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Association between physical activity, sleep, and screen time and cardiometabolic risk factors among Brazilian adolescents: a cross-sectional analysis of a nationally representative sample

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Abstract

Background A prominent gap in the literature is the lack of evidence from low-middle-income countries on the association between adherence to 24-Hour Movement Guidelines (physical activity, sleep, and screen time) and cardiometabolic risk factors among adolescents. This study examined the association between adherence to the 24-Hour Movement Guidelines and cardiometabolic risk factors among Brazilian adolescents.

Methods The probabilistic sample consisted of 29,226 adolescents (60.5% females) aged 12 to 17 years. This school-based cross-sectional study was conducted across all geographical regions of Brazil. Body mass and height were measured to estimate body mass index. Waist circumference, blood pressure, and venous blood samples were collected to estimate fasting glucose, triglycerides, and HDL cholesterol. Cardiometabolic risk factors were classified according to International Diabetes Federation criteria. Data on 24-hour movement behaviors (moderate-to vigorous-intensity physical activity, sleep duration, and recreational screen time) were collected using a self-administered questionnaire and classified according to the Canadian 24-Hour Movement Guidelines. Binary logistic regression models were used to estimate odds ratios (OR) and 95% confidence intervals (95%CI).

Results For males, lower ORs for high blood pressure [OR: 0.34 (95%CI: 0.20–0.58)], high triglycerides [OR: 0.47 (0.28–0.78)], metabolic syndrome [OR: 0.36 (0.17–0.78)], and the presence of two [OR: 0.49 (0.32–0.58)] and ≥ 3 cardiometabolic risk factors [OR: 0.35 (0.15–0.80)] were observed in adolescents who met the 24-Hour Movement Guidelines compared to peers who did not meet the guidelines. For females, no association was found between adherence to 24-Hour Movement Guidelines and cardiometabolic risks.

Conclusion Meeting 24-Hour Movement Guidelines was beneficial for reducing the odds of cardiometabolic risk factors in males.

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Keywords Epidemiology, Physical activity, Recommendations, Risk factors, Sedentary behavior, Sleep

Background

In 2016, the Canadian Society for Exercise Physiology released the Canadian 24-Hour Movement Guidelines for the Children and Youth (aged 5–17 years) [1]. This groundbreaking initiative was based on a scientific framework comprising four systematic reviews. These reviews critically evaluated the interactions between physical activity [2], sedentary behavior [3], sleep [4], and the combinations of these behaviors [5] in relation to health indicators. According to the guidelines [1], children and adolescents should accumulate at least 60 min/day of moderate- to vigorous-intensity physical activity (MVPA), limit recreational screen time to no more than 2 h/day, and obtain between 9 and 11 h of sleep per night for those aged 5–13 years, or 8–10 h per night for those aged 14–17 years. Prior to these guidelines, international research and policy focused mainly on isolated behavioral analyses. This integrative approach marked a paradigm shift, promoting a holistic understanding of lifestyle and multiple health behaviors [1]. Adolescents who accumulated at least 60 min/day of moderate- to vigorous-intensity physical activity.

Since the publication of the systematic review by Saunders et al. [5], which focused on how individual behaviors (physical activity, sedentary behavior, and sleep) interact and relate to health indicators in different combinations, an increasing body of evidence supports the simultaneous adherence to the guidelines of the three 24-Hour movement behaviors for greater benefits to physical and mental health, as well as improved academic performance in the pediatric age group [6, 7]. Despite these findings, a systematic review by Rollo et al. [6] examined the associations between adherence to the 24-Hour Movement Guidelines and health indicators across the lifespan, reporting some gaps and inconsistent results. This review found only two original studies that investigated the association between adherence to the 24-Hour Movement Guidelines and cardiometabolic risk factors in adolescents [8, 9]. The study conducted with a Canadian adolescent sample reported that adherence to the 24-Hour Movement Guidelines resulted in a healthy profile of systolic blood pressure, triglycerides, HDL cholesterol, and insulin [8]. On the other hand, the study conducted with a sample from the United States reported that adherence to the 24-Hour Movement Guidelines resulted only in a healthy profile of triglycerides and glucose [9], with no association with other cardiometabolic profile indicators.

Continuing the review of evidence on this theme, a systematic review published in 2023 [7], which included 141 studies up to 2020, analyzed the combination of at

least two 24-Hour movement behaviors (physical activity, sleep, and sedentary behavior/screen time) with physical, psychological, or educational outcomes. Consistent evidence shows that high physical activity and low sedentary behavior/screen time benefit cardiometabolic outcomes in adolescents. However, a prominent gap identified was the lack of recent studies (beyond those reported by Rollo et al. [6]) analyzing adherence to the 24-Hour Movement Guidelines and cardiometabolic risk factors in adolescents. The combination of sleep with physical activity or sedentary behavior/screen time in relation to undesirable cardiometabolic indicators also lacked recent investigation [7].

The limited information regarding adolescents contrasts with data derived from child-based studies. In children, evidence from both cross-sectional and longitudinal studies indicates that good sleep combined with low screen time and high physical activity benefits cardiometabolic outcomes [6, 7]. While it is believed these findings might be extrapolated to adolescents due to potential stability of cardiometabolic risk factors from childhood to adolescence [10], such inferences should be approached cautiously regarding health behaviors and cardiometabolic outcomes [11, 12]. Adolescents, being older, may have greater exposure to undesirable cardiometabolic indicators, potentially increasing the risk of developing cardiovascular and metabolic diseases over time. Chronic exposure to these risk factors can cause cumulative damage to the cardiovascular and metabolic systems [12], making non-pharmacological interventions less effective. Therefore, the association between adherence to 24-Hour Movement Guidelines and undesirable cardiometabolic indicators may be compromised.

In light of the need for more evidence on the relationship between adherence to 24-Hour Movement Guidelines and cardiometabolic risk factors in adolescents, and considering that systematic reviews [6, 7] on this topic have highlighted that the evidence was predominantly derived from high-income countries, which limits the inferences for low- and middle-income countries with different contextual characteristics, the current research, conducted across all geographical regions of Brazil, aims to examine the association between adherence to the 24-Hour Movement Guidelines and cardiometabolic risk factors. This study hypothesizes that adherence to the 24-Hour Movement Guidelines results in favorable cardiometabolic outcomes.

