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Revista Hacia la promoción de la SALUD

ISSN: 0121-7577 e-ISSN: 2462-8425

# Abdominal obesity, body mass index, and physical activity in children and adolescents in Los Nevados Natural Park

Received December 13, 2024, accepted July 13, 2025

**How to cite**
Melo-Betancourt LG, Castaño-Marín JC. Abdominal obesity, body mass index, and physical activity in children and adolescents in Los Nevados Natural Park. Hacia Promoc. Salud. 2025; 30(3): 9-19. DOI: 10.17151/hpsal.2025.30.3.2

## Abstract

**Objective**: To analyze abdominal obesity, body mass index (BMI), and physical activity (PA) levels in children and adolescents living on the outskirts of Los Nevados National Natural Park, Colombia. **Materials and methods:** A quantitative, cross-sectional study was conducted between June and September 2024 in rural schools at altitudes above 3600 m. A convenience sample of 42 schoolchildren (18 males and 24 females, average age 11.7 ± 2.7 years) was evaluated. Weight, height, BMI, waist circumference (WC), and waist-to-height ratio (WHR) were measured. The Physical Activity Questionnaire for Children (PAQ-C) and for Adolescents (PAQ-A) were administered. Descriptive and Pearson correlation analyses ($p \leq 0.05$) were performed. **Results:** The average BMI was 18.6 ± 3.1, within normal parameters. The WHI (0.43) was below the cutoff point (0.5), indicating no abdominal obesity. In physical education class, 46.4% of children and 50% of adolescents reported always being active. Post-school physical activity was practiced 2 to 3 times per week in 46.4% and 42.9% respectively, while on weekends the levels rose to 60.7% and 85.7%. A positive and significant correlation was found between BMI and WC in both age groups ($p < 0.01$). **Conclusions:** Children and adolescents living at high altitude have normal BMI, no abdominal obesity, and high levels of physical activity, suggesting a possible protective effect of the high-altitude environment against excess weight.

## Keywords

Abdominal obesity; body mass index; physical activity; children and adolescents (Sources: *DeCS, BIREME*).

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# Obesidad abdominal, índice de masa corporal y actividad física en niños y adolescentes del Parque Natural Los Nevados


## Resumen

**Objetivo:** Analizar la obesidad abdominal, el índice de masa corporal (IMC) y el nivel de actividad física (AF) en niños y adolescentes de la periferia del Parque Nacional Natural Los Nevados, Colombia. **Materiales y métodos:** Estudio cuantitativo, transversal, realizado entre junio y septiembre de 2024 en instituciones rurales a más de 3600 m de altitud. Se evaluó una muestra por conveniencia de 42 escolares (18 hombres y 24 mujeres, edad promedio 11,7 ± 2,7 años). Se midieron peso, talla, IMC, circunferencia de cintura (CC) e índice cintura-estatura (ICE). Se aplicaron los cuestionarios *Physical Activity Questionnaire for Children (PAQ-C)* y *for Adolescents (PAQ-A)*. Se realizaron análisis descriptivos y de correlación de Pearson ($p \leq 0,05$). **Resultados:** El IMC promedio fue 18,6 ± 3,1, dentro de parámetros normales. El ICE (0,43) estuvo por debajo del punto de corte (0,5), sin obesidad abdominal. En clase de educación física, el 46,4 % de los niños y el 50 % de los adolescentes reportaron estar siempre activos. La AF post-jornada fue practicada 2 a 3 veces por semana en el 46,4 % y 42,9 % respectivamente, mientras que el fin de semana los niveles ascendieron a 60,7 % y 85,7 %. Se halló correlación positiva y significativa entre IMC y CC en ambos grupos etarios ($p < 0,01$). **Conclusiones:** Los niños y adolescentes de alta montaña presentan IMC normal, ausencia de obesidad abdominal y niveles elevados de actividad física, lo que sugiere un posible efecto protector del entorno de altura frente al exceso de peso.



