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Association Between Physical Fitness and Cardiovascular Health in Chilean Schoolchildren from the Metropolitan Region

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Abstract: Background: Cardiovascular diseases increasingly impact youth, with early development of risk factors such as obesity, hypertension, and inadequate nutrient intake. Proper nutrient intake and physical fitness are vital for reducing these risks, especially in pediatric populations. This study explores the connection between physical fitness, metabolic risk, and nutrient status among 1656 Chilean schoolchildren from diverse socio-economic backgrounds. **Methods:** Anthropometric measures included weight, height, skinfold thickness, waist circumference, and blood pressure. Physical fitness was assessed via handgrip strength, standing long jump, and a six-minute walk test. Nutrient intake was also evaluated, and a composite metabolic risk score was calculated based on waist circumference, skinfolds, and blood pressure. **Results:** Children from public schools exhibited higher obesity rates and waist circumferences than those from private schools. Physical fitness performance was strongly linked to cardiovascular health indicators: better fitness correlated with smaller waist circumferences, lower skinfold measurements, and healthier blood pressure levels. Children from private schools had better fitness test outcomes, indicating socio-economic disparities in access to physical activity and nutrient resources. Students with lower fitness and nutrient intake had higher metabolic risk scores, pointing to increased cardiovascular risk. **Conclusions:** Nutrient intake and physical fitness are essential to reducing cardiovascular risk in children. Significant differences in nutrient intake and fitness levels across socio-economic lines suggest that equal access to nutrition and physical activity programs in schools could benefit public health outcomes. Further research should investigate the lasting effects of nutrient-focused interventions on childhood metabolic health.

Keywords: Nutrient intake; physical fitness; cardiovascular health

1. Introduction

Cardiovascular diseases (CVDs) are partly a pediatric problem, as the onset of atherosclerosis appears to occur in early childhood [1]. Atherosclerosis, characterized by the hardening and narrowing of the arteries due to the buildup of fatty plaques, is a pathological process that can begin to develop very early in life, often because of a combination of genetic and environmental factors. These factors include an unhealthy diet, lack of physical activity, and a genetic predisposition to hypertension and dyslipidemia.

The clustering of cardiovascular and metabolic risk factors, such as abdominal obesity, hypertension, insulin resistance, elevated triglycerides (TG), and low HDL cholesterol, has been observed in children and adolescents and tends to persist from childhood into adulthood [2,3]. This phenomenon of "clustering" of risk factors is particularly concerning because it increases the likelihood of developing CVD in later stages of life. The persistence of these risk factors underscores the need for early interventions to prevent the progression of cardiovascular disease. The clustering of these risk factors is considered an appropriate measure of cardiovascular health in young people, as composite risk scores can, to some extent, compensate for daily fluctuations in individual risk factors [4].

High cardiorespiratory fitness during childhood and adolescence has been associated with a healthier cardiovascular profile in these stages and into adulthood [5,6]. Cardiorespiratory fitness, often measured through tests such as the 20-meter shuttle run test, reflects the heart and lungs' ability to supply oxygen to the muscles during prolonged exercise. Numerous studies have shown that children and adolescents with high cardiorespiratory fitness are less likely to develop cardiovascular risk factors such as hypertension and dyslipidemia and have better overall metabolic health. Additionally, these benefits appear to persist into adulthood, highlighting the importance of promoting physical activity from an early age [7].

The role of muscular fitness has also been increasingly recognized in preventing chronic diseases, and the characteristics of metabolic syndrome have been negatively associated with muscular strength in both men and women [8,9]. Muscular fitness, which includes strength, endurance, and power, is crucial not only for physical performance but also for metabolic health. Research has shown that greater muscular strength is associated with lower body fat levels, better insulin sensitivity, and more favorable lipid profiles [10]. During childhood and adolescence, muscular fitness has been inversely associated with established and emerging cardiovascular risk factors [11,12]. This means that youth with better muscular fitness tend to have lower levels of risk factors such as obesity, hypertension, and dyslipidemia, potentially reducing their future risk of developing CVD.

