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Joint associations of accelerometer-measured physical activity and sedentary time with body mass index: Cross-sectional evidence from the Latin American Study of Nutrition and Health

Eduardo Rossato de Victo^{a,b}, Georgina Gómez^c, Mauro Fisberg^{d,e}, Irina Kovalskys^f, Paloma Ferrero-Hernandez^g, Claudio Farias-Valenzuela^h, Tatiane K.F. Figueiredoⁱ, Gerson Ferrari^{j,*}

^a Núcleo de Investigación en Ciencias del Movimiento, Universidad Arturo Prat, Iquique, Chile

^b Postgrad Program in Health Sciences, Faculdade Israelita de Ciências da Saúde Albert Einstein, Hospital Israelita Albert Einstein, São Paulo, SP, Brazil

^c Departamento de Bioquímica, Escuela de Medicina, Universidad de Costa Rica, San José, Costa Rica

^d Instituto Pensi, Fundação José Luiz Egydio Setubal, Hospital Infantil Sabará, São Paulo, Brazil

^e Departamento de Pediatria da Universidade Federal de São Paulo, São Paulo, Brazil

^f Carrera de Nutrición, Facultad de Ciencias Médicas, Pontificia Universidad Católica Argentina, Buenos Aires, Argentina

^g Vicerrectoría de Investigación e Innovación, Universidad Arturo Prat, Chile

^h Escuela de Ciencias de la Actividad Física, Universidad de Las Américas, Santiago, Chile

ⁱ Facultad de Ciencias de la Salud, Universidad Autónoma de Chile, Campus Providencia, Santiago, Chile

^j Escuela de Ciencias de la Actividad Física, el Deporte y la Salud, Universidad de Santiago de Chile (USACH), Santiago, Chile

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ABSTRACT

Background: More research is required to determine the joint associations of physical activity and sedentary time with body mass index (BMI) in Latin America. Therefore, the objective of the present study was to investigate said associations in eight countries in the region.

Methods: Physical activity and sedentary time were measured using accelerometers in 2404 participants aged 39.30 ± 12.93 years who took part in the Latin American Study of Nutrition and Health. Linear regression was used to investigate associations with BMI and logistic regression was used to investigate associations with obesity.

Results: The average BMI was 27.51 ± 5.35 kg/m². Physical activity was inversely associated with BMI, such that every 30 min/day was associated with a BMI 3.75 kg/m² lower. Compared to the group with high physical activity and low sedentary time, the odds ratio for obesity was no greater in the group with high physical activity and high sedentary time [0.70 (0.45,1.09)]. The risk was greater in the group with low physical activity and low sedentary time, although the confidence interval was relatively wide and included the value of 1.00 [1.36 (0.92,1.80)]. The risk was greater in the group with low physical activity and high sedentary time [1.71 (1.21,2.41)].

Conclusions: Weight loss is incredibly difficult at the population level and primary prevention may be more effective in countries where obesity is still emerging as a major health issue. This study suggests that physical activity may have a more important role than sedentary time in the primary prevention of obesity in Latin America.

Trial registration: ClinicalTrials.Gov NCT02226627. Retrospectively registered on August 27, 2014.

Abbreviations: BMI is body mass index;, MVPA is moderate-to-vigorous physical activity; WHO is World Health Organization;, ELANS is Latin American Study of Nutrition and Health.

* Correspondence to: Escuela de Ciencias de la Actividad Física, el Deporte y la Salud, Facultad de Ciencias Médicas, Universidad de Santiago de Chile, USACH, Las Sophoras 175, Estación Central, Santiago, Chile

E-mail address: gerson.demoraes@usach.cl (G. Ferrari).

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1. Background

Obesity is a major public health concern, recognized by the World Health Organization (WHO) as a key risk factor for non-communicable diseases, including cardiovascular diseases, diabetes, chronic respiratory diseases, and certain types of cancer [1]. The prevalence of overweight and obesity is increasing across all age groups in most parts of the world, affecting children, adolescents, and adults [2,3]. WHO data currently show that 43 % of the global population aged 18 years or older has a body mass index (BMI) of 25 kg/m² or higher [1]. In the Americas, this proportion reaches 67 %, making it the region with the highest prevalence of excess weight globally, which underscores the concern for excess weight in the region [1]. The economic burden of overweight and obesity is substantial, estimated to be around 2.2 % of global gross domestic product, with projections indicating a rise to 3.3 % by 2060 [4].