## Palabras clave

Obesidad abdominal; índice de masa corporal; actividad física; niños y adolescentes (Fuentes: *DeCS, BIREME*).


# Obesidade abdominal, índice de massa corporal e actividade física em crianças e adolescentes del Parque Natural Los Nevados


## Resumo

**Objetivo:** Analisar a obesidade abdominal, o índice de massa corporal (IMC) e o nível de atividade física (AF) em crianças e adolescentes da periferia do Parque Nacional Natural Los Nevados, Colômbia. **Materiais e métodos**: Estudo quantitativo, transversal, realizado entre junho e setembro de 2024 em instituições rurais a mais de 3600 m de altitude. Foi avaliada uma amostra por conveniência de 42 escolares (18 homens e 24 mulheres, idade média 11,7 ± 2,7 anos). Foram medidos o peso, a altura, o IMC, a circunferência da cintura (CC) e o índice cintura-estatura (ICE). Foram aplicados os questionários Physical Activity Questionnaire for Children (PAQ-C) e for Adolescents (PAQ-A). Foram realizadas análises descritivas e de correlação de Pearson ($p \leq 0,05$). **Resultados:** O IMC médio foi de 18,6 ± 3,1, dentro dos parâmetros normais. O ICE (0,43) ficou abaixo do ponto de corte (0,5), sem obesidade abdominal. Na aula de educação física, 46,4 % das crianças e 50 % dos adolescentes relataram estar sempre ativos. A AF pós-jornada foi praticada 2 a 3 vezes por semana em 46,4 % e 42,9 %, respetivamente, enquanto que no fim de semana os níveis subiram para 60,7 % e 85,7 %. Foi encontrada uma correlação positiva e significativa entre IMC e CC em ambos os grupos etários ($p < 0,01$). **Conclusões:** Crianças e adolescentes de alta montanha apresentam IMC normal, ausência de obesidade abdominal e níveis elevados de atividade física, o que sugere um possível efeito protetor do ambiente de altitude contra o excesso de peso.



## Palavras-chave

Obesidade abdominal; índice de massa corporal; atividade física; crianças e adolescentes (Fontes: *DeCS, BIREME*).

# Introduction

Human life at altitudes over 3,000 meters above sea level (masl) creates a distinct physiological environment characterized by chronic hypoxia, reduced barometric pressure, and extreme environmental conditions. These factors push forward biological adaptations with direct implications for the health of children, particularly regarding growth, body composition, and aerobic capacity. Findings from multinational research demonstrate that exposure at high altitudes systematically modulates child growth and development regardless of socio-economic determinants (1).

At the metabolic level, chronic hypoxia activates molecular pathways such as hypoxia-inducible factor 1-alpha (HIF-1α) in adipose tissue, modulating lipid metabolism and adipokine signaling, which underscores the multifaceted nature of systemic adaptation to high-altitude environments (2,3). Globally, it is estimated that over 418 million people live at moderate altitudes (1500–2499 m), and another 81 million live at higher altitudes, making high-altitude living a phenomenon of considerable public health relevance. It is worth noting that, while acute exposure to high altitude is consistently associated with reductions in physical performance, these results may not accurately represent the physiological adaptations observed in long-term high-altitude residents, due to acclimatization and developmental adjustment processes (4).

Epidemiological studies conducted in Peru have reported markedly lower prevalence rates of overweight among schoolchildren residing in high-altitude regions (6.3%) compared to their counterparts in coastal areas (41.3%) (5). Furthermore, the risk of abdominal obesity exhibits an inverse association with altitude, which persist even after adjustment for age, sex, and residential context (6). Complementary findings from the Tibetan Plateau (3,650 m) describe distinct anthropometric and physiological characteristics of high-altitude populations, underscoring the need to critically assess the validity of conventional anthropometric indicators in these environments (7). Taken together, this evidence highlights the importance of researching obesity patterns and physical activity behaviors in high-mountain populations, particularly in understudied contexts such as the vicinity of Los Nevados National Natural Park (NNNP), Colombia, where empirical data remain limited.

