Physical Fitness and Cardiometabolic Risk in Seven to Nine Years Old Children

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Abstract

Background: Obesity and lower physical fitness levels in children are related to the development of cardiometabolic risk. The objective of the study was to determine the relationship of cardio-metabolic risk and physical fitness in school children from Santiago de Chile.

Methods: Physical fitness was assessed as cardiorespiratory fitness and muscle strength. Fitness was measured using the six-minute-walk-test and muscle strength was assessed by hand grip and standing lung jump. Overweight (≥ 1 SD) and obesity (≥ 2 SD) were determined by body mass index. A cross sectional study was done in 452 children (185 boys and 267 girls), age range (7-9 years). Cardio-metabolic-risk (serum glucose, triglycerides, HDL, insulin) and waist for height ratio was expressed as z score. Data was analyzed using bivariate analysis and multiple and logistic regression.

Results: A 21**%** were obese and 27% overweight. Children with high body fat and low cardiorespiratory fitness and muscle strength had an OR of 6.8-fold (IC 95% 3.4 to 13.9) cardiometabolic risk z-score, compared to those most fit.

Conclusion: School children with higher body fat and lower physical fitness had increased cardio-metabolic-risk-score. No significant difference in cardio-metabolic risk in the non-obese children was found independent of their physical fitness.

Background

The prevention and treatment of cardiovascular disease and its risk factors are commonly focused on the adult population. However, in recent years, evidence has revealed that these risk factors can be observed in early life [1, 2]. Childhood obesity in Chilean children has tripled in recent decades, reaching 23.9% in 2017 [3]. Obesity has been shown to be associated with a high prevalence of hypercholesterolemia (27%) and high insulin levels during fasting (42% of all obese children have abnormal values) [4]. Childhood obesity is also associated with an increased risk of cardiovascular disease in adulthood [5]. The sum of risk factors, assessed using a cardiometabolic risk (CMR) score, is considered a more appropriate tool for defining disease risk in children [6,7]. Inappropriate eating patterns and a lack of regular moderate to vigorous physical activity [8] are important contributors to the early onset of CMR. Sixty percent of the world's population does not have an adequate level of physical activity in terms of preventing noncommunicable disease [9,10]. Chilean children are predominantly sedentary, given that only 20.2% of them meet the physical activity recommended guidelines [11, 12, 13]. Similarly, in northeast England, sedentary behaviour was found in 78% to 82% of 7- to 9-year-old children [14]. In school children and adolescents, this problem has further consequences if we consider that only 9% of school-age Chilean children have acceptable physical fitness levels [15].

Cardiorespiratory and muscle fitness are inversely associated with the risk factors for cardiovascular diseases [16]. Physical fitness assessments are feasible measures that could help improve the monitoring of paediatric health status [17].The independent biological effect of cardiorespiratory fitness and muscle strength on cardiometabolic risk has been demonstrated in adolescents [18,19].

Artero el al, evaluated the relationship between metabolic risk and physical fitness in 709 adolescents. They founded that muscular fitness was negatively associated with clustered metabolic risk independent of cardiorespiratory fitness ($\beta = -0.249$, $p < 0.001$). Independent of muscular fitness, an inverse association was also found between cardiorespiratory fitness and clustered metabolic risk ($\beta = 0.264$, $p < 0.001$) [20] . Steene-Johannessen J, et al, measured in 2818 children 9- and 15-yr-olds physical fitness and metabolic risk. They also encountered that muscle fitness was negatively associated with clustered metabolic risk, independent of cardiorespiratory fitness, and after adjustment for age, sex, and pubertal stage (beta = -0.112, $P < 0.001$) [21, 22] . Additionally, there is scarce information in this group age. The objective of the study is to determine the relationship of cardiometabolic risk and physical fitness in school children from Santiago de Chile.

Methods

This study is cross-sectional; the sample was drawn from children enrolled in the "Growth and Obesity Chilean Cohort Study", which assesses the association of early growth and development with adiposity and metabolic risk [23].

We randomize by using random numbers, included healthy 7- to 9-year-old schoolchildren from the original study, both girls and boys, who had provided a blood sample in 2009. According to the objective of this project, fitness tests were performed in 2010. Parents or guardians signed a previously approved informed consent form by the Institute of Nutrition and Food Technology Ethics Committee for research in human subjects. The final sample size was 452 children (267 girls and 185 boys).

