southern Brazilian schoolchildren at higher cardiometabolic risk. Previous data have already shown that levels of cardiometabolic risk are relatively high among Brazilian schoolchildren [37]. Similar to the present study, Reuter et al. [38] also previously reported a cardiometabolic risk prevalence of 9.4% among 754 boys and 8.5% among 985 girls within an earlier cross-sectional report of southern Brazilian adolescents. These findings are generally consistent with those reported in some international cohorts using similar methodologies to define higher cardiometabolic clustering, such as 6.2% in European school children reported by Andersen et al. [1].

The findings of the present study demonstrated that cCRS median value was higher amongst unfit participants, independent of TV viewing levels. Our study was not able to confirm strong independent associations between higher TV viewing and increased cCRS. Although TV viewing constitutes only a part of the daily time in SB in children and adolescents, it has been associated with poor dietary habits, including self-reported sugar-sweetened beverage consumption and unhealthy snack intakes. The association between ST and inappropriate eating habits/energy intake may partially explain the increased cardiometabolic risk observed within some previous investigations [17, 39, 40]. In agreement with our findings, it seems that SB is not independently associated with cardio-metabolic health as demonstrated by recent reviews both with cross-sectional and prospective study designs [41–43].

There has been insufficient literature concerning the joint relationship between ST and CRF with the presence of cardiometabolic risk, especially among children and adolescents. Mielke et al. [44] evaluated cardiometabolic risk factors and their association with both PA and ST in the Brazilian Pelotas Birth Cohort study including 3613 adolescents of different ages (namely 11, 15 and 18 years old). Overall, at least 25% of the male and female adolescents across each age group were categorized into an inactive, high screen group. Their combined physically inactive (< 1 h per day) and high ST (> 5 h per day) was adversely associated with cardiometabolic health outcomes at 18 years old. Cross-sectional analyses of the joint associations of PA and ST showed that WC and triglycerides values were higher among those who were physically inactive, regardless of ST. Those who were inactive, but presented high ST, also had worst levels of glucose and non-HDL-C. Amongst, both active and inactive adolescents, diastolic blood pressure (DBP) was observed to be lower in those reporting lower ST. Perhaps, most notably, these investigators demonstrated that their joint (inactive/high ST) variable, evaluated in earlier adolescence (11–15 years old), was not associated with adverse cardiometabolic outcomes at age 18. Although the authors did not objectively measured CRF and its association with cardiometabolic risk factors, it is likely that those who were more physically active were more likely to have a higher CRF [45].

Other studies have examined associations with cardiometabolic risk and its risk factors using only ST, or CRF

Table 2 Comparison of clustered cardio-metabolic risk score between different TV/CRF categories

	TV viewing/CRF Relationship				*p*
	Low TV/fit	Low TV/unfit	High TV/fit	High TV/unfit	
Median (Q1; Q3)					
Boys	*n* = 467	*n* = 226	*n* = 153	*n* = 81	
Clustered cardiometabolic risk score	– 0.368 (– 0.669 to – 0.064)	0.188 (– 0.239 to 0.639)	– 0.271 (– 0.579 to – 0.014)	0.398 (– 0.020 to 0.720)	< 0.001[a]
Girls	*n* = 645	*n* = 298	*n* = 173	*n* = 109	
Clustered cardiometabolic risk score	– 0.241 (– 0.591 to 0.105)	0.362 (– 0.047 to 0.780)	– 0.307 (– 0.665 to 0.085)	0.371 (– 0.020 to 0.759)	< 0.001[b]
All participants	*n* = 1112	*n* = 524	*n* = 326	*n* = 190	
Clustered cardiometabolic risk score	– 0.306 (– 0.626 to 0.053)	0.289 (– 0.133 to 0.714)	– 0.277 (– 0.603 to 0.029)	0.386 (– 0.016 to 0.748)	< 0.001[c]

Data expressed as median (interquartile range); Kruskal–Wallis test with Post Hoc of Dunn–Bonferroni ($p < 0.05$)

[a]Low TV/fit versus low TV/unfit (< 0.001); low TV/fit versus high TV/unfit (< 0.001); high TV/fit versus low TV/unfit (< 0.001); high TV/Fit versus high TV/unfit ($p < 0.001$);

[b]High TV/fit versus low TV/unfit (< 0.001); high TV/fit versus high TV/unfit (< 0.001); low TV/fit versus low TV/unfit (< 0.001); low TV/fit versus high TV/unfit (< 0.001);