Childhood and adolescence overweight (OW) and obesity (OB) during pose a significant global public health challenge. In 2022, an estimated 390 million children and adolescents aged 5–19 years were classified as overweight, reflecting an increase in global prevalence from 8% in 1990 to 20% in 2022, with comparable rates for girls (19%) and boys (21%) (8,9). Obesity in early-life significantly increase the risk of later non-communicable diseases (NCDs), including type 2 diabetes, hypertension, cardiovascular disease, and various forms of cancer, and is frequently accompanied by serious metabolic and physiological complications such as metabolic syndrome, non-alcoholic fatty liver disease, dyslipidemia, sleep apnea, and musculoskeletal disorders. Beyond these medical consequences, adverse psychosocial outcomes, such as stigma, discrimination, diminished self-esteem, impaired academic performance, and reduced quality of life, are commonly reported (10,11). In addition, children with obesity are highly likely to persist with this condition into adulthood, which emphasizes the urgency of implementing early and sustained preventive interventions (12).

The economic burden of excess weight in low- and middle-income countries is projected to exceed USD 7 trillion between 2011 and 2025 (8), underscoring its significant economic and social impact beyond the clinical setting. The ongoing nutritional transition in Latin America has contributed to worrying prevalence rates. For example, the 2022 National Health and Nutrition Survey (NHANS) in Mexico reported prevalence rates of 19.2% overweight and 18.1% obesity among schoolchildren, and 23.9% and 17.2%, respectively, among adolescents (13). Similarly, recent studies conducted in Cali, Colombia, documented prevalence rates of overweight and obesity of 28% and 13% in schoolchildren respectively, with results strongly influenced by family determinants and insufficient physical activity (14). Taken together, these regional findings underscore the magnitude of the problem and emphasize the need for context-specific evidence, particularly among populations residing in high-altitude environments.

The assessment of overweight (OW) and obesity (OB) in children and adolescents is typically conducted using simple, cost-effective anthropometric indicators with validity established in epidemiological research. Key indicators include body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR), all of which are endorsed by international bodies such as the World Health Organization (WHO) and the National Institute for Health and Care Excellence (NICE) for their usefulness in cardiometabolic risk stratification among pediatric populations (9,15). The interpretation of pediatric BMI is based on age- and sex specific growth references, while WC and WHtR

are used to estimate central adiposity, where WHtR ≥ 0.5 serves as an age- and sex-independent indicator of elevated cardiometabolic risk (11,16).

Regular physical activity (PA) during childhood and adolescence offers well-documented benefits in multiple areas of health and development. Physically active children consistently demonstrate superior cardiorespiratory fitness, motor competence, metabolic profiles, and academic performance, and report a higher quality of life compared to inactive peers (17–19). Taken together, this evidence underscores the importance of promoting PA from early childhood as an integral component of comprehensive public health strategies.

In response to the global burden of physical inactivity, the World Health Organization (WHO) launched the Global Action Plan on Physical Activity 2018–2030 (GAPPA), which aims to achieve a 15% relative reduction in global physical inactivity by 2030 (20). However, evidence in Latin America indicates that a considerable proportion of school-aged children remain physically inactive, highlighting the urgent need for context-specific research to elucidate the relationship between physical activity, adiposity, and health outcomes in specific environments, including high-altitude populations.

Measurement of physical activity (PA) in school-aged children has often be based on low-cost instruments with proven validity and broad applicability in population-based research. The Physical Activity Questionnaire for Children (PAQ-C, 8–12 years) and the Physical Activity Questionnaire for Adolescents (PAQ-A, 13–18 years) have shown acceptable reliability and validity in Spanish-speaking populations (21,22). Although these instruments are widely used as reference tools, recent reviews emphasize the need to update pediatric PA questionnaires to better capture contemporary patterns of sedentary behavior and physical activity (23). In this context, the objective of the present study was to examine abdominal obesity, body mass index (BMI), and PA levels, as well as their interrelationships among children and adolescents living near Los Nevados National Natural Park, Colombia.