To address this challenge, international guidelines emphasize promoting physical activity and reducing sedentary behavior as strategies to prevent and control obesity and other non-communicable diseases [5, 6]. However, despite these recommendations, there remains a gap in understanding the joint associations between physical activity, sedentary behavior, and obesity, particularly within the specific context of Latin America [5–9]. While some studies have explored these associations using accelerometer-measured data in various populations, there's an ongoing debate about how physical activity might mitigate or eliminate the detrimental effects of sedentary time on health [10–14].

Specifically, more research is needed to understand these associations in Latin America [13,15]. Studies that pool population data from Latin America with those from other regions may be inappropriate due to significant differences in income, health, and healthcare systems between them [15–19]. Therefore, the objective of this analysis was to investigate the joint associations of physical activity and sedentary time with BMI in adults in Latin America.

2. Methods

2.1. Study design and sample

The Latin American Study of Nutrition and Health (ELANS, according to its initials in Spanish) is described in detail elsewhere [20]. Briefly, the ELANS is an eight-country, observational epidemiological study. The design was based on a complex and multistage sample, stratified by conglomerates, with all the regions from each country represented, and random selection of the main urban areas within each region according to the proportional probability to size method. The target sample was 9000 adolescents and adults aged 15–65 years living in households in cities in Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, and Peru. Each sample was stratified by age, gender, and socioeconomic status in order to be representative of the country [20]. A standardized and harmonized protocol was used to collect data across the eight countries [20]. Field workers were trained for 7–10 days, participants were interviewed in their homes, and data were collected in 2014 and 2015 [20,21]. The ELANS protocol was approved by the Western Institutional Review Board (approval number 20140605). Local review boards also approved the protocol. All adolescents aged less than 18 years completed an assent form and participated with the consent of a parent or legal guardian. All adults signed a consent form before participating in the study. It was planned that physical activity and sedentary time would be assessed using accelerometers in a sub-sample of 3600 people [20]. The present analysis includes 2404 participants aged 20 years or older with valid accelerometer data, which is equivalent to two thirds of the planned sub-sample. The accelerometer sub-sample was randomly selected to fill quotas by sex, age, and socioeconomic status. For logistical and financial reasons, efforts were made to ensure that a range of 23–34 % of participants from each specific country each sample wore the accelerometer on all seven days.

2.2. Outcome variable

The main outcome variable was BMI, which was expressed as weight in kilograms divided by height in meters squared. Body weight was measured with a calibrated electronic scale up to 200 kg with an accuracy of 0.1 kg (Seca Corporation, Hamburg, Germany). Height was measured with a Seca 213 portable stadiometer up to 205 cm with an accuracy of 0.1 cm. The measurements were taken during inspiration, with the base of the stadiometer lightly touching the upper reaches of the head and with the participant's head in the Frankfort Plane.

The trained field workers measured weight and height after pockets were emptied and heavy clothes, shoes, and socks were removed. Weight and height were measured twice and the average value was used in the analysis. A third measurement was taken if weight differed by more than 0.1 kg and if height differed by more than 0.5 cm [20]. All equipment was calibrated regularly and replaced if faulty.

2.3. Exposure variables

The main exposure variables were physical activity and sedentary time, as measured using accelerometers. The accelerometer protocol is described in detail elsewhere [21]. Briefly, participants were asked to wear an accelerometer on the right hip for seven days (model GTX3 +, ActiGraph, Pensacola, Florida, USA). Participants were instructed to wear the accelerometer while awake and to remove it while sleeping, showering or swimming. Participants were encouraged to wear the device for at least 12 h a day. Accelerometer data were processed using ActiLife software (Version 6.0, ActiGraph, Pensacola, Florida, USA). Data were collected at a sampling rate of 30 hertz and downloaded in epochs of 60 s. Moderate-to-vigorous physical activity (MVPA) was defined as ≥ 1952 accelerometer counts per minute [22]. Sedentary time was defined as ≤ 100 counts per minute [22]. Non-wear time was defined as at least 60 consecutive minutes of zero counts [23]. Having valid accelerometer data was defined as a minimum of five days (including at least one weekend day) with at least ten hours per day of wear time following the removal of sleep time [24,25]. Participants were instructed to complete a daily log, and to report the time they put the accelerometer belt on and the time when it was removed. Sleep duration was calculated by identifying non-wear time during valid accelerometer days, identifying the time between going to bed (removing the device) and waking up (wearing the device). Accelerometers are thought to be sufficiently valid and reliable to be used to assess physical activity in children and adults [26].