[c]Low TV/fit versus low TV/unfit (< 0.001); low TV/fit versus high TV/unfit (< 0.001); high TV/fit versus low TV/unfit (< 0.001); high TV/fit versus high TV/unfit (< 0.001)

Table 3 Association between the presence of cardio-metabolic risk and the ST/CRF relationship

	Cardio-metabolic risk presence			
	Unadjusted models		Adjusted models	
	PR (CI 95%)	*p*	PR (CI 95%)	*p*
Boys				
Cardiorespiratory fitness				
Fit (< 33.3th percentile)	1		1	
Unfit	1.16 (1.11–1.20)	< 0.001	1.04 (1.01–1.08)	0.028[a]
TV viewing				
Low	1		1	
High (> 66.7th percentile)	1.00 (0.97–1.04)	0.849	1.00 (0.97–1.04)	0.849
TV viewing/Cardiorespiratory fitness relationship				
Low TV/fit	1		1	
Low TV/unfit	1.15 (1.10–1.20)	< 0.001	1.04 (1.00–1.08)	0.051[a]
High TV/fit	1.00 (0.98–1.01)	0.606	0.99 (0.97–1.01)	0.347[a]
High TV/unfit	1.16 (1.08–1.25)	< 0.001	1.03 (0.96–1.10)	0.463[a]
Girls				
Cardiorespiratory fitness				
Fit (< 33.3th percentile)	1		1	
Unfit	1.20 (1.16–1.24)	< 0.001	1.05 (1.01–1.08)	0.006[b]
TV viewing				
Low	1		1	
High (> 66.7th percentile)	1.00 (0.97–1.03)	0.974	1.00 (0.97–1.03)	0.974
TV viewing/cardiorespiratory fitness relationship				
Low TV/fit	1		1	
Low TV/unfit	1.20 (1.15–1.25)	< 0.001	1.05 (1.01–1.09)	0.015[b]
High TV/fit	0.99 (0.98–0.99)	0.002	0.99 (0.97–0.99)	0.037[b]
High TV/unfit	1.19 (1.11–1.26)	< 0.001	1.04 (0.97–1.11)	0.253[b]
All participants				
Cardiorespiratory fitness				
Fit (< 33.3th percentile)	1		1	
Unfit	1.18 (1.15–1.21)	< 0.001	1.04 (1.02–1.07)	< 0.001[a]
TV viewing				
Low	1		1	
High (> 66.7th percentile)	1.00 (0.98–1.03)	0.913	0.99 (0.97–1.02)	0.588[c]
TV viewing/cardiorespiratory fitness relationship				
Low TV/fit	1		1	
Low TV/unfit	1.18 (1.14–1.21)	< 0.001	1.03 (0.99–1.05)	0.062[d]
High TV/fit	0.99 (0.98–0.99)	0.036	1.00 (0.98–1.01)	0.408[d]
High TV/unfit	1.18 (1.12–1.23)	< 0.001	1.02 (0.97–1.06)	0.512[d]

Poisson regression considering presence versus absence of cardiometabolic risk; significant values for $p < 0.05$

CI confidence interval, *PR* prevalence ratio

[a]Adjusted for BMI and housing area

[b]Adjusted for BMI

[c]Adjusted for BMI, pubertal status, and skin color

[d]Adjusted for BMI, housing area, pubertal status, and skin color

measures. Silveira et al. [9] demonstrated that children and adolescents in the worst profile regarding CRF presented higher odds of being at higher cardiometabolic risk three years later. Whereas, Barker et al. [46] investigated both SB and TV viewing time with CRF and their association with cardiometabolic risk among over 500 European adolescents. These investigators reported that although SB was not significantly related to cCRS (skinfolds, HOMA-homeostasis model of insulin resistance, in addition to BP and lipids), TV viewing time was independently associated with measures of triglycerides, insulin resistance and cCRS. Lower CRF also showed inverse associations with WC, all other body composition indexes and their cCRS. As outlined earlier, low CRF has been shown to be strongly associated with the cCRS, independent of age and sex, within culturally diverse samples of children and youth [1, 7–9].