## Materials and methods

This study used a quantitative, correlational, and cross-sectional design. Data collection was carried out between June and September 2024 in three rural educational institutions (Aspar, Letras, and Porvenir) located on the periphery of the Los Nevados National Natural Park (PNNN), at altitudes over 3,600 meters above sea level. A non-probabilistic convenience sampling strategy was applied. Participation was voluntary: parents or legal guardians provided written informed consent, and children gave their verbal and written assent at the time of evaluation. Individuals with medical contraindications or who refused to participate were excluded.

The final sample consisted of 42 participants, of whom 18 were boys (42.8%) and 24 were girls (57.2%). Prior authorization was obtained from the principals of each institution to conduct the assessments. Data collection took place in classroom during the morning school hours, under the supervision of homeroom teachers, to ensure an environment of trust and compliance with ethical standards.

Sociodemographic and anthropometric characteristics were collected using a structured questionnaire that included school year, sex, and age. Physical activity (PA) levels were assessed using the short validated Spanish versions of the PAQ-C (8–12 years) and PAQ-A (13–18 years) questionnaires (21,22), which evaluate the frequency and intensity of PA. Activities were categorized as high-intensity PA during physical education classes, and as PA carried out outside school hours and on weekends. Response options were grouped into two dimensions: regularity (almost never, sometimes, often, always) and frequency (once, 2–3 times, 4 times, 5 times). Both instruments have demonstrated adequate reliability and validity. Specifically, PAQ-C showed good to excellent reliability (ICC >0.73 across comparisons, 95% CI) and internal consistency (Cronbach's $\alpha = 0.83$), while the Spanish version of PAQ-A also demonstrated acceptable test–retest reliability (ICC = 0.71) (22).

All anthropometric assessments were carried out following the standardized procedures of the International Society for the Advancement of Kinanthropometry (ISAK) (24). Body weight was measured with an accuracy of 0.1 kg using a digital scale (Tanita 0.67®, TaKappa; capacity: 140 kg, accuracy: 0.1 kg). Participants were assessed barefoot, wearing minimal clothing, standing unassisted at the center of the platform, with their arms at their sides and without contact with surrounding objects.

Height was measured with an accuracy of 0.5 cm using a stadiometer (Seca 700® with Seca 220® attachment). Participants stood with their feet together, heels, buttocks, upper back, and occiput aligned to the stadiometer, and the head in the Frankfurt horizontal plane. Measurements were taken during deep inspiration with gentle upward traction applied

to the mastoid processes. Body mass index (BMI = kg/m²) was calculated and classified according to WHO reference criteria: underweight (<p5), normal weight (p5–p85), overweight (p85–p95), and obesity (≥p95).

Waist circumference (WC) was measured with a non-elastic measuring tape (Lufkin®, Rosscraft, 2 m). The tape was placed parallel to the last floating rib, at the midpoint between the lower rib and the iliac crest, with the participant standing upright and abdomen relaxed. Measurements were recorded at the end of a normal expiration.

Statistical analyses were performed using Microsoft Excel (version 2010) and SPSS (version 20.0; IBM Corp., Armonk, NY, USA). Descriptive statistics included means, standard deviations, and frequency distributions. The Shapiro–Wilk test was used to assess the normality of the data. Since the assumptions of normality were met, the Pearson correlation coefficient was used to examine associations between variables. A significance threshold of $p \leq 0.05$ was adopted for all analyses.

**Ethical considerations:** Participation by children and adolescents was voluntary. Parents or guardians provided written informed consent, and participants gave their assent at the time of data collection. The anonymity of participants was guaranteed, and the information collected was used exclusively for academic purposes. The study was classified as minimal risk according to Resolution 8430/1993, Article 11 of the Ministry of Health of Colombia, which establishes the scientific, technical, and administrative standards for health research (25).