Methods

Study design

The ERICA, from which the data for this study were obtained, was national, school-based, cross-sectional multicenter study designed to estimate the prevalence of cardiovascular risk factors associated with metabolic syndrome in a representative sample of Brazilian adolescents aged 12 to 17. The ERICA sample consisted of students attending either the seventh, eighth, or ninth grade of elementary school or the first, second, or third year of high school in the morning shift. These students came from both public and private schools located in Brazilian municipalities with populations exceeding 100,000 [13].

Sample

The sample was stratified into 32 strata, comprising the 27 capital municipalities of the Federal Units and five sets of other municipalities in the interior, each with populations exceeding 100,000, representing all five macro-regions of the country. Stratification occurred at multiple levels, including schools, grade levels, shifts (morning or afternoon), and classes. Sample weights were calculated as the product of the inverse of the inclusion probabilities at each stage of sample selection, with calibration considering population estimates of adolescents enrolled in schools within the specified geographic strata, categorized by gender and age [13].

Sample size determination considered the anticipated prevalence of metabolic syndrome in adolescents, a maximum allowable error of 0.9%, and a 95% confidence level, while also accounting for a clustering effect of 2.97. Additional details about the sampling process can be found in the literature [13].

Since the present study used a set of information to examine issues different from those addressed in the broader study, the statistical power, which refers to the probability of rejecting a false null hypothesis (i.e., to determine that there is no difference when in fact there is) [14], was calculated, and values >80% were considered adequate to prevent this error. In the present study, most of the associations presented sufficient power to investigate the association between 24-hour movement behaviors and cardiometabolic outcomes. More detailed information regarding statistical power can be found in Supplementary Tables S1-S3.

Measures

Anthropometric, clinical, and laboratory measurements

Anthropometric measurements, including height, body weight, and waist circumference, were employed in this study. Two measurements were taken for each variable, and in the presence of discrepant values, a third measurement was taken. Field staff were trained by the central coordination team of ERICA, following the standardized

study protocol [15]. Specific training materials, including instructional videos, were developed to ensure consistency in anthropometric assessments. Field staff received practical instruction in anthropometric techniques, and all measurements were carried out by trained researchers following detailed written procedures. For standardization, adolescents were assessed wearing light clothing and without shoes, and each measurement was taken in duplicate to enhance quality control [15]. Before data collection, a pretest was conducted in a public school in a Brazilian city, followed by a multicenter pilot study in five cities across different regions of the country, involving two public and one private school in each location. Approximately 1,900 adolescents participated in this pilot phase, which allowed refinement of procedures and instruments. To maintain data quality, routine logic checks were implemented to detect outliers, inconsistencies, or patterns of digit preference. When issues were identified, corrective actions included examiner retraining and equipment replacement, as needed. Extreme but plausible values were retained if within the operational range of the instruments. However, a monitoring rule was established: if more than 10% of an examiner's records fell outside the 5th and 95th percentiles (based on pilot study distributions), the data were flagged as potentially erroneous, and the examiner was promptly retrained [15].

The mean of the two closest measurements for height and waist circumference were utilized for analysis. Height measurements were obtained using an Altura Exata[®] stadiometer (Belo Horizonte, Brazil) with a tripod, while body weight was measured with a Lider[®] P200M (São Paulo, Brazil) digital scale. Waist circumference was determined using an inextensible Sanny[®] measuring tape (São Paulo, Brazil) with a precision of 0.1 cm. Waist measurements were taken at the midpoint between the lower curvature of the last fixed rib and the upper curvature of the iliac crest, with the adolescent in a standing position, arms alongside the body, feet together, and the abdomen in a relaxed state. The classification criteria for abdominal obesity followed recommendations in the literature [16, 17].

Systolic and diastolic blood pressure were measured using the automated Omron[®] 705-IT device, validated for use in the adolescent population [18]. Among the three blood pressure measurements taken, the mean of the last two readings was used to classify blood pressure as high or normal. Systemic blood pressure was considered high if the systolic blood pressure was greater than or equal to 130 mmHg and the diastolic blood pressure was greater than or equal to 85 mmHg [17]. Adolescents with a previous diagnosis of hypertension or those using hypertensive medication were also considered to have high blood pressure [17].

Venous blood samples were collected in the early morning, following a fasting period of at least 12 h. Therefore, only students attending morning classes had their blood information evaluated. Fasting blood glucose levels were assessed using the enzymatic GOD-PAP method on Roche modular analytical equipment (Roche Group®, Basel, Switzerland). Values of ≥ 100 mg/dL or the use of medication to control blood glucose were considered indicative of high blood glucose [19]. Triglycerides and HDL-cholesterol were analyzed using the calorimetric enzymatic method on Roche modular analytical equipment. For triglycerides, values ≥ 150 mg/dL were used to classify adolescents as having elevated triglyceride levels [17]. Regarding HDL-cholesterol, adolescents of both sexes under the age of 16 with values ≥ 40 mg/dL were considered to have acceptable levels for this indicator. For adolescents aged 16 years or older, values < 40 mg/dL for males and < 50 mg/dL for females, were considered indicative of low levels of HDL-cholesterol [17]. Previous medical diagnosis “Has a doctor ever told you that you have.” was also used to identify adolescents in relation to the presence of lipid disorders.

Cardiometabolic risk factors

In this study, three distinct undesirable cardiometabolic indicators were considered: (1) isolated cardiometabolic risk factors, including abdominal obesity, high blood pressure, high blood glucose, elevated triglycerides, and low HDL-cholesterol; (2) metabolic syndrome, as defined by the International Diabetes Federation criteria [17], characterized by the presence of at least three of the following components: abdominal obesity, high blood pressure, high blood glucose, elevated triglycerides, and low HDL-cholesterol, with the obligatory presence of abdominal obesity [17]; (3) the number of cardiometabolic risk factors within each individual. Given that fewer than 1.0% of the sample had four or more undesirable cardiometabolic indicators, they were grouped into a single category (i.e., ≥ 3). Therefore, for the purposes of analysis, adolescents in this study were classified as having either “0”, “1”, “2”, or “ ≥ 3 ” undesirable cardiometabolic indicators.