2.4. Potential confounders

Potential confounders that may influence the relationships between physical activity, sedentary time, and BMI include age, sex, energy intake, and socioeconomic level [27,28]. The questionnaires used to assess potential confounders are described in detail elsewhere [20]. Energy intake was assessed using the information on food and drink intake that was obtained on two non-consecutive days within one week [20]. The trained field workers conducted semi-structured interviews that included multiple passes through the 24 h of the previous day [20]. Then, nutritionists converted food and drink intake into energy intake using the Nutrition Data System for Research computer program (NDS-R, Minnesota University, MN, USA; 2013 version) [29]. The multiple pass method has been shown to reduce bias in the collection of energy intakes [30]. Diet quality was assessed using the "Dietary Diversity Score (DDS)" [20,29,30]. DDS classified foods in nine groups: (i) cereals, (ii) white roots and tubers, (iii) vegetables, (iv) fruits, (v) meat, poultry, and offal, (vi) fish and seafood, (vii) eggs, (viii) pulses, legumes, and nuts; and (ix) milk and dairy products. The consumption of 15 g for each food group (equivalent to a tablespoon) was the cut-off point for meeting or not meeting the recommendation [20,29,30]. Alcohol consumption was assessed using the Beverage Intake Questionnaire

designed to obtain the frequency of beverage. Alcoholic beverages were deemed as beer, wines, and liquor and cocktails. The sum of these group of beverages was calculated and then the median for these two groups were calculated to provide a cut-off point for meeting the recommendations. The cut-off point alcohol beverages 0.5 of a glass [20,29,30]. Socioeconomic level was assessed using country-specific questionnaires that included questions about the participant's home and about the head of household's income, occupation, and education [31].

2.5. Statistical analyses

Participants' characteristics are presented for the entire ELANS sample and the accelerometry sub-sample. Means and standard deviations are used to describe continuous variables and numbers and percentages are used to describe categorical variables. In the main analysis, multiple linear regression was used to investigate joint associations of physical activity and sedentary time with BMI after adjustment for potential confounders. Body mass index (kg/m^2), physical activity (min/day), sedentary time (min/day), age (years), and energy intake (kcal/day) were expressed as continuous variables. Sex (male or female), socioeconomic level (low, medium, or high), diet quality (adherence or no) and alcohol consumption (adherence or no) were expressed as categorical variables. The model also included an interaction term between physical activity and sedentary time. The Wald statistic was used to test whether the interaction term was statistically significant. Data from participants of all ages were included in the main analysis.

In the secondary analysis, logistic regression was used to investigate joint associations of physical activity and sedentary time with obesity. Obesity was defined as a BMI of 30 or more, according to the World Health Organization definition [5]. Physical activity and sedentary time were defined as high or low and four groups were created: high physical activity and low sedentary time (reference); high physical activity and high sedentary time; low physical activity and low sedentary time; and, low physical activity and high sedentary time. Individuals were categorized as meeting (high) or not meeting (low) the World Health Organization's physical activity recommendations, which advise adults to engage in 150–300 min per week of moderate-intensity aerobic physical activity, 75–150 min per week of vigorous-intensity aerobic physical activity, or an equivalent combination of both intensities [6]. For sedentary time, the 50th percentile was used as a cut-off point (high: >50th; low: <50th) due to inconsistencies in the literature regarding various thresholds (e.g., ≥ 4 , ≥ 6 , and ≥ 8 h per day) across different health outcomes. Currently, there is insufficient evidence to establish a specific public health recommendation (a single cut-off) for sedentary behavior limits to optimize cardiovascular health benefits [6]. Models were adjusted for age, sex, socioeconomic level, energy intake, alcohol consumption, and diet quality using the same definitions as the linear regression models. Weighting was done according to sociodemographic characteristics, sex, socioeconomic level, and country. All analyses were performed using IBM SPSS Statistics (IBM Corp., NY, USA; version 26).

3. Results

The medians for MVPA and sedentary time in the full sample and each category are presented in [Supplementary Material \(Table S1\)](#). Median MVPA was 28.0 min per day, and median sedentary time was 558.1 min per day.

[Table 1](#) shows the characteristics of the 5590 participants in ELANS and the 2404 participants in the sub-sample in which accelerometry was used to assess physical activity and sedentary time. Age, proportion of males, BMI, energy intake, adherence to diet quality and alcohol consumption guidelines, and socioeconomic level were similar between the entire sample and the sub-sample. Age was 38.41 ± 12.73 years in the entire sample and 39.30 ± 12.93 in the sub-sample. BMI was $27.52 \pm 5.58 \text{ kg}/\text{m}^2$ in the entire sample and $27.51 \pm 5.35 \text{ kg}/\text{m}^2$ in the

Table 1

Characteristics of participants in the Latin American Study of Nutrition and Health and the accelerometry sub-sample.