However, there is limited knowledge about the independent association of muscular fitness with individual cardiovascular risk factors and clustered metabolic risk in youth [13]. Most studies have focused on cardiorespiratory fitness, leaving a gap in our understanding of the specific role of muscular fitness in the cardiovascular and metabolic health of young people. This research gap is concerning, as muscular fitness may offer unique benefits that are not fully captured by assessing only cardiorespiratory fitness.

The cross-sectional Healthy Lifestyle in Europe by Nutrition in Adolescence (HELENA-CSS) study offers the opportunity to expand the association between muscular fitness and metabolic risk observed in Norwegian youth to a broader population of European adolescents. This study is significant because it provides data from a large and diverse sample of adolescents from various European countries, allowing for a more comprehensive and generalizable assessment of these associations. The objective of the present study is to analyze the independent associations between muscular and cardiorespiratory fitness with clustered metabolic risk in schoolchildren and adolescents from 10 different European centers [14]. This analysis can provide valuable information for developing public health interventions aimed at improving fitness and reducing metabolic risk in young people.

In recent years, additional research has supported and expanded these findings. For example, García-Hermoso et al. [15] found that cardiorespiratory fitness and muscular strength are inversely associated with the risk of metabolic syndrome in children and adolescents. This study reinforces the idea that both types of fitness play a crucial role in metabolic health. Another study by Kim et al. [16] showed that adolescents with higher levels of muscular strength had more favorable cardiovascular risk profiles, even after adjusting for cardiorespiratory fitness. Additionally, Ortega et al. [17] demonstrated that the combination of high cardiorespiratory and muscular fitness provides the greatest benefits for cardiovascular and metabolic health in adolescents. This finding underscores the importance of incorporating both aerobic and strength training exercises into physical activity recommendations for young people. In more recent research, García-Hermoso et al. [18] indicated that exercise-based interventions combining aerobic and resistance activities are effective in improving metabolic risk factors in overweight and obese adolescents. Finally, a study by Aadland et al. [19] emphasized the importance of regular physical activity and fitness in preventing obesity and improving metabolic health in children and adolescents. These recent studies reinforce and expand the existing evidence, highlighting the importance of physical fitness for cardiovascular and metabolic health in youth.

The objective of this research was to link factors associated with cardiovascular health to physical fitness, determined in schoolchildren from first to eighth grade in the Metropolitan Region.

2. Materials and Methods

Study Population

1656 schoolchildren from first to eighth grade from public school, subsidized private school and private schools in the communes of Cerro Navia, Macul, Providencia, Pedro Aguirre Cerda, Pudahuel, Quinta Normal, Santiago, San Miguel, and Vitacura participated in this study. The percentage distribution was similar to the proportion found in the urban Metropolitan Region (14% private, 61% subsidized private, and 25% public).

Methodology

Anthropometry

1. Weight and height: Weight was obtained with the schoolchild standing at the center of the scale (SECA Ltd.) wearing light clothing (no shoes, long pants, sweaters, or shirts) and without support. Height measurement was taken with heels together, arms along the body, and back against the scale (SECA Ltd.), with the head in the Frankfurt plane. The BMI Z-score was calculated based on the 2007 WHO reference for sex and age [20].
2. Skinfold thickness: Skinfolds (triceps, biceps, suprailiac, and subscapular) were measured with a LANGE caliper, in triplicate, with an average precision of 0.3 mm [21]. The mid-upper arm circumference was measured at the midpoint between the acromion and olecranon, with the arm extended and relaxed, without depressing the skin. The sum of skinfolds was used as a measure of subcutaneous fat [22].
3. Waist circumference: A fiberglass tape measure was used to measure waist circumference at the top of the iliac crest, ensuring that the tape did not compress and was parallel to the floor. The measurement was taken at the end of a normal expiration [23].
4. Blood pressure: A sphygmomanometer was used to measure blood pressure after the schoolchild had been seated for 10 minutes, with the arm supported and at heart level. The NANHES 2004 standard and the 90th percentile were used to determine the proportion of schoolchildren with altered blood pressure (systolic or diastolic) [24].