Weight was measured with an electronic scale (Body Composition Analyzer TANITA BC-418, USA) with a 0.1 kg accuracy and 220 kg maximum measurement. Children were measured in underclothing, while placing their feet in the centre of the scale. Height measurements were performed with a portable stadiometer (SECA 222 ®) with a range between 0 and 200 cm and a 1 mm precision using the Frankfurt standard [24]. Nutritional status was determined using body mass index (BMI) and BMI-Z. Overweight and obesity were define as BMI-z ≥1 and 2≥ SD respectively (WHO 2007) [25,26]. Waist circumference was measured with an inextensible tape (SECA ®) [27]. All variables were measured twice for each child. The measurements agreed within 0.5 cm for height and waist circumference and 20 g for weight. Finally, waist circumference and height were used to calculate the waist-to-height ratio (WHtR), and central obesity was defined as having a WHtR ≥ 0.5 [28].

The body composition of a child was classified in tertiles of BMI or WHtR. According to the results, body fat mass was classified as low, medium and high.

Identification of pubertal status (Tanner stages I–II) was assessed by study professionals using the method described by Tanner and Whitehouse [29].

Blood samples were obtained between 08.30 and 10.30 after an 8-h overnight fast. Glucose, insulin and blood lipids were assessed after 8 h of fasting. Ten millilitres of venous blood were collected, and serum glucose was assessed using a commercial kit by the GOD-PAP (Clinical Chemistry Applied SA) enzymatic colorimetric method. Insulin was measured by RIA (RIA DCP Diagnostic Products Corporation, LA, USA). Glucose intolerance was defined by a fasting glucose ≥ 100 mg/dL [30]. Basal insulin sensitivity was estimated by homeostatic model assessment - HOMA (fasting insulin (mIU/dl) * fasting glucose (mmol/l)/22.5) [31]. Hyperinsulinemia was defined as baseline insulin ≥ 10 mIU / dl in children with Tanner I or II [32]. Insulin resistance was diagnosed if HOMA ≥ 2.1, which corresponds to > 75th percentile of the observed quartile in Chilean children [33]. Cholesterol, HDL and triglycerides were determined by dry analytical methodology (Vitros, Johnson & Johnson, Clinical Diagnostics Inc.) using the USA population as a reference (Non-HDL cholesterol > 145 mg/dL; HD < 40 mg/dL and triglycerides > 130 mg/dL) [34]. The remaining blood was eliminated.

The CMR score was defined by the sum of the Z score of the WHtR-z and blood lipid related variables: (Glycaemia-z, Insulin-z and Triglycerides-z – HDL-z)/5, as previously reported [35]. These variables were chosen because they are commonly used in adults as criteria to diagnose metabolic syndrome [36, 37].

Physical fitness was assessed as cardiorespiratory fitness and muscle strength. Cardiorespiratory fitness was measured using a sub-maximal test, the six-minute walk test (6MWT) [38, 39] and the six-minute walk test divide by height [40] The 6MWT, hand grip strength and standing long jump without momentum have been shown to be valid, reliable, and feasible for health monitoring purposes at the population level [34]. The 6MWT results were expressed as the maximal distance (metres) divided by height because leg length was not assessed [41]. The value was also standardized using the z score.

Muscle strength was assessed using hand grip and standing long jump. Handgrip was measured using an adjustable hand grip digital dynamometer (Baseline 12-0286 ®; 100 g accuracy), and the results were expressed in kg. The hand grip was performed twice by each child, by squeezing the dynamometer as hard as possible, for at least two seconds. One minute of recovery between squeezes was measured (alternating the right and left hands). Finally, hand grip strength was divided by body weight (kg) to take into account body size differences. The best result of two attempts was registered [42]. The best value was also standardized using the z score.

The standing long jump was performed by starting in a semi-squatting position, then jumping forward. This test was performed on a 2-m long non-slippery surface, free of obstacles. A cross mark was made to identify the initial position from which the child jumped. A piece of chalk was used to mark the landing point for each of the two attempts; the distance in cm served to register the best jump [43]. The best value was also standardized using the z score[16].

The results for muscle strength are expressed as a z score and were calculated based on standard values of hand grip and standing long jump from this study (hand grip/ weight z + standing long jump -z) [44].

The physical fitness z score was defined as 6MWT/height –z score + (hand grip/ weight z score + standing long jump –z score). The z score data were continuous.