	Entire sample, n = 5590	Accelerometer sub-sample, n = 2404
Age in years, mean \pm SD	38.41 \pm 12.73	39.30 \pm 12.93
Male sex, n (%)	2610 (46.1)	1116 (46.6)
BMI in kg/m^2 , mean \pm SD	27.52 \pm 5.58	27.51 \pm 5.35
Obesity (BMI \geq 30 kg/m^2), n (%)	1403 (25.1)	665 (27.7)
MVPA in min/day, mean \pm SD	-	34.02 \pm 24.88
Sedentary time in min/day, mean \pm SD	-	566.53 \pm 24.88
Energy intake in kcal/day, mean \pm SD	1984.35 \pm 609.32	1997.17 \pm 634.86
Adherence to diet quality guidelines, n (%)	2189 (39.1)	987 (41.0)
Adherence to alcohol consumption guidelines, n (%)	3085 (55.2)	1310 (54.5)
Socioeconomic level		
Low, n (%)	2935 (52.5)	1217 (50.7)
Medium, n (%)	2136 (38.2)	938 (39.0)
High, n (%)	519 (9.3)	249 (10.3)
Country		
Argentina, n (%)	850 (15.2)	264 (11.0)
Brazil, n (%)	1264 (22.6)	500 (20.8)
Chile, n (%)	496 (8.9)	265 (11.0)
Colombia, n (%)	777 (13.9)	305 (12.7)
Costa Rica, n (%)	441 (7.9)	236 (9.8)
Ecuador, n (%)	440 (7.9)	232 (9.6)
Peru, n (%)	664 (11.9)	284 (11.8)
Venezuela, n (%)	658 (11.8)	318 (13.2)

MVPA: Moderate-to-vigorous physical activity; BMI: body mass index

sub-sample. Mean MVPA was 34.02 ± 24.88 min per day and mean sedentary time was 566.53 ± 24.88 min per day in the accelerometry sub-sample. The proportion of data from each country was also similar in the entire sample and the sub-sample.

[Table 2](#) shows the joint associations of physical activity and sedentary time with BMI in the accelerometry sub-sample. Physical activity was inversely associated with BMI, with every minute of MVPA per day associated with a BMI that was $0.125 \text{ kg}/\text{m}^2$ lower. Sedentary time was also inversely associated with BMI, with every minute of sedentary time per day associated with a BMI that was $0.007 \text{ kg}/\text{m}^2$ lower. No statistically significant interaction was observed between physical activity and sedentary time.

[Table 3](#) shows joint associations of physical activity and sedentary time with BMI in each country after adjustment for age and sex. Physical activity was more strongly associated with BMI than sedentary time in each of the eight Latin American countries.

[Table 4](#) shows the joint associations of physical activity and sedentary time with obesity. Compared to the group with high physical

Table 2

Joint associations of physical activity and sedentary time with body mass index*.

Variable	Coefficient (95 % confidence interval)
MVPA (min/day)	-0.125 (-0.151, -0.100)
Sedentary time (min/day)	-0.007 (-0.005, -0.009)
Interaction term	0.002 (-0.001, 0.003)

*Data are from 2404 participants in the ELANS accelerometry sub-sample (ELANS is the Latin American Study of Nutrition and Health, according to its initials in Spanish). Values are mutually adjusted linear regression coefficients. Models were adjusted for age, sex, socioeconomic level, energy intake, alcohol consumption, and diet quality. The regression coefficient for each variable shows the expected change in body mass index, expressed as kg/m^2 . The interaction term is the product of the MVPA and sedentary time variables. The Wald statistic for the interaction term was -1.087 ($p = 0.277$).

MVPA: Moderate-to-vigorous physical activity

Table 3

Joint associations of physical activity and sedentary time with body mass index in each of the eight countries in ELANS*.