Physical Fitness Tests

1. Handgrip dynamometry: Handgrip strength (kg) was measured with a digital dynamometer (TKK 5101 Grip-D; Takei, Tokyo, Japan). The size of the right hand was measured to find the optimal grip span [25].
2. Standing long jump: To measure lower body explosive strength, the schoolchild stood behind the jump line with feet shoulder-width apart. They bent their knees and swung their arms before jumping as far as possible [26].
3. Six-minute walk test: This functional cardiorespiratory test measures the maximum distance covered in six minutes. It was performed on a flat, non-slip surface with a minimum perimeter of 30 meters [27].
4. Heart rate: Heart rate was measured with a POLAR heart rate monitor before, during, and after the walk test. It was recorded in three consecutive periods: a) Pre-test, after three minutes in a seated position; b) Minute by minute during the test; c) Post-exercise recovery in each of the three minutes following the test [28].

Metabolic Risk Factors

A continuous score representing a composite metabolic risk factor profile was computed from the following variables: waist circumference, sum of four skinfolds, systolic blood pressure and diastolic blood pressure. Each of these variables was standardized as follows: standardized value =

(value − mean)/SD, separately for boys and girls and by 1-yr age groups. The z-scores of the individual risk factors were summed to create the metabolic risk score (Zscore MR). A lower metabolic risk score is indicative of a better overall CVD risk factor profile.

Statistics. Normality distribution of variables: Kolmogorov-Smirnov test. Chi-Square test ($\chi2$). Determine significant differences when comparing groups of observed frequencies with expected frequencies. Kruskal-Wallis test. Significant differences to compare non-normal samples of a quantitative variable in three groups and T-Test for comparison of normal samples. Analyses were performed using STATA version 18.0 and $p < 0.05$ determined statistical significance (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC.)

3. Results

The Table 1 presents data on obesity, waist circumference, and blood pressure in schoolchildren from different types of educational establishments (public, subsidized private, and private). The results show weight, height, sum of skinfolds, obesity (percentage), waist circumference > p 90 (percentage), and blood pressure > p 90 (percentage). Significant differences were observed between types of establishments in obesity and waist circumference variables ($p < 0.01$).

Table 1. Obesity and proportion of schoolchildren with waist circumference and blood pressure > percentile 90.

Types of educational establishment	Weight	Height	Sum of skinfolds	Obesity (%)	Waist circumference > p 90 (%)	Blood pressure > p 90 (%)
Public school (n=486)	40.6±15	139.4±14.1	52.4±23.6	23.7	21.0	3.7
Private subsidized school (n=1012)	40.7±13.9	141.9±14.6	51.5 ± 23	18.4	15.9	3.9
Private school (n=158)	39.7±11.9	141.6±13.6	49.6±23.8	14.6	12.7	---
				p< 0.01*	p<0.01*	

* χ^2.

Table 2 compares physical fitness among schoolchildren from different types of educational establishments. The variables include horizontal jump, grip strength, distance covered in the 6-minute walk test (6MWT). A significantly higher jump was observed in students from private schools.

Table 2. Physical fitness and heart rate by types of educational establishment.

Types of educational establishment	Horizontal jump (m)*	Grip strength (k)	Distance 6-minute test (m)
Public school (n=486)	1.2 ± 0.3	16.6 ± 6.7	643.6 ± 65
Private subsidized school (n=1012)	1.2 ± 0.3	17.6 ± 6.9	654.2 ± 64
Private school (n=158)	1.6 ± 0.3	17.0 ± 6.4	636.4 ± 36

*Kuskal-Wallis p <0.001

The results from Table 3 show significant correlations between physical fitness tests, adjusted for height or weight, and cardiovascular health variables in schoolchildren. A strong negative correlation was found between waist circumference and both distance/height (r = -0.45, p = 0.001) and sum of skinfolds (r = -0.38, p = 0.001), indicating that better performance in these fitness tests is associated with smaller waist circumferences and lower body fat. Similarly, there was a strong positive correlation between grip strength/weight and both waist circumference (r = 0.56, p = 0.0001) and sum of skinfolds (r = -0.48, p = 0.001), suggesting that higher muscular strength is linked to improved body composition.