## Results

A total of 42 participants (18 boys and 24 girls) from the Aspar, Letras, and Porvenir educational institutions with a mean age of 11.69 ± 2.7 years were evaluated. The distribution by grade level was as follows: third grade (12 students), fourth grade (3 students), fifth grade (4 students), sixth grade (12 students), seventh grade (2 students), eighth grade (2students), ninth grade (4 students), and tenth grade (3 students). It is worth noting that 57.1% of the participants were in the third and sixth grades.

The results for boys and girls aged 8 to 12 years were as follows (Table 1): age, 10.05 ± 1.48 years; weight, 33.33 ± 7.18 kg; height, 1.37 ± 0.09 m; BMI, 17.32 ± 2.1 kg/m²; and waist circumference, 60.0 ± 5.5 cm. A strong and statistically significant correlation was observed between BMI and waist circumference ($r = 0.883$; $p < 0.001$), as well as between BMI and body weight ($r = 0.775$; $p < 0.001$). In contrast, the correlation between BMI and height ($r = 0.508$; $p = 0.06$) did not reach statistical significance.

For adolescents aged 13–18 years, the results were as follows (Table 2): age, 14.86 ± 1.48 years; weight, 52.41 ± 7.72 kg; height, 1.58 ± 0.06 m; BMI, 20.85 ± 2.52 kg/m²; and waist circumference, 69.0 ± 5.68 cm. A statistically significant correlation was observed between BMI and waist circumference ($r = 0.775$; $p < 0.05$). In contrast, the correlations between BMI and body weight ($r = 0.693$; $p = 0.06$) and between BMI and height ($r = –0.164$; $p = 0.574$) did not reach statistical significance. Regarding WHtR in this age group, values remained below 0.5, consistent with the WHO and NICE clinical recommendations, indicating the absence of abdominal obesity.

Likewise, the BMI results for both genders fell between the 50th-85th percentiles classified as normal weight for this age group (9,15,26). The WHtR was calculated by dividing the waist circumference by height. Both children and adolescents showed a mean value of 0.43. These parameters indicate the absence of abdominal adiposity.

Regarding PA during physical education classes, categorized as *almost never, sometimes, often,* and *always,* results indicated that 46.4% of children and 50% of adolescents reported "always" being active in this class (Figure 1).

With regard to PA after school hours, 46.4% of children and 42.9% of adolescents reported being active two to three times a week. On weekends, 60.71% of children (8–12 years) and 85.71% of adolescents indicated being physically active (Figure 2). In children the correlation between BMI and PA during physical education class was inverse but not statistically significant. ($r = –0.101$; $p = 0.616$); with PA after school ($r = 0.021$; $p = 0.916$); and weekend PA ($r = 0.26$; $p = 0.894$), showing no significant differences.

The correlation between BMI and PA in adolescents during physical education class was inverse but not statistically significant ($r = –0.539$; $p = 0.47$); Extracurricular activity ($r = 0.021$; $p = 0.968$); and weekend activity ($r = –0.352$; $p = 0.217$), with no significant differences observed.

**Table 1.** Characteristics of children aged 8 to 12 years

| Characteristics | All n=28 | | Males n=11 | | Females n=17 | |
|---|---|---|---|---|---|---|
| | X | DE | X | DE | X | DE |
| **Age (years)** | 10.05 | 1.48 | 9.82 | 1.53 | 10.29 | 1.44 |
| **Weight (kg)** | 33.33 | 7.18 | 30.55 | 6.42 | 36.12 | 7.95 |
| **Height (cm)** | 1.37 | 0.09 | 1.36 | 0.11 | 1.39 | 0.08 |
| **BMI** | 17.32 | 2.1 | 16.31 | 1.34 | 18.33 | 3.01 |
| **Waist circumference** | 60.4 | 5.5 | 57.73 | 3.60 | 63.12 | 7.44 |

The sample consisted of 28 participants (11 boys and 17 girls) aged 8–12 years from the Aspar, Letras, and Porvenir educational institutions.
*Abbreviations:* n = number of participants; X = mean; SD = standard deviation; BMI = body mass index.