Country	Physical activity	Sedentary time
Argentina	−0.033 (−0.062, −0.003)	−0.003 (−0.008, 0.003)
Brazil	−0.023 (−0.042, −0.004)	−0.005 (−0.009, −0.001)
Chile	−0.021 (−0.046, 0.005)	−0.003 (−0.008, 0.002)
Colombia	−0.041 (−0.060, −0.022)	−0.003 (−0.008, 0.001)
Costa Rica	−0.034 (−0.060, −0.008)	−0.003 (−0.009, 0.003)
Ecuador	−0.031 (−0.051, −0.011)	−0.003 (−0.009, 0.002)
Peru	−0.037 (−0.057, −0.017)	−0.001 (−0.006, 0.004)
Venezuela	−0.035 (−0.062, −0.009)	−0.013 (−0.018, −0.008)

*ELANS is the Latin American Study of Nutrition and Health, according to its initials in Spanish. Values are linear regression coefficients (95 % confidence interval). Models were adjusted for age, sex, socioeconomic level, energy intake, alcohol consumption, and diet quality.

Table 4

Joint associations of physical activity and sedentary time with obesity*.

	Low sedentary time	High sedentary time
Low physical activity	1.36 (0.92, 1.80)	1.71 (1.21, 2.41)
High physical activity	1.00 (Reference)	0.70 (0.45, 1.09)

**Data are from 2404 participants aged 20 years or older in the ELANS accelerometer sub-sample (ELANS is the Latin American Study of Nutrition and Health, according to its initials in Spanish). Physical activity and sedentary time were expressed in min/day and were defined as high or low. Obesity was defined as body mass index of 30 or more. Values are mutually adjusted odds ratios (95 % confidence interval). Models were adjusted for age, sex, socioeconomic level, energy intake, alcohol consumption, and diet quality.

activity and low sedentary time, the risk of obesity was not significantly greater in the group with high physical activity and high sedentary time after adjustment for age, sex, socioeconomic level, energy intake, alcohol consumption, and diet quality (odds ratio: 0.70; 95 % confidence interval: 0.45, 1.09). The risk of obesity was significantly greater in the group with low physical activity and high sedentary time (odds ratio: 1.71; 95 % confidence interval: 1.21, 2.41).

4. Discussion

The objective of the present study was to investigate joint associations of physical activity and sedentary time with BMI in eight countries in Latin America. In the main analysis, we found that physical activity was strongly and inversely associated with BMI, such that every 30 min of physical activity per day was associated with a BMI that was 3.75 kg/m² lower. We also found that sedentary time was weakly and inversely associated with BMI, such that every 30 min of sedentary time per day was associated with a BMI that was 0.21 kg/m² lower. In the secondary analysis, we found that the odds ratio for obesity was no greater in the group with high physical activity and low sedentary time compared to the group with high physical activity and high sedentary time. We also found that the risk of obesity was greater in the group with low physical activity and high sedentary time compared to the group with high physical activity and high sedentary time. Overall, the present study suggests that physical activity is inversely associated with markers of adiposity independent of sedentary time and other potential confounders.

Our results, based on data from eight Latin American countries (comprising 2404 individuals), provide a unique regional perspective on the joint associations between physical activity and sedentary time with BMI, allowing comparisons with global populations. To our knowledge, this is the largest such study conducted in Latin America using accelerometer-measured physical activity. For instance, the multinational study by Van Dyck et al. [15], which included accelerometer-based data from 5712 adults (330 in Brazil, 223 in

Colombia, and 656 in Mexico) across 10 countries from different continents, similarly highlighted the predominant role of physical activity. They reported significant inverse associations between MVPA and BMI in several countries, including Brazil, Colombia, and Mexico, while weaker or non-significant associations were observed in some European contexts such as Spain, the Czech Republic, and the United Kingdom. Van Dyck et al.'s study generally found no significant associations between sedentary time and BMI in most settings, with positive associations observed only among women in the United States.

Aligning with these global observations, our analysis showed that physical activity was inversely associated with BMI in nearly all (seven out of eight) Latin American countries, with the strongest associations in Colombia ($\beta = -0.041$) and Peru ($\beta = -0.037$). In contrast, sedentary time generally showed weak or non-significant inverse associations with BMI across most countries in our study, although we found significant inverse associations in Venezuela ($\beta = -0.013$) and Brazil ($\beta = -0.005$). These cross-regional and intra-regional comparisons reinforce the evidence that physical activity plays a more decisive role than sedentary time in determining adiposity, although cultural, environmental, and behavioral differences may influence the strength and direction of these associations across populations [15].