Table 3. Correlations between physical fitness tests (adjusted for height or weight) and variables related to cardiovascular health.

Variable	Distance/ Height	Jump/ Height	Grip strength/ Weight
Waist circumference	-0.45	0.13	0.56
p	0.001	0.0001	0.0001
Sum of skinfolds	-0.38	-0.43	-0.48
p	0.001	0.001	0.001
Blood pressure	0.27	---	---
p	0.01		

Additionally, a significant positive correlation was found between distance/height and blood pressure (r = 0.27, p = 0.01), implying that better aerobic fitness is moderately associated with lower blood pressure. No significant correlations were found for jump/height with blood pressure.

Table 4 provides the cut-off points for the Z-Score MR based on the Distance/Height and Jump/Height tests. Schoolchildren who scored high in both tests had lower Z-Scores (indicative of better cardiovascular health), with values such as -0.58, while those who scored low in both tests showed higher Z-Scores (indicating worse health outcomes), with values up to 1.86.

Table 4. Cut-off points for Z-Score MR (y-axis) for the categories high, medium and low categories of the Distance/Height (z-axis) and Jump/Height (x-axis) tests. Adjusted for sex and tanner stage.

Variable	Low	Medium	High	Distance/Height
High	-0.58	-0.79	-1.03	
Medium	0.36	0.23	-0.47	
Low	1.86	0.89	-0.17	
Jump/Height				

Table 5. presents the cut-off points for the Z-Score MR based on the Distance/Height and Grip Strength/Weight tests. Schoolchildren with high performance in both tests had lower Z-Scores, indicating better cardiovascular health, with values such as -0.75. In contrast, those with low performance in both tests had higher Z-Scores, up to 2.10, indicating worse health outcomes.

Table 5. Cut-off points for Z-Score MR (y-axis) for the categories high, medium and low categories of the Distance / Size (z-axis) and Grip Strength / Weight (x-axis) tests. Adjusted for sex and tanner stage.

Variable	Low	Medium	High	Distance/Height
High	-0.75	-1.15	-1.1	

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Medium	0.16	0.06	-0.78
Low	2.1	1.26	0.27
Grip strength/Weight			

Figure 1 and 2 show the comparison by type school of nutritional status, waist circumference, blood pressure and total body fat in girls and boys, respectively.