Source: Authors' own data.

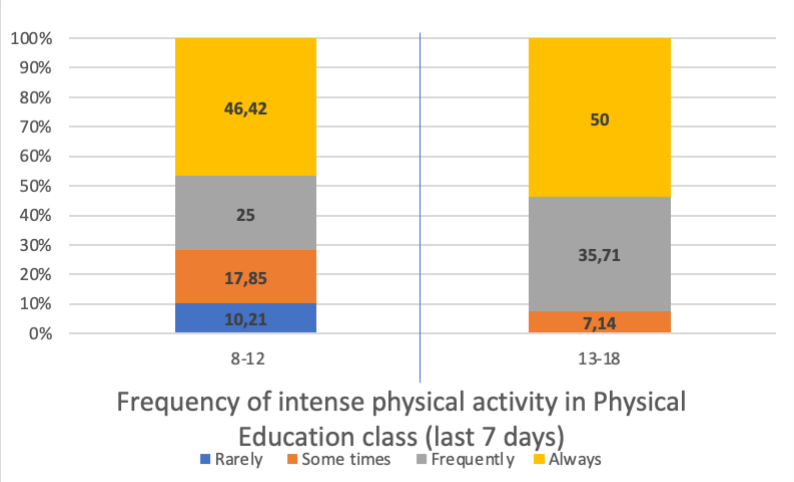
**Table 2.** Characteristics of adolescents aged 13 to 18 years

| Characteristics | All n=14 | | Males n=7 | | Females n=7 | |
|---|---|---|---|---|---|---|
| | X | DE | X | DE | X | DE |
| **Age (years)** | 14.86 | 2.7 | 14.86 | 2.26 | 14.86 | 1.06 |
| **Weight (kg)** | 52.41 | 7.72 | 52.39 | 7.73 | 52.44 | 7.72 |
| **Height (cm)** | 1.58 | 0.06 | 1.62 | 0.09 | 1.54 | 0.04 |
| **BMI** | 20.85 | 2.52 | 19.71 | 1.84 | 22.00 | 3.20 |
| **Waist circumference** | 69.92 | 5.68 | 69.71 | 4.68 | 70.14 | 6.69 |

The sample consisted of 14 participants (7 boys and 7 girls) aged 13–18 years from the Aspar, Letras, and Porvenir educational institutions.
*Abbreviations:* n = number of participants; X = mean; SD = standard deviation; BMI = body mass index.

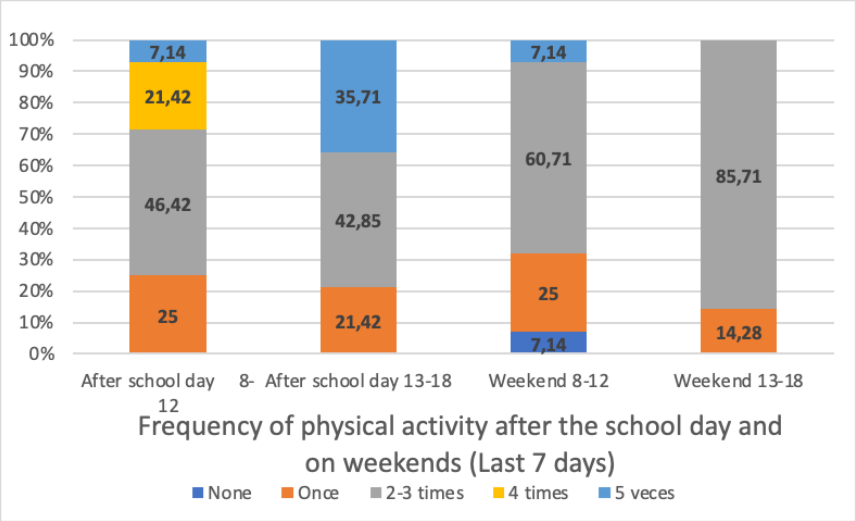
Source: Authors' own data.