Statistical analysis

The normality of the data for each variable was checked using the Shapiro-Wilk test and graphical methods. Statistical normality was tested using both statistical (Shapiro Wilk test) and graphical methods (normal probability plots). The majority of outcomes were normally distributed except hand grip, hand grip/weight, triglycerides, insulin, HOMA and body mass index.

Based on the distribution of the variables, the Mann-Whitney test or a t test was used to analyse independent samples. Preliminary analyses showed significant interactions between sex, physical fitness and cardiometabolic variables; therefore, combined association analyses were performed with boys and girls together to increase the statistical power of the results.

The effect of muscle strength and cardiorespiratory fitness on the CMR was also studied using two-way ANCOVA by dividing groups by muscle strength and cardiorespiratory fitness tertiles. The interaction between CMR-z score and fatness categories (low and high BMI or WHtR) was assessed. The post hoc analysis of differences between groups was performed using a Bonferroni adjustment to test for significance and was adjusted by age and maturation stage. The respective physical fitness values for age groups were segregated by tertiles since no reference values are available. Finally, the odds ratio (OR) and 95% CI of having a high CMR were examined by combined physical fitness variables (i.e., cardiorespiratory fitness and muscle strength). A multinomial logistic regression adjusted by age, sex and maturation stage was used. All analyses were performed using SPSS software, version 21.0. Statistical significance was set at $p < 0.05$.

Results

Descriptive statistics for the studied children are shown.

Table 1 shows that girls were significantly older than boys and that boys had slightly higher blood glucose than girls ($p < 0.05$).

Table 1
Description of anthropometric variables and cardiometabolic risk.

	Boys (n = 185)	**Girl (n = 267)**	**Total (n = 452)**	***p*** [1]
Age (years)	7.75 ± 0.5	7.88 ± 0.4	7.8 ± 0.5	0.002*
Weight (kg)	27.9 ± 7.6	28.2 ± 8.1	28 ± 8.1	0.2
Height (cm)	126.6 ± 5.6	127.1 ± 5.8	126.9 ± 5.7	0.7
BMI (kg/m^2)	17.1 (3.2)	17.4 (3.9)	17.3 (3.8)	0.2
Waist-to-height ratio	0.47 ± 0.05	0.48 ± 0.08	0.5 ± 0.07	0.1
Body fat (%)	27,6 ± 7,9	32,2 ± 6,7	29,8 ± 7,6	0.01
Glycaemia (mg/dl)	90.2 ± 6.2	88.7 ± 6.5	89.3 ± 6.4	0.002*
Triglyceride (mg/dl)	88.0 (51.5)	87.0 (49)	87 (49.8)	0.6
High-density lipoprotein (mg/dl)	49.6 ± 14.4	50.1 ± 12.3	49.9 ± 13.2	0.3
Insulin (uU/dl)	5.10 (0.6)	5.20 (0.7)	5.2 (0.7)	0.1
HOMA	1.14 (0.2)	1.13(0.2)	1.1 (0.2)	0.7
Cardiometabolic risk z-score	-0.04 ± 0.6	-0.02 ± 0.6	-0.02 ± 0.6	0.7

Mean ± SD or median and (interquartile range), [1] Differences between boys and girls were examined with Student’s t test for independent observations with equal variances (variables with normal distribution) or with the Mann-Whitney nonparametric test. BMI was calculated as weight (kg)/height $(cm)^2$

Table 2 shows the CMR factors by sex and nutritional status. Significant differences in CMR score and WHtR were found in both sexes; higher values for both variables were observed in overweight children compared to normal weight children (p <0.001). Overweight girls had significantly higher triglycerides, insulin and HOMA than normal weight girls (p <0.001).

Table 2
Description of cardiometabolic risk factors by nutritional status.

	Boys (n = 185)			**Girls (n = 267)**		
	Normal (n = 93)	**OvOb (n = 92)**	p	**Normal (n = 141)**	**OvOb (n = 126)**	p
WC/Height	0.45 ± 0.03	0.50 ± 0.06	< 0.001	0.45 ± 0.04	0.53 ± 0.05	< 0.001
Glycaemia (mg/dl)	89.5 ± 5.9	90.9 ± 6.4	0.06	88 ± 6.7	89.4 ± 5.7	0.06
TG (mg/dl)	84 (55.5)	91.5(46.7)	0.16	79 (41)	101(47.2)	< 0.001
HDL (mg/dl)	49.8 ± 14.3	49.3 ± 14.6	0.92	51.2 ± 12.6	48.9 ± 11.9	0.12
Insulin (uU/dl)	5.10(0.75)	5.20(0.75)	0.29	5.10(0.5)	5.30(0.8)	0.004
HOMA	1.14 (0.20)	1.17(0.21)	0.06	1.12 (0.16)	1.15(0.22)	< 0.001
CMR-z	-0.19 ± 0.54	0.15 ± 0.63	< 0.001	-0.26 ± 0.54	0.20 ± 0.57	< 0.001