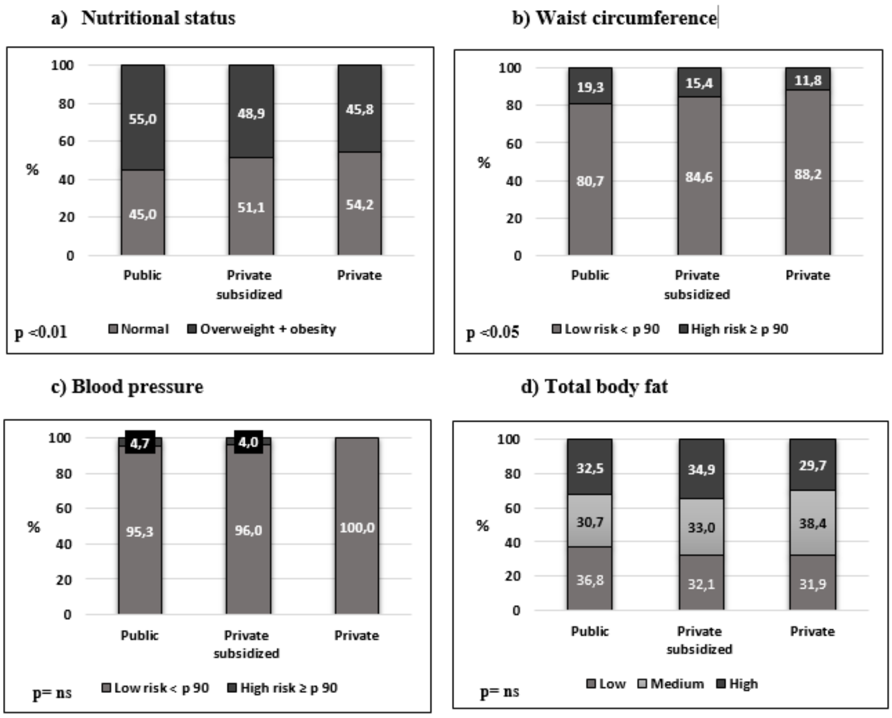

Figure 1. Nutritional status indicators by tertiles in girls according to educational establishment.

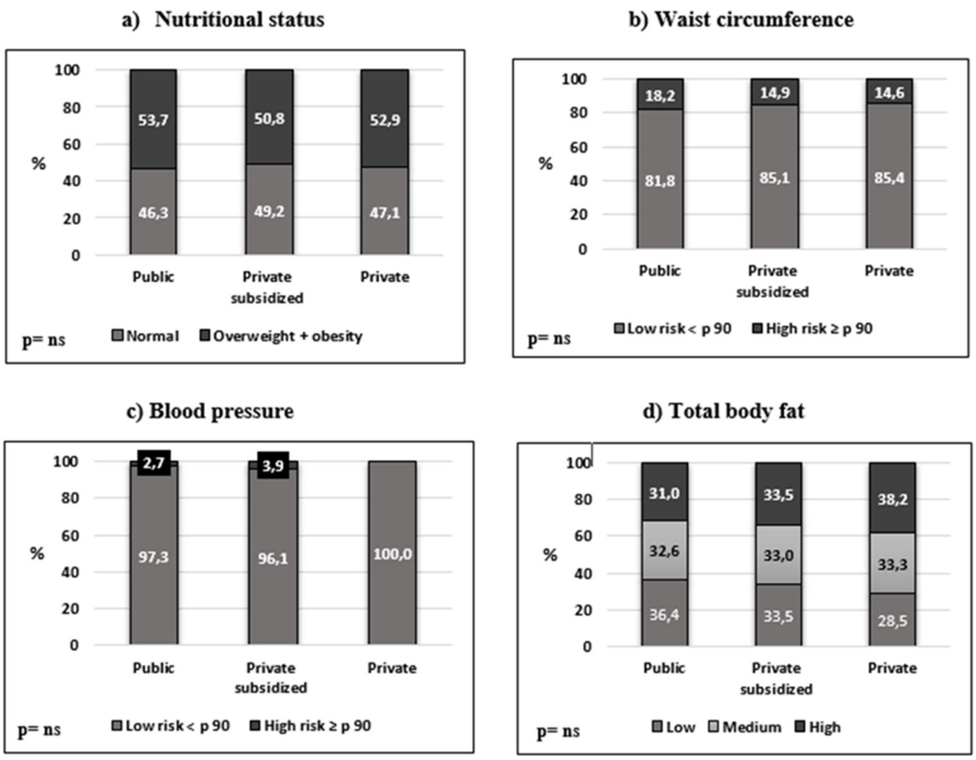

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Figure 2. Nutritional status indicators by tertiles in boys according to educational establishment.

Girls from public schools show a significantly higher proportion of malnutrition due to excess weight and waist circumference compared to girls from subsidized and private schools ($p<0.05$). No significant differences were detected in blood pressure and total body fat variables. In boys, no significant differences were observed across types of educational establishments.

Figure 3. This figure illustrates the relationship between ZScore MR and the tertiles of performance in the horizontal jump and distance covered in the walk test. Schoolchildren in the high tertile for both tests show lower ZScores, indicating better cardiovascular health, while those in the low tertile demonstrate higher ZScores, suggesting higher cardiovascular risk.