24-Hour movement behavior targets

Physical activity was assessed considering information from the week before the adolescent participated in the research. We used questions adapted from the Self-Administered Physical Activity Checklist [20], which has been validated for use among Brazilian adolescents [21]. To determine the level of physical activity, we calculated the product of the duration and frequency for each activity and then summed the obtained values. Adolescents who accumulated at least 60 min/day of MVPA were considered to meet the MVPA guidelines [1].

In the study questionnaire, the sleep module consisted of four questions. Adolescents were asked to indicate their usual bedtime and wake-up time separately for weekdays and weekends. These questions were specifically developed for the study, and the consistency and quality of the information obtained were evaluated and reported in a previous publication [22]. Hours of sleep per night was determined as the weighted average of weekday and weekend days sleep hours, calculated as the difference between bedtime and wake-up time. The equation used was as follows: $[(\text{weekday sleep hours} \times 5) + (\text{weekend sleep hours} \times 2)/7]$. For adolescents aged 13 years or younger, the recommended sleep hours were considered adequate if they slept between 9 and 11 h per night [1]. In the 14 to 17-year-old age group, adolescents who reported sleeping 8 to 10 h per night were considered to meet the sleep duration guideline [1].

Screen time was evaluated with a single question: “On a typical weekday, how many hours do you usually spend watching television, using a computer, or playing video games?” Response options were provided in hours, ranging from 0 (does not engage in these activities) to ≥ 7 h per day. This question was adapted from National School-Based Health Surveys in Brazil [23]. Estimates of construct validity and factorial structure for these measures have been previously tested and published [24]. Adolescents who spent ≤ 2 h per day were considered to meet the screen time guidelines [1].

In terms of analytical approach, the main focus of this study was to analyze adherence to the 24-Hour Movement Guidelines considering adherence to all three target behaviors [1]. Furthermore, we present in this study the associations of isolated movement behaviors (physical activity, sleep, screen time), and two-by-two combinations of adherence to each target behavior (MVPA + sleep; MVPA + screen time; sleep + screen time) with outcomes.

Sociodemographic, lifestyle, and sexual maturation

Sociodemographic factors, alcohol consumption, smoking, consumption of snacks in front of screens, and sexual maturation were included as co-variables. Sex (male; female), age recorded in years; type of school (public; private); and race/ethnicity (Black; White; Brown; Yellow; Indigenous) were self-reported. Smoking was assessed through a question regarding the use of cigarettes in the last 30 days. Respondents who answered positively at least once were classified as smokers [25]. To assess alcohol consumption, information was collected by asking about the number of days in the last 30 days on which the respondents consumed at least one glass or one dose of alcoholic beverage. Those who provided affirmative responses at least once were considered to have consumed alcohol [25]. A variable was created to reflect

consuming snacks while watching TV, using a computer, or playing video games. Thus, variables related to consuming snacks in front of screens were combined and the following classifications were possible: “never has meals in front of screens”; “sometimes has one of the two meals in front of screens”; “almost always has one of the two meals in front of screens”, or “always has at least one of the two meals in front of screens”.

Sexual maturation was evaluated using images representing maturational development [26]. Self-assessment of breast development and pubic hair (female) and genital development and pubic hair (male) were used to determine the stages of sexual maturation [26]. For analysis purposes, the most advanced stage of sexual maturation between the two assessments according to sex was considered. Stage 1 corresponded to the prepubertal stage, while stages 2, 3, and 4 indicated puberty, and stage 5 represented the postpubertal stage [22]. Due to the low prevalence of adolescents in the “pre-pubertal” stage (less than 1.0% of the sample), participants were categorized as “pre-pubertal/pubertal” or “postpubertal” [26].

Statistical analysis

Means and 95% confidence intervals (95%CI) were used to describe continuous variables, while categorical variables were presented as percentages (%) with their respective 95%CI.

Binary logistic regression models were used to investigate the association between 24-Hour movement behavior targets with each one of the cardiometabolic risk factors. Multinomial logistic regression models were used to test the association between the number of cardiometabolic risk factors (0, 1, 2, ≥ 3 ; with category 0 as a reference) with 24-Hour movement behavior targets. For both regression analyses, results were expressed as odds ratio (OR) and 95%CI.

Considering the potential influence of sex on 24-Hour movement behavior targets [8, 27], interactions between these variables in relation to cardiometabolic risk factors were examined within the regression models. In most instances, whether investigating 24-Hour movement behavior targets in association with isolated cardiometabolic risk factors or considering the cumulative number of risk factors within each individual, the results suggested that sex may moderate the tested interactions (p -value for interaction < 0.10) [28]. Consequently, the association analyses were stratified by sex. All association analyses were adjusted for age, race/ethnicity, school type, smoking, alcohol consumption, and maturational status, irrespective of their statistical significance in relation to the outcomes.

Data analyses were conducted in the statistical software Stata 16.0 (StataCorp LP, College Station, Texas, USA), considering sampling weights and the survey design.

Ethics approval

This study was conducted according to the principles of the Helsinki Declaration. The Ethical Committee of the Federal University of Rio de Janeiro – Brazil approved the study in January, 2009. Written informed consent was obtained from each student, and also from their parents for those who are invited to take blood collection.

Results

A total of 29,226 adolescents aged 12 to 17 years (males, $n = 11,523$; females, $n = 17,703$) with complete data for all investigated outcomes were assessed in this study. Females had higher values for diastolic blood pressure, triglycerides, and HDL-cholesterol than males ($p < 0.05$). Additionally, more females were classified with abdominal obesity than males ($p < 0.05$). Conversely, males showed higher values of systolic blood pressure, fasting glucose, and waist circumference than females ($p < 0.05$). The proportion of adolescents classified with high blood pressure, elevated blood glucose, low HDL cholesterol, Black race/ethnicity, meeting all three 24-Hour movement behaviors, and with ≥ 3 cardiometabolic risk factors was higher in males than in females ($p < 0.05$). More males met the guidelines for MVPA compared to females ($p < 0.05$). For the other movement behavior targets, there were no differences between sexes ($p > 0.05$) (Table 1).