**Figure 1.** Distribution of vigorous physical activity levels during Physical Education classes among children (8–12 years) and adolescents (13–18 years).




Source: Authors' own data.

**Figure 2.** Distribution of physical activity frequency after school and on weekends among children (8–12 years) and adolescents (13–18 years).




Source: Authors' own data.

## Discussion

The combination of high-altitude environments with rural lifestyles in Colombia creates a distinctive setting for examining health-related outcomes (6). Therefore, this study aimed to assess abdominal obesity, body mass index (BMI), and physical activity (PA) levels in children and adolescents living on the outskirts of Los Nevados National Natural Park (PNNN).

The waist-to-height ratio (WHtR) among participants aged 8 to 18 years had a mean value of 0.43, below the recommended cutoff of 0.5 for abdominal obesity (16). This result does not indicate evidence of excess central fat in the sample. In contrast, studies conducted in urban areas of Colombia report high prevalence of overweight (OW) and obesity (OB). For example, the prevalence of overweight and obesity among children aged 5 to 11 years in Bucaramanga was 17.3% and 5.6%, respectively (27). Obesity was observed in 7.7% of boys and 3.6% of girls in Bogotá, and was associated with shorter sleep duration and low levels of moderate-to-vigorous physical activity (28). The overall prevalence of excess weight in Medellín reached 24%, comprising 19.9% overweight and 4.1% obesity (29). A study in the indigenous Nasa population of Cauca reported a lower prevalence, with 13.4% overweight and 0.9% obesity, with higher rates among girls (30). Similarly, a 39.3% of schoolchildren presented elevated waist circumference in Popayán, which was associated with increased cardiovascular risk (31).

The analysis revealed a strong positive correlation between BMI and waist circumference in children aged 8 to 12 years ($r = 0.883$; $p < 0.001$), supporting the use of waist circumference (WC) as a reliable marker of central adiposity. These findings underline the role of altitude as a determinant of body composition.

A heterogeneous picture emerges at the international level. Three out of ten children and adolescents are overweight in Latin America, with prevalence rates of 64% in Mexico and 63% in Chile (32). Abdominal obesity in schoolchildren in Venezuela was diagnosed using a waist-to-height ratio (WHtR) greater than 0.5 (33). The prevalence in urban areas in Mexico was 36.7%, compared with 31.7% in rural areas. In addition, the prevalence of overweight among children aged 6 to 11 years was 19.8% and obesity (OB) 15.9% (34). In contrast, findings from the Peruvian Andes reflect the results of this study: 81.4% of children had normal weight, while the prevalence of overweight and obesity was 6.4% and 0.6%, respectively (35).

These differences between urban, rural, and high-altitude contexts, along with the researchers´ observations in the periphery of the Los Nevados National Natural Park (PNNN) at altitudes above 3,600 meters, suggest that living in high-altitude areas may have a protective effect against overweight development.This finding underlines the importance of waist circumference (WC) as an indicator of cardiometabolic risk in these populations (5,31).

Regarding physical activity (PA), 46.42% of children and 50% of adolescents reported participating in vigorous activity during physical education classes, and both groups remained highly active on weekends, although age-related differences were evident. The correlation between BMI and PA during class was negative among children aged 8 to 12 years, but not significant ($r = –0.101$; $p = 0.616$). This pattern is consistent with previous validations of the PAQ-C, which highlight its limitations in capturing activity variations in rural or high-altitude contexts (21,22). In contrast, adolescents aged 13 to 18 years showed a significant inverse correlation between BMI and PA during class ($r = –0.539$; $p = 0.047$), highlighting the protective role of structured school exercise. Comparable findings have been reported in Colombian adolescents, where both BMI and waist circumference (WC) were associated with higher cardiometabolic risk (31).

At the national level, physical activity (PA) data from the 2015 National Survey of Nutritional Status in Colombia (ENSIN) indicate that only 24.1% of children and adolescents meet the recommended PA guidelines (36). The highest prevalence of compliance was observed in the Atlantic region (42.2%) and the Amazon-Orinoquía region (40.7%), whereas the lowest rates were reported in Bogotá (19.4%) and the Eastern Region (24.1%). These values are lower than the PA levels observed in schoolchildren participating in this research, supporting the hypothesis that rural and high-altitude environments could favor greater physical activity compared to urban contexts (37).