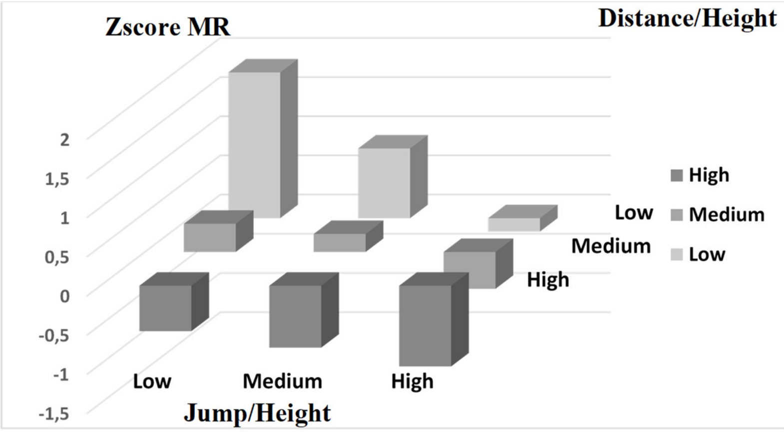

Figure 3. ZScore MR vs. high, medium and low tertiles of horizontal jump (m) and distance covered in the walk test (m).

Figure 4 shows the ZScore MR in relation to the tertiles of performance in distance covered and grip strength. As in Figure 3, those in the high tertile for both tests display lower ZScores, indicating better cardiovascular health outcomes, whereas those in the low tertile exhibit higher ZScores, reflecting increased cardiovascular risk.

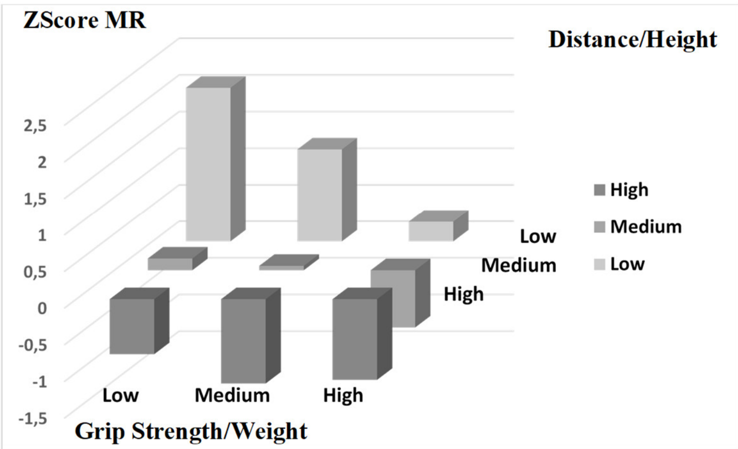

Figure 4. ZScore MR vs. high, medium and low tertiles of distance (m) and grip strength (kg).

4. Discussion

The relationship between nutrition, physical activity, and cardiovascular health in schoolchildren is a critical area of research given the global increase in childhood obesity rates and cardiovascular diseases [29]. This study examines differences in anthropometric indicators, physical fitness, and cardiovascular risk in schoolchildren from different types of educational establishments. The findings highlight significant disparities in obesity and physical fitness that can influence these children's future health.

The study shows that schoolchildren from public establishments have a higher prevalence of obesity and waist circumference > p 90 compared to those from private schools. These findings are consistent with previous studies suggesting that children from lower socioeconomic families tend to have higher obesity rates [30,31]. Childhood obesity is a known predictor of cardiovascular diseases in adulthood [32], and early interventions are crucial to mitigate this risk.

Waist circumference is an important indicator of central adiposity and cardiovascular risk [33]. In this study, schoolchildren with elevated waist circumference also showed a higher prevalence of elevated blood pressure, a significant risk factor for cardiovascular diseases [34]. The association between obesity and high blood pressure in children has been well documented [35], and our results underscore the need to monitor these parameters in school health programs.

Physical fitness tests revealed that schoolchildren from private establishments outperform those from other types of establishments in tests such as the standing long jump. Aerobic capacity and muscular strength are important indicators of general physical health and are inversely related to the risk of chronic diseases [36]. Additionally, a lower resting and post-exercise heart rate in schoolchildren from private establishments suggests better cardiovascular fitness.