Table 2 shows the association analysis of each individual 24-Hour movement behavior target with undesirable cardiometabolic indicators. In males, meeting the MVPA guidelines was associated with reduced odds of having high triglycerides (OR: 0.64; 95%CI: 0.47–0.88) and the simultaneous presence of one (OR: 0.78; 95%CI: 0.65–0.94) and two cardiometabolic risk factors (OR: 0.73; 95%CI: 0.54–0.98). Meeting the sleep guidelines was linked to lower odds of low HDL cholesterol (OR: 0.75; 95%CI: 0.58–0.98), high triglycerides (OR: 0.69; 95%CI: 0.51–0.93), abdominal obesity (OR: 0.54; 95%CI: 0.36–0.82), metabolic syndrome (OR: 0.47; 95%CI: 0.27–0.83), and the simultaneous presence of ≥ 3 cardiometabolic risk factors (OR: 0.33; 95%CI: 0.20–0.54). Meeting the screen time guidelines was associated with reduced odds of low levels of HDL cholesterol (OR: 0.80; 95%CI: 0.66–0.97), high triglycerides (OR: 0.74; 95%CI: 0.57–0.96), and the simultaneous presence of two (OR: 0.60; 95%CI: 0.47–0.79) and ≥ 3 cardiometabolic risk factors (OR: 0.63; 95%CI: 0.40–0.98). In females, meeting the screen time guidelines was inversely associated with abdominal obesity (OR: 0.75; 95%CI: 0.61–0.91). Also in females, meeting the MVPA guidelines (OR: 1.16; 95%CI: 1.00–1.34) and meeting the screen time guidelines (OR: 1.27; 95%CI: 1.04–1.55) were directly associated with low HDL cholesterol.

Table 3 shows the association analysis of two-by-two combinations of adherence to each target behavior with

Table 1 Sample characteristics

		Total (n = 29,226)	Male (n = 11,523)	Female (n = 17,703)
Variables	mean	(95%CI)	mean	(95%CI)
Age (years)	14.6	(14.6; 14.6)	14.6	(14.6; 14.6)
SBP (mm Hg)	111.3	(110.8; 111.8)	114.5	(113.8; 115.2)
DBP (mm Hg)	66.4	(66.0; 66.7)	66.1	(65.6; 66.5)
TRG (mg/dL)	78.5	(76.8; 80.1)	77.5	(75.4; 79.4)
HDL-C (mg/dL)	47.4	(46.7; 48.1)	45.0	(44.3; 45.6)
FG (mg/dL)	86.2	(85.7; 86.6)	87.6	(87.0; 88.1)
WC (cm)	72.3	(71.7; 72.7)	73.6	(73.0; 74.2)
		% (95%CI)		% (95%CI)
Race/ethnicity				
White		41.9 (40.0; 43.9)	42.0 (39.7; 44.4)	41.9 (39.5; 44.2) [†]
Black		6.5 (5.8; 7.4)	7.4 (6.2; 8.7)	5.7 (4.9; 6.7)
Brown		49.2 (47.2; 51.2)	48.3 (45.7; 50.9)	50.1 (47.9; 52.3)
Yellow		1.8 (1.5; 2.1)	1.6 (1.2; 2.2)	2.0 (1.7; 2.3)
Indigenous		0.6 (0.3; 0.7)	0.7 (0.5; 0.8)	0.3 (0.2; 0.5)
Type of school				
Public		76.8 (71.1; 81.5)	76.1 (70.2; 81.0)	77.5 (71.8; 82.3)
Private		23.2 (18.4; 28.8)	23.9 (18.9; 29.7)	22.5 (17.7; 28.1)
Smoking				
No		95.3 (94.6; 95.9)	94.9 (93.7; 95.9)	95.7 (94.9; 96.4)
Yes		4.7 (4.1; 5.3)	5.1 (4.0; 6.3)	4.3 (3.6; 5.0)
Alcohol consumption				
No		77.8 (76.4; 79.0)	78.3 (76.0; 80.5)	77.1 (75.0; 79.1)
Yes		22.2 (20.9; 23.6)	21.7 (19.5; 23.9)	22.9 (20.9; 24.9)
Consumption of snacks in front of screens				
No		10.2 (9.2; 11.3)	12.1 (10.7; 13.7)	8.4 (7.3; 9.6) [†]
Sometimes		53.3 (51.8; 54.7)	54.7 (52.3; 57.1)	51.8 (50.4; 53.3)
Almost everyday		22.2 (21.1; 23.3)	20.4 (18.8; 22.0)	24.1 (22.4; 25.7)
Every day		14.3 (13.1; 15.4)	12.8 (11.2; 14.6)	15.7 (14.5; 17.0)
Sexual maturation				
Pre-pubertal/pubertal		63.0 (61.8; 64.2)	64.5 (62.6; 66.4)	61.5 (59.7; 63.2) [†]
Post pubertal		37.0 (35.8; 38.2)	35.5 (33.6; 37.3)	38.5 (36.8; 40.3)
Meets MVPA guidelines				
No		63.1 (62.0; 64.2)	48.3 (46.5; 50.2)	77.8 (76.3; 79.2) [†]
Yes		36.9 (35.8; 38.0)	51.7 (49.8; 53.5)	22.2 (20.8; 23.7)
Meets sleep hours guidelines				
No		23.5 (21.9; 25.2)	24.5 (21.7; 27.5)	22.5 (21.1; 23.8)
Yes		76.5 (74.8; 78.1)	75.5 (72.5; 78.2)	77.5 (76.2; 78.8)
Meets screen time guidelines				
No		39.8 (38.2; 41.4)	39.7 (36.7; 42.8)	39.9 (38.3; 41.5)
Yes		60.2 (58.6; 61.8)	60.3 (57.2; 63.3)	60.1 (58.5; 61.7)
Number of 24-hour movement behaviors met				
0		31.5 (30.0; 33.0)	24.4 (22.3; 26.6)	38.5 (36.9; 40.2) [†]
1		42.0 (40.5; 43.4)	42.6 (40.5; 44.7)	41.4 (39.4; 43.3)
2		21.4 (20.4; 22.4)	25.8 (24.1; 27.5)	17.0 (15.7; 18.4)
3		5.1 (4.0; 6.5)	7.2 (5.1; 10.0)	3.1 (2.4; 3.7)
High blood pressure				
No		91.5 (90.7; 92.3)	87.3 (85.9; 88.6)	95.7 (94.9; 96.4) [†]
Yes		8.5 (7.7; 9.2)	12.7 (11.3; 14.1)	4.3 (3.5; 5.0)
High triglycerides				
No		87.4 (86.4; 88.3)	88.6 (87.2; 89.9)	86.2 (85.1; 87.2) [†]
Yes		12.6 (11.7; 13.6)	11.4 (10.1; 12.8)	13.8 (12.8; 14.9)