The present study adds to the ongoing debate about the joint associations of physical activity and sedentary time with obesity and supports the notion that public health guidelines may need to give greater emphasis to increasing physical activity rather than reducing sedentary time [14]. However, experimental evidence shows that some people may compensate for physical activity energy expenditure by increasing sedentary time [32]. For example, a review of 24 exercise training interventions found that there was a compensatory decrease in non-exercise physical activity in two thirds of the interventions [32]. It should be stressed that any compensatory decreases in non-exercise physical activity and any compensatory increases in food intake with exercise training are thought to be small in magnitude [32,33]. Indeed, exercise training is accompanied by a mean weight loss of −1.5 to −3.5 kg in adults with overweight or obesity [34].

The present study may have important implications for policy and practice because evidence about overweight and obesity from high-income countries may not be generalizable to low- and middle-income countries [28,35,36]. There is an ongoing transition of overweight and obesity from the wealthy to the poor in low- and middle-income countries [37]. Weight loss is incredibly difficult at the population level [36, 38], and it is now thought that the promotion of healthy lifestyles may be a more effective strategy than the promotion of weight loss in low- and middle-income countries where obesity is still emerging as a major health issue (that is, primary prevention may be more effective than secondary prevention in low- and middle-income countries) [36,37]. We found that physical activity was more strongly associated with BMI in each of the eight countries in Latin America. The present study suggests that physical activity may have a more important role than sedentary time in the primary prevention of overweight and obesity in Latin America. Dozens of cities in Latin America have adopted bold policies and practices that might help increase physical activity levels [39–41]. In Bogotá in Colombia, for example, more than 120 kilometers of roads are closed to motor vehicles every Sunday and public holiday and the streets fill with more than one million walkers, runners, and cyclists [42]. Furthermore, 42 % of participants report taking part in at least three hours of moderate to vigorous activity [43]. In Medellín in Colombia, up to 850,000 of 2.5 million residents use the city's sport and exercise facilities every month free of charge [40]. It has been argued that policy makers in other regions should implement comparable measures in order to tackle the "pandemic of physical inactivity" [41, 42].

This study has strengths and limitations. Key strengths include the objective measurement of physical activity and sedentary time using accelerometers, and rigorous adjustment for energy intake and other potential confounders. However, certain limitations should be

acknowledged. The cross-sectional design prevents establishing causality, necessitating prospective cohort studies to confirm our findings in Latin America. Although physical activity and sedentary time were objectively measured, the monitoring period of five to seven days might be less reliable than longer durations [44]. While our sample provided precise estimates for BMI associations, an even larger sample might be needed for more precise estimates concerning obesity outcomes. Additionally, despite the ELANS study's general representativeness [20], the present sub-samples may not fully represent each country due to Latin America's diversity [17,19]. Future research should consider combining accelerometers with questionnaires to capture both activity volume and specific domains, especially given the unique physical activity patterns in Latin America [26,45–47].

5. Conclusions

The Latin American Study of Nutrition and Health is a large cross-sectional study of eight countries and the present analysis suggests that physical activity is a more important determinant of BMI and obesity than sedentary time in adults in the region. Weight loss is incredibly difficult at the population level and this study may have implications for policy and practice in Latin America because it suggests that physical activity is more important than sedentary time in the primary prevention of obesity.

Ethics approval and consent to participate

The ELANS protocol was approved by the Western Institutional Review Board (approval number 20140605). Local review boards also approved the protocol. Adolescents aged less than 18 years completed an assent form and participated with the consent of a parent or legal guardian. Adults signed a consent form before participating in the study.

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CRediT authorship contribution statement

Irina Kovalskys: Writing – review & editing, Methodology, Investigation. **Ferrero Hernandez Paloma Andrea:** Writing – review & editing, Validation, Investigation. **Claudio Farias-Valenzuela:** Writing – review & editing, Investigation. **K. F. Figueiredo Tatiane:** Writing – original draft, Project administration. **Georgina Gómez:** Writing – review & editing, Investigation. **Mauro Fisberg:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Eduardo Rosato de Victo:** Writing – review & editing, Investigation. **Gerson Ferrari:** Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Consent for publication

Not applicable.

Authors' contributions

GF conceived the study. GF and ERdV designed the study. GF analysed the data and is guarantor. GF and ERdV wrote the initial draft and revised the manuscript. All authors (GG, MF, IK, PF-H, CF-V, TKFF) helped to interpret the results and to revise the manuscript.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.orcp.2025.08.004](https://doi.org/10.1016/j.orcp.2025.08.004).

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due the terms of consent/assent to which the participants agreed but are available from the corresponding author on reasonable request. Please contact the corresponding author to discuss availability of data and materials.

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