Our study showed that cardiometabolic risk was 18.0% more prevalent within the sample in the low TV/unfit and high TV/unfit categories. Most of the evidence supports stronger associations between higher levels of MVPA, or objectively measured CRF, compared to self-reported ST, in defining cardiometabolic health [44]. Barker et al. [46] reported that the strength of the associations between CRF and cCRS was 'independent' and stronger than all other measured exposure variables in children and adolescents. This finding was considered to be explained by the simultaneous inclusion of multiple behavioural measures as covariates within regression models, including different intensities of PA, SB, and TV viewing. Some of these differences may also clearly relate to measurement inaccuracies across the different exposure variables. Ekelund et al. [39] examined the independent and combined associations between objectively measured time in MVPA and SB (using accelerometry) with cardiometabolic risk factors, comprising more than 20,000 children and adolescents from the International Children's Accelerometry (ICA) Study. In that study, SB was not associated with any outcome independent of time in MVPA. Additionally, a cross-sectional study of Brazilian male adolescents [47], using analytical isotemporal substitution techniques for different PA, indicated that replacing SB with low-intensity PA showed positive results on cardiometabolic risk factors (HDL-C, HOMA, and SBP) while replacing SB with MVPA was associated with only body fat percentage.

Several reports have considered the effect of different ways of adjusting for measures of obesity on the observed associations for both PA, CRF, and TV viewing (hours per day) with aspects of cCRS. We found the associations between cardiometabolic risk with both unfitness alone and combined high TV/unfit were attenuated following adjustment for BMI. Our findings, therefore, concur that measures of body fat seems to play an important role in the association of CRF with cardiometabolic risk. As discussed by Ekelund et al. [15], an alternative explanation may be that adiposity is part of the causal pathway between CRF and cardiometabolic risk. In these circumstances, adjusting for adiposity as a confounding variable will diminish a true association between CRF and cardiometabolic risk.

Strengths and limitations

Our study has some worthwhile features in examining the joint cross-sectional associations amongst lifestyle-related variables and cardiometabolic risk factor clustering in children and adolescents. First, the utilization of a large representative sample of schoolchildren from a well-defined geographical area within southern Brazil. Second, we have utilized a standardized and internationally applied method for defining cardiometabolic health in school-aged children. However, our study also has some limitations that should be appreciated. Firstly, the cross-sectional design of the present study makes it impossible to establish a causal impact between TV viewing and CRF with cCRS. A notable limitation of this study is the use of a self-reported questionnaire for classifying TV viewing. Also, we did not include in our SB variable the time spent in other screen-based devices (computer/mobile phones) frequently used by adolescents. Therefore, caution should be exerted when comparing our findings to other studies that considered other screen-based devices. We also estimated CRF with a timed running/walking measure, and the majority of other previous studies have used physical fitness, or predictions of VO_{2peak} from similar performance measures. It should be recognized that these are imprecise measures and have residual relationships between body fatness [48]. Artero et al. [49] systematically reviewed the reliability of field-based fitness tests in youth, including four studies investigating the 1-mile run/walk test. At the time, there was only moderate evidence to support test reliability (from intraclass correlation coefficients), contrasting with stronger evidence supporting the progressive, maximal 20-m shuttle-run test. Others have subsequently indicated higher reliability for run/walk testing in schoolchildren, together with strong associations with maximal oxygen consumption [50]. There are also the potential issues relating to the well-establish associations between both SB and PA on measures of physical fitness. Likewise, the potential confounding effect of overall adiposity on the associations between ST and CRF with cardiometabolic risk requires further consideration with criterion methods. We suggest that future studies aim to verify the role of more objectively measured ST, other SB, and CRF (using physical fitness tests and ideally scientifically valid tests estimating VO_{2peak}) in the development of cardiometabolic risk.

Conclusion

The present analysis has highlighted subtle differences between male and female children and adolescents of different ages and cCRS associated with the lifestyle-related exposure variables of high TV viewing and poor CRF levels. The cCRS was higher among unfit participants, independent of TV viewing. However, the higher cCRS associated with unfitness appeared to be attenuated by higher adiposity.

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Availability of data and material The database is available with the corresponding author on reasonable request.

Declarations

Conflict of interest The authors state no conflict of interest.

Ethical approval The present research is part of a larger survey named 'Schoolchildren's Health-Phase IV' conducted between 2016 and 2017, which was conducted in accordance to the Helsinki Declaration for Human Studies of 1964. The present study was approved by the Committee of Ethics in Research with Human Subjects of the University of Santa Cruz do Sul, under protocol number 1,498,305.

Consent to participate The schoolchildren's parents were informed about the research and signed informed consent.

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