Table 1 (continued)

	Total (n = 29,226)	Male (n = 11,523)	Female (n = 17,703)
Low HDL Cholesterol			
No	61.3 (58.6; 63.9)	60.1 (57.1; 63.0)	62.5 (59.5; 65.3)
Yes	38.7 (36.1; 41.4)	39.9 (31.1; 37.3)	37.5 (34.6; 40.5)
High Glycemia			
No	96.0 (95.2; 96.7)	94.3 (92.8; 95.5)	97.8 (97.2; 98.2) [†]
Yes	4.0 (3.3; 4.8)	5.7 (4.5; 7.2)	2.2 (1.8; 2.8)
Abdominal obesity			
No	87.2 (85.8; 88.4)	89.9 (88.2; 91.4)	84.4 (82.8; 85.9) [†]
Yes	12.8 (11.6; 14.1)	10.1 (8.6; 11.7)	15.6 (14.1; 17.2)
Number of cardiometabolic risk factors			
0	53.9 (51.1; 56.6)	51.8 (48.5; 55.7)	56.0 (53.3; 58.6) [†]
1	33.6 (31.5; 35.8)	34.3 (31.6; 37.1)	32.9 (30.8; 35.1)
2	9.4 (8.4; 10.6)	10.2 (8.7; 12.0)	8.7 (7.6; 9.9)
3+	3.1 (2.5; 3.6)	3.7 (3.0; 4.5)	2.4 (1.8; 3.0)
Metabolic syndrome			
No	97.4 (96.9; 97.7)	97.0 (96.4; 97.5)	97.7 (97.0; 98.2)
Yes	2.6 (2.2; 3.0)	3.0 (2.4; 3.6)	2.3 (1.8; 3.0)

SBP Systolic Blood Pressure, DBP Diastolic Blood Pressure, WC Waist Circumference, FG Fasting Glucose, TRG Triglycerides, HDL High density lipoprotein CI 95% Confidence interval

*: $p < 0.05$ for difference between groups by T-test; †: $p < 0.05$ for difference between groups by Chi-Square test for heterogeneity

undesirable cardiometabolic indicators. Males who simultaneously adhered to the MVPA and sleep guidelines had lower odds of having high triglycerides (OR: 0.59; 95%CI: 0.41–0.84), metabolic syndrome (OR: 0.48; 95%CI: 0.25–0.90), and ≥ 3 cardiometabolic risk factors (OR: 0.41; 95%CI: 0.25–0.95). Males who met both the MVPA and screen time guidelines were less likely to have high triglycerides (OR: 0.65; 95%CI: 0.49–0.85), low HDL-cholesterol (OR: 0.67; 95%CI: 0.53–0.85), and two (OR: 0.60; 95%CI: 0.45–0.81) or ≥ 3 cardiometabolic risk factors (OR: 0.55; 95% CI: 0.32–0.93). Males who adhered to both the sleep and screen time guidelines had reduced odds of having high triglycerides (OR: 0.50; 95%CI: 0.33–0.77), low HDL-cholesterol (OR: 0.62; 95%CI: 0.44–0.88), metabolic syndrome (OR: 0.48; 95%CI: 0.24–0.96), and two (OR: 0.51; 95%CI: 0.33–0.79) or ≥ 3 (OR: 0.34; 95%CI: 0.17–0.65) cardiometabolic risk factors. Females who adhered to the MVPA and screen time guidelines had lower odds of high blood pressure (OR: 0.52; 95%CI: 0.33–0.81) and higher odds of low HDL-cholesterol (OR: 1.40; 95%CI: 1.11–1.78). Additionally, females who met both the sleep and screen time guidelines were less likely to have abdominal obesity (OR: 0.70; 95%CI: 0.51–0.96) (Table 3).

Table 4 shows the association analysis of adherence to all 24-Hour movement behavior targets with undesirable cardiometabolic indicators. For males, lower odds of high blood pressure (OR: 0.34; 95%CI: 0.20–0.58), high triglycerides (OR: 0.47; 95%CI: 0.28–0.78), metabolic syndrome (OR: 0.36; 95%CI: 0.17–0.78), and the presence of two (OR: 0.49; 95%CI: 0.32–0.58) and ≥ 3 cardiometabolic

risk factors (OR: 0.35; 95%CI: 0.15–0.80) were observed in adolescents who met all three movement behavior targets. For females, no associations were found between adherence to all 24-Hour movement behavior targets and undesirable cardiometabolic indicators.

Discussion

The primary finding of this study was that male adolescents who adhered to the 24-Hour Movement Guidelines had lower odds of undesirable cardiometabolic indicators compared to their peers who did not adhere to these guidelines, particularly for high blood pressure, high triglycerides, metabolic syndrome, and the presence of two or more cardiometabolic risk factors. For females, no association between adherence to the 24-Hour Movement Guidelines and cardiometabolic outcomes was found in this study. The isolated analysis of each of the 24-Hour movement behaviors or the combination of two of these target behaviors showed similar trends, indicating that adherence to the guidelines was associated with lower odds of undesirable cardiometabolic indicators, especially among males.

In our study we found that the prevalence of meeting the MVPA guidelines was higher in males (51.7%; 95%CI: 49.8–53.5), compared to females (22.2%; 95%CI: 20.8–23.7), while the prevalence of meeting recreational screen time guidelines and sleep hours guidelines were similar between sexes, resulting in greater adherence to the 24-Hour Movement Guidelines in males (7.2%; 95% CI: 5.1–10.0) compared to females (3.1%; 95% CI: 2.4–3.7), with physical activity exerting a greater influence on

Table 2 Adjusted association from binary or multinomial logistic regression between each one of 24-hour movement behavior targets and cardiometabolic risk factors according to sex