These findings coincide with studies showing that children with better physical fitness have a lower risk of developing metabolic risk factors [37]. Regular physical activity is crucial for maintaining good cardiovascular health, and our results suggest that physical education programs should be a priority in all schools, especially those with fewer resources.

Subcutaneous body fat was higher in girls and schoolchildren in the lowest fitness tertile, which is concerning given that higher adiposity is associated with poorer metabolic health [38]. The difference in body fat between sexes could be explained by hormonal and developmental factors [39], but it also underscores the need for gender-specific interventions. Physical performance was lower in schoolchildren from public establishments, suggesting possible differences in opportunities for physical activity or the quality of physical education provided. Promoting a school environment that encourages regular physical activity is essential for children's physical development and long-term health [40].

The observed correlations between physical fitness and cardiovascular health variables are consistent with the existing literature. For example, waist circumference showed a strong correlation with grip strength, reflecting the interrelationship between central adiposity and muscular strength [41]. The sum of skinfolds also negatively correlated with physical performance, which is consistent with studies indicating that excessive adiposity can limit physical capacity [42]. Systolic blood pressure, although less prevalent, still showed an association with physical fitness. Studies have shown that physical activity can improve blood pressure in children [43], and our results support the inclusion of regular physical activities to manage blood pressure and promote cardiovascular health.

The use of the SCV Z-Score provides a useful tool for assessing cardiovascular risk in schoolchildren. Schoolchildren in the lowest tertile of physical fitness tests had a significantly higher SCV Z-Score, indicating a higher risk of cardiovascular diseases. These results are consistent with studies showing that low physical fitness is associated with poorer cardiovascular risk profiles [4]. The importance of muscular strength and aerobic capacity in cardiovascular health is well documented. Evidence suggests that even moderate levels of physical activity can have significant health benefits [44]. Therefore, promoting regular physical activity at all ages is crucial to reduce the risk of cardiovascular diseases in the future.

The results of this study have important public health implications. The disparity in obesity and physical fitness among different types of educational establishments suggests the need for policies that ensure equal opportunities for physical activity and nutritional education. Specific programs targeted at low-resource schoolchildren may be necessary to address these disparities [45]. Additionally, implementing physical activity programs that include both aerobic and strength training exercises can be an effective strategy to improve schoolchildren's cardiovascular health. Integrating physical activities into the school curriculum and promoting healthy habits from an early age are essential to prevent chronic diseases and improve long-term health [46].

This study highlights the importance of nutrition and physical activity in the cardiovascular health of schoolchildren. Significant differences in obesity and physical fitness among different types of educational establishments underscore the need for specific interventions to reduce health disparities. Promoting regular physical activity and a balanced diet is crucial for physical development and the prevention of cardiovascular diseases in childhood and adulthood.

5. Conclusions

This study emphasizes the critical role of physical activity and nutrition in promoting cardiovascular health from an early age. Findings reveal that better physical fitness and a balanced diet are associated with a healthier cardiovascular risk profile in schoolchildren, underscoring the need to encourage these practices from childhood. However, there are significant health disparities among students from different types of schools. Children attending public schools show higher rates of obesity and lower physical fitness performance compared to those in private institutions, indicating a socioeconomic gap in access to resources for physical activity and healthy nutrition. Addressing these differences through policies that provide equal opportunities for physical activity and nutritional education is essential to reduce these inequalities.

Early intervention is crucial, as childhood obesity and increased waist circumference are associated with a higher prevalence of hypertension, a significant risk factor for future cardiovascular disease. These results highlight the importance of monitoring and managing these health indicators within school health programs, focusing on early strategies to address them. Additionally, physical fitness assessments, such as handgrip strength and standing long jump, are positively correlated with cardiovascular health indicators, suggesting that physical education programs should be prioritized in all schools. Including both aerobic and strength exercises could have a substantial impact on improving children's health and reducing long-term risks of chronic diseases.

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Conflicts of Interest: Declare conflicts of interest or state "The authors declare no conflicts of.

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