Interestingly, a very strong positive correlation was observed between BMI and PA performed after school hours among adolescents, ($r = 0.968$; $p = 0.012$). This finding contrasts with previous international evidence, where the association is generally inverse and nonsignificant (38,39). One possible explanation is the over-reporting bias inherent in self-report questionnaires such as the PAQ-A, which can inflate activity estimates in adolescents. As a matter of fact, studies using objective methods such as accelerometry have consistently shown discrepancies when compared with self-reported PA (40). Another plausible explanation is related to the high-altitude environment: routine activities such as walking on steep slopes may involve considerable energy expenditure, which adolescents may perceive and report as intentional PA, thereby contributing to this paradoxical association.

Furthermore, the trend observed among adolescents in this study to report higher PA levels than children, differ from global patterns, where inactivity typically increases with age and has been reported in up to 81% of adolescents according to the WHO (9), as corroborated by a multicenter study on global trends in insufficient PA in adolescent (41). These contrasts suggest that the high-altitude environment may influence patterns of physical activity and body fat distribution.

The public health and educational implications of these findings are considerable. First of all, school-based physical education programs in high-altitude contexts should take advantage of the environmental conditions by incorporating contextualized activities—such as games adapted to sloping terrain, intermittent walks in varied landscapes, and outdoor activities—that enhance the protective association between PA and central adiposity. In second place, anthropometric surveillance should be strengthened by incorporating routine measurement of the waist circumference and developing specific cutoff points for each altitude. International clinical guidelines emphasize the application of multiple indicators (BMI, WC, WHtR) in pediatric screening to improve the early detection of cardiometabolic risk (15,16).

Furthermore, the WHO highlights the importance of a comprehensive 24-hour movement approach in childhood, which integrates PA, reduced sedentary behavior, and adequate sleep. This recommendation is strongly supported by scientific evidence and international guidelines for school-aged children, which emphasize that addressing all components of daily movement together is essential to promote cardiometabolic health and overall well-being (17,20,42).

Strengths of this study include the novel approach on a high-altitude population, the inclusion of children and adolescents, and the integration of standard anthropometric indicators with validated physical activity (PA) questionnaires. However, the cross-sectional design prevents causal inference, and the lack of control for variables such as diet, biological maturation, and socioeconomic status which represents an additional limitation. Nevertheless, the findings highlight the need for longitudinal studies using objective measures such as accelerometry, as well as comparative cohorts at different altitudes, to develop more precise and context-specific reference standards for cardiometabolic risk in childhood and adolescence (17,43,44)

Despite these limitations, the present study provides new insights into the interaction between altitude, central adiposity, and PA in schoolchildren living above 3,600 meters, a context that has been rarely

studied in Latin America. These findings represent a valuable contribution to the design of public policies and educational programs, aimed at strengthening physical education in schools, encouraging active lifestyle behaviors, and recognizing altitude as a distinctive determinant of the health profile of children and adolescents.

## Conclusions

Children and adolescents living near Los Nevados National Park, at aktitudes above 3,600 m, show normal BMI values and no evidence of abdominal obesity, in addition to high levels of physical activity. The strong correlation between BMI and waist circumference supports the use of this indicator in high-altitude environments and suggests a possible protective role of the mountain environment against overweight.

**Acknowledgments:** We would like to thank the Vice-Rector´s Office for Research and Graduate Studies at Universidad de Caldas (Colombia) for their support in developing this research, and the students of the Genetics, Physical Activity, Sports, and Health Research Group for their collaboration in data collection. We also extend our special thanks to the administrators and teachers of the Aspar, Porvenir, and Letras schools for their invaluable assistance.

**Conflict of interest:** The authors declare that they have no conflicts of interest.

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