Outcomes	Meets MVPA guidelines			Meets sleep guidelines			Meets screen time guidelines		
	OR*	(95% CI)	p-value	OR*	(95% CI)	p-value	OR*	(95% CI)	p-value
Males									
High Blood Pressure									
No	1		0.51 [†]	1		0.06 [†]	1		0.13 [‡]
Yes	1.08	(0.86; 1.36)		0.77	(0.51; 1.01)		0.85	(0.69; 1.04)	
High Triglycerides									
No	1		0.03 [‡]	1		0.02 [†]	1		0.02 [‡]
Yes	0.73	(0.54; 0.98)		0.69	(0.51; 0.93)		0.74	(0.57; 0.96)	
Low HDL-C									
No	1		0.10 [†]	1		0.03 [†]	1		<0.01 [‡]
Yes	0.86	(0.72; 1.03)		0.75	(0.58; 0.98)		0.75	(0.62; 0.90)	
High Fasting Glucose									
No	1		0.31 [†]	1		0.80 [†]	1		0.69 [‡]
Yes	0.81	(0.55–1.21)		0.94	(0.62–1.44)		0.92	(0.61–1.38)	
Abdominal Obesity									
No	1		0.77 [†]	1		<0.01 [†]	1		0.08 [‡]
Yes	1.04	(0.77; 1.43)		0.54	(0.36; 0.82)		0.70	(0.48; 1.04)	
Metabolic syndrome									
No	1		0.54 [†]	1		0.01 [†]	1		0.08 [‡]
Yes	0.89	(0.61; 1.29)		0.47	(0.27; 0.83)		0.64	(0.38; 1.06)	
Number of cardiometabolic risk factors									
0 [§]	1			1			1		
1	0.78	(0.65; 0.94)	0.01 [‡]	0.85	(0.71; 1.01)	0.08 [‡]	0.99	(0.81; 1.19)	0.89 [‡]
2	0.73	(0.54; 0.98)	0.03 [‡]	0.81	(0.58; 1.13)	0.22 [‡]	0.60	(0.47; 0.79)	<0.01 [‡]
3+	1.03	(0.71; 1.51)	0.84 [‡]	0.33	(0.20; 0.54)	<0.01 [‡]	0.63	(0.40; 0.98)	0.04 [‡]
Females									
High Blood Pressure									
No	1		0.38 [†]	1		0.11 [†]	1		0.20 [‡]
Yes	0.81	(0.51; 1.29)		1.32	(0.93; 1.87)		0.79	(0.55; 1.13)	
High Triglycerides									
No	1		0.35 [†]	1		0.69 [†]	1		0.78 [‡]
Yes	0.90	(0.71; 1.12)		0.94	(0.74; 1.22)		1.04	(0.78; 1.38)	
Low HDL-C									
No	1		0.04 [†]	1		0.82 [†]	1		0.02 [‡]
Yes	1.16	(1.00; 1.34)		0.97	(0.81; 1.17)		1.27	(1.04; 1.55)	
High Fasting Glucose									
No	1		0.33 [†]	1		0.15 [†]	1		0.74 [‡]
Yes	0.77	(0.45–1.31)		1.48	(0.86–2.55)		0.92	(0.55–1.51)	
Abdominal Obesity									
No	1		0.99 [†]	1		0.35 [†]	1		<0.01 [‡]
Yes	1.00	(0.79; 1.27)		0.88	(0.68; 1.14)		0.75	(0.61; 0.91)	
Metabolic syndrome									
No	1		0.63 [†]	1		0.09 [†]	1		0.08 [‡]
Yes	1.20	(0.56; 2.59)		1.68	(0.91; 3.08)		0.63	(0.38; 1.06)	
Number of cardiometabolic risk factors									
0 [§]	1			1			1		
1	1.06	(0.90; 1.25)	0.48 [‡]	1.01	(0.82; 1.23)	0.92 [‡]	1.04	(0.86; 1.25)	0.67 [‡]
2	0.93	(0.76; 1.14)	0.48 [‡]	0.81	(0.64; 1.04)	0.10 [‡]	1.16	(0.87; 1.54)	0.31 [‡]
3+	1.14	(0.72; 1.79)	0.57 [‡]	1.37	(0.88; 2.12)	0.16 [‡]	0.82	(0.55; 1.22)	0.32 [‡]

OR Odds Ratio, CI Confidence interval

*Models adjusted for age, ethnicity, type of school, smoking, alcohol consumption, consumption of snacks in front of screens, and maturational status; † Results from logistic regression; ‡Results from multinomial logistic regression. §Reference category for multinomial logistic regression

Table 3 Adjusted association from binary or multinomial logistic regression between two-by-two combinations of adherence to each target movement behavior and cardiometabolic risk factors according to sex

Outcomes	Meets MVPA and sleep guidelines			Meets MVPA and screen time guidelines			Meets screen time and sleep guidelines		
	OR*	(95% CI)	p value	OR*	(95% CI)	p value	OR*	(95% CI)	p value
Males									
High Blood Pressure									
No	1		0.14 [†]	1		0.06 [†]	1		0.13 [†]
Yes	0.60	(0.31; 1.17)		0.72	(0.52; 1.01)		0.75	(0.53; 1.08)	
High Triglycerides									
No	1		<0.01 [†]	1		<0.01 [†]	1		<0.01 [†]
Yes	0.59	(0.41; 0.84)		0.65	(0.49; 0.85)		0.50	(0.33; 0.77)	
Low HDL-C									
No	1		0.32 [†]	1		<0.01 [†]	1		<0.01 [†]
Yes	0.78	(0.49; 1.25)		0.67	(0.53; 0.85)		0.62	(0.44; 0.88)	
High Fasting Glucose									
No	1		0.89 [†]	1		0.52 [†]	1		0.86 [†]
Yes	1.04	(0.54–2.03)		0.82	(0.46–1.49)		1.06	(0.54–2.09)	
Abdominal Obesity									
No	1		0.26 [†]	1		0.68 [†]	1		0.23 [†]
Yes	0.76	(0.46; 1.23)		0.91	(0.60; 1.40)		0.71	(0.41; 1.23)	
Metabolic syndrome									
No	1		0.02 [†]	1		0.12 [†]	1		0.04 [†]
Yes	0.48	(0.25; 0.90)		0.57	(0.28; 1.17)		0.48	(0.24; 0.96)	
Number of cardiometabolic risk factors									
0 [§]	1			1			1		
1	0.81	(0.52; 1.27)	0.35 [‡]	0.80	(0.59; 1.07)	0.14 [‡]	0.99	(0.71; 1.40)	0.99 [‡]
2	0.97	(0.52; 1.82)	0.93 [‡]	0.60	(0.45; 0.81)	<0.01 [‡]	0.51	(0.33; 0.79)	<0.01 [‡]
3+	0.41	(0.21; 0.83)	0.01 [‡]	0.55	(0.32; 0.93)	0.03 [‡]	0.34	(0.17; 0.65)	<0.01 [‡]
Females									
High Blood Pressure									
No	1		0.52 [†]	1		<0.01 [†]	1		0.62 [†]
Yes	0.84	(0.49; 1.44)		0.52	(0.33; 0.81)		1.21	(0.56; 2.63)	
High Triglycerides									
No	1		0.69 [†]	1		0.06 [†]	1		0.23 [†]
Yes	1.08	(0.74; 1.55)		0.78	(0.61; 1.01)		0.84	(0.64; 1.11)	
Low HDL-C									
No	1		0.11 [†]	1		<0.01 [†]	1		0.99 [†]
Yes	1.30	(0.94; 1.81)		1.40	(1.11; 1.78)		1.00	(0.80; 1.23)	
High Fasting Glucose									
No	1		0.89 [†]	1		0.49 [†]	1		0.08 [†]
Yes	0.95	(0.46–1.96)		0.84	(0.51–1.38)		0.63	(0.38–1.06)	
Abdominal Obesity									
No	1		0.37 [†]	1		0.40 [†]	1		0.03 [†]
Yes	1.19	(0.81; 1.77)		0.89	(0.69; 1.15)		0.70	(0.51; 0.96)	
Metabolic syndrome									
No	1		0.80 [†]	1		0.64 [†]	1		0.46 [†]
Yes	1.00	(0.44; 2.27)		0.88	(0.51; 1.51)		0.74	(0.33; 1.65)	
Number of cardiometabolic risk factors									
0 [§]	1			1			1		
1	1.12	(0.74; 1.72)	0.57 [‡]	1.27	(0.98; 1.66)	0.07 [‡]	1.10	(0.79; 1.53)	0.56 [‡]
2	1.36	0.88; 2.10)	0.16 [‡]	0.95	(0.69; 1.30)	0.77 [‡]	0.89	(0.66; 1.21)	0.47 [‡]
3+	1.05	(0.45; 2.45)	0.90 [‡]	1.04	(0.71; 1.53)	0.84 [‡]	0.63	(0.36; 1.08)	0.09 [‡]

OR Odds Ratio CI, Confidence interval

*Models adjusted for age, race/ethnicity, type of school, smoking, alcohol consumption, consumption of snacks in front of screens, and maturational status; [†] Results from logistic regression; [‡] Results from multinomial logistic regression; [§] Reference category for multinomial logistic regression

Table 4 Adjusted association from binary or multinomial logistic regression between meeting all the three movement behavior targets and cardiometabolic risk factors according to sex

Outcomes	Meets all 24-hour movement behavior targets		
	OR*	(95% CI)	p-value
Males			
High Blood Pressure			
No	1		< 0.01 [†]
Yes	0.34	(0.20; 0.58)	
High Triglycerides			
No	1		< 0.01 [†]
Yes	0.47	(0.28; 0.78)	
Low HDL-C			
No	1		0.10 [†]
Yes	0.59	(0.32; 1.10)	
High Fasting Glucose			
No	1		0.77 [†]
Yes	1.17	(0.41; 3.28)	
Abdominal Obesity			
No	1		0.89 [†]
Yes	0.95	(0.47; 1.92)	
Metabolic syndrome			
No	1		0.01 [†]
Yes	0.36	(0.17; 0.78)	
Number of cardiometabolic risk factors			
0 [§]	1		
1	0.87	(0.43; 1.76)	0.70 [‡]
2	0.49	(0.28; 0.87)	0.02 [‡]
3+	0.30	(0.13; 0.68)	< 0.01 [‡]
Females			
High Blood Pressure			
No	1		0.71 [†]
Yes	0.87	(0.41; 1.83)	
High Triglycerides			
No	1		0.12 [†]
Yes	0.72	(0.47; 1.09)	
Low HDL-C			
No	1		0.10 [†]
Yes	1.46	(0.93; 2.31)	
High Fasting Glucose			
No	1		0.78 [†]
Yes	0.89	(0.42; 1.92)	
Abdominal Obesity			
No	1		0.76 [†]
Yes	1.06	(0.71; 1.57)	
Metabolic syndrome			
No	1		0.71 [†]
Yes	1.18	(0.48; 2.92)	
Number of cardiometabolic risk factors			
0 [§]	1		
1	1.59	(0.91; 2.79)	0.10 [‡]
2	0.94	(0.60; 1.48)	0.80 [‡]
3+	1.21	(0.63; 2.32)	0.55 [‡]

OR Odds Ratio, CI Confidence interval

Table 4 (continued)

	Meets all 24-hour movement behavior targets
*Results adjusted for age, race/ethnicity, type of school, smoking, alcohol consumption, consumption of snacks in front of screens, and maturational status; † Results from logistic regression; ‡Results from multinomial logistic regression; §Reference category for multinomial logistic regression	

the number of males meeting the guidelines. These findings may help explain the sex differences observed in the relationship between adherence to the 24-Hour Movement Guidelines and undesirable cardiometabolic indicators. Previous studies have demonstrated the modifying effects of sex on the relationship between MVPA and cardiometabolic outcomes, including metabolic syndrome, hypertension, obesity, diabetes, glucose, and lipid metabolism [29–33]. These studies suggested a greater protective effect of MVPA on undesirable cardiometabolic indicators in males compared to females [32, 33].

Sex-specific differences in the impact of MVPA on undesirable cardiometabolic indicators, including metabolic syndrome, are influenced by biological, behavioral, and social mechanisms [32, 34]. Estrogen in females provides a protective effect against cardiometabolic risk factors by influencing fat distribution and enhancing insulin sensitivity, while androgens in males affect muscle mass and fat distribution, modulating the metabolic benefits of MVPA [32, 34]. Estrogen promotes the accumulation of subcutaneous fat, which is metabolically less harmful than visceral fat, the latter being linked to higher cardiometabolic risk. Additionally, estrogen enhances insulin sensitivity, aiding in effective glucose regulation and mitigating metabolic syndrome risk factors [32, 34]. Conversely, androgens, such as testosterone, promote greater muscle mass and influence fat distribution towards more visceral areas [35]. As males generally have higher levels of visceral fat, its reduction through MVPA is more pronounced, leading to greater improvements in cardiometabolic biomarkers. Muscle mass plays a critical role in metabolism and insulin sensitivity, thereby enhancing the effectiveness of MVPA in reducing metabolic risk factors in males [30]. The combination of higher muscle mass and MVPA improves the utilization of glucose and fatty acids, reduces insulin resistance, and significantly enhances overall cardiometabolic health in males compared to females [35, 36].

In relation to MVPA behavioral patterns, these may explain the sex differences observed in this study regarding the relationship between adherence to the 24-Hour Movement Guidelines and undesirable cardiometabolic indicators. Males generally engage in higher-intensity physical activities compared to females [37]. High-intensity physical activities exert a greater effect on the release of anabolic hormones, which increase muscle

mass, elevate basal metabolism, enhance the utilization of muscle glycogen, and subsequently improve insulin sensitivity [35, 36]. Additionally, these activities induce a higher excess post-exercise oxygen consumption (EPOC) compared to lower-intensity activities, which is associated with a more significant impact on undesirable cardiometabolic indicators [32].

The present study found that, in males, simultaneous adherence to two targeted movement behaviors significantly reduced the odds of various cardiometabolic risk factors, regardless of the specific combination analyzed. These findings highlight that combined adherence to movement behavior targets is more effective than focusing on a single behavior, emphasizing a holistic approach to healthy movement behaviors [1]. Previous research indicates that adhering to screen time recommendations improves cardiometabolic outcomes [38, 39] and that adequate sleep duration in adolescents is linked to healthy blood pressure and lower inflammatory markers [40]. It is hypothesized that, for males, the effects of adherence to 24-Hour movement behaviors on certain cardiometabolic outcomes may be further amplified due to males' tendency to accumulate more visceral fat, exhibit greater susceptibility to insulin resistance, and experience higher blood pressure levels compared to females [41, 42].

In our study, adherence to MVPA recommendations and reduced recreational screen time in females significantly decreased the odds of having two cardiometabolic risk factors (i.e., high blood pressure and low HDL-C). Other combinations of 24-Hour movement behaviors showed weaker or non-significant associations. A systematic review and meta-analysis identified two longitudinal and 12 cross-sectional studies, indicating high physical activity and low sedentary behavior correlate with favorable cardiometabolic markers in adolescents of both sexes [7]. Our findings align with this literature, suggesting that favorable cardiometabolic health can be achieved by increasing MVPA levels and reducing recreational screen time [38].

The findings of the present study, which identified sex differences in the association between adherence to the 24-Hour Movement Guidelines and undesirable cardiometabolic indicators, reinforce a recent debate in this field: the necessity of proposing guidelines that consider the specific characteristics of different population subgroups. This debate, led by Tremblay et al. [43], questions the current "one-size-fits-all" approach to the 24-Hour Movement Guidelines. The Canadian 24-Hour Movement Guidelines and those of other countries recommend the same amount of MVPA, recreational screen time, and sleep hours for both males and females aged 5 to 17, with only sleep duration varying slightly by age group. Tremblay et al. [43] argue that while these

guidelines are relatively easy to interpret and feasible in public health terms, the evidence supporting their development primarily comes from low-quality studies that do not account for different population characteristics, such as sex, age, race, ethnicity, socioeconomic status, and health condition, which may influence how movement behaviors affect health indicators in different individuals. Additionally, the authors suggest that the 24-Hour Movement Guidelines should be revised based on a "precision health" approach that considers the diverse characteristics of children and adolescents. The present study provides evidence that the association between adherence to the 24-Hour Movement Guidelines and undesirable cardiometabolic indicators varies by sex, supporting Tremblay et al.'s [43] proposition for a "precision health" approach.

The present research has several limitations. First, the cross-sectional design precludes the establishment of causal relationships between variables, and the potential for reverse causality is inherent in this design. Second, the investigation focused on general recreational screen time without distinguishing between active or passive screen time, which is a notable limitation. Previous studies have shown sex differences in the adoption of active versus passive screen time [44]. Third, this study did not assess total sitting time among adolescents; instead, it measured recreational screen time as an indicator of sedentary behavior. The recommendations adopted [1] focus specifically on limiting recreational screen time (≤ 2 h/day) and reducing prolonged periods of sitting. Fourth, this study did not employ a compositional analytical approach to 24-Hour movement behaviors. Such an approach considers the total distribution of time across different movement behaviors throughout the day, rather than merely analyzing adherence to each behavior individually [45].

This study has several strengths, notably the complex sampling involving adolescent students from all Brazilian capitals and cities with more than 100,000 inhabitants, ensuring the external validity of the research. Another significant strength of this study is the rigorous methodology employed in the analysis and storage of blood samples, which was conducted by specialized professionals and laboratories. Additionally, investigating 24-Hour movement behaviors is another strength of this research, as it aligns with holistic perspectives on movement behavior analysis [1]. Finally, conducting a study in a middle-income country adds valuable information to the literature on adherence to the 24-Hour Movement Guidelines, which is predominantly derived from high-income countries.

Conclusions

There was a direct association between adherence to the 24-Hour Movement Guidelines and lower odds of high blood pressure, high triglycerides, metabolic syndrome, and the presence of two or more undesirable cardiometabolic indicators in Brazilian male adolescents. For females, no association between adherence to the 24-Hour Movement Guidelines and undesirable cardio-metabolic indicators was found in this study.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12889-025-24886-4>.

Supplementary Material 1.

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Authors' contributions

DASS was responsible for study concept and design, assisted with data interpretation, and drafted the manuscript; TRL conducted the statistical analyses, and was the primary sources for data interpretation; FAGV, KVB, and FVC were responsible for data acquisition, assisted with data interpretation, and edited the manuscript; MST assisted with data interpretation and edited the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

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Data availability

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study adheres to ethical guidelines. The Ethical Committee of the Federal University of Rio de Janeiro – Brazil approved the study in January, 2009. Written informed consent was obtained from each student, and also from their parents for those who are invited to take blood collection. They were also granted access to the study results if desired. The researchers complied with the principles outlined in the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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