Mean ± SD or median and (interquartile range); **BMI**, body mass index; **WC/height** waist circumference / height; **TG**, triglycerides; **HDL**, high-density lipoprotein; **HOMA**, homeostasis model assessment; **CMR z**, cardiometabolic risk score, **OvOb**, overweight and obese

Table 3 shows the physical fitness results by nutritional status and sex. Compared to obese children, the normal nutritional status group had better muscle strength and cardiorespiratory fitness in both sexes in most tests (p <0.05). Notably, on the hand grip strength test, children with overweight and obesity had better records than normal weight children, but when adjusted for weight, the results were reversed. Boys showed higher values of muscle strength and cardiorespiratory fitness compared to girls (p <0.05). The findings of suggest the time of moderate-intensity physical activity and sedentary time modifies cardiometabolic risk in children.

Table 3
Description of physical fitness variables by nutritional status.

	Boys (n = 185)			**Girls (n = 267)**		
	Normal (n = 93)	**OvOb (n = 92)**	p[1]	**Normal (n = 141)**	**OvOb (n = 126)**	p
Standing long jump (cm)	116.9 ± 7.5	111.2 ± 4.9	0.02	106.2 ± 15.6	101.0 ± 3.5	< 0.005
Hand grip (kg)	11.1 (2.4)	12.5 (4.0)	< 0.001	10.6 (2.3)	11.4 (3.2)	< 0.001
Hand grip/weight	0.45 (0.1)	0.39 (0.1)	< 0.001	0.44 (0.1)	0.40 (0.1)	< 0.001
6MWT (m)	625.2 ± 53.7	615.9 ± 44.9	0.2	615.8 ± 52.8	609.2 ± 42.4	0.2
6MWT/height (m)	503.6 ± 49.8	477.6 ± 53.3	0.002	493.1 ± 48.7	474.9 ± 48.6	< 0.001
Muscle strength-z score	1.14 ± 2.1	-0.01 ± 1.7	< 0.001	0.34 ± 1.9	-1.10 ± 1.6	< 0.001
6MWT/height- z score	0.43 ± 1.2	-0.20 ± 1.3	0.002	0.17 ± 1.2	-0.30 ± 1.2	< 0.001

Mean ± SD or median and (interquartile range),, **OvOb**, overweight and obese **6MWT** Six-minute walk test; [1] Differences in nutritional status were examined with Student's t test for normal distributions or with the Mann-Whitney non-parametric test for non-normal observations.

Figure 1a shows the CMR score tertiles in relation to physical fitness and fat categories (BMI and WHtR). In subjects with a low fat mass tertile, there was no difference in the CMR risk by muscle strength and cardiorespiratory fitness tertiles. Whereas in children with a high fat mass tertile, higher muscle strength or cardiorespiratory fitness was associated with a lower CMR than that of other groups. The post hoc analysis found significant differences between the low and high tertiles ($p < 0.05$), and CMR was lower for the higher tertile.

The post hoc analysis found significant differences between the low and high tertiles ($p < 0.05$), and CMR was lower for the higher tertile.

Figure 1b shows the CMR score according to fat categories and muscle strength tertiles. In subjects with a low fat mass tertile, there were no differences in CMR according to cardiorespiratory fitness tertile. In high-fat tertile children, the group with higher cardiorespiratory fitness had lower CMR values than the low tertile cardiorespiratory fitness group. The results of Figure 1a and 1b were adjusted by age, sex and maturation status.

Table 4 shows the odds ratio (OR) of the relationship between high CMR and the combined association of physical fitness (cardiorespiratory fitness and muscle strength). The analysis was performed with the high tertile of cardiorespiratory fitness and the high tertile of muscle strength as references. The results show that a low tertile of cardiorespiratory fitness and a low tertile of muscle strength are associated with a 6.8 times higher CMR (95% CI, 3.4 to 13.9) compared to the high tertiles for both of these factors. In addition, a low tertile of muscle strength and a medium tertile of cardiorespiratory fitness had a high CMR (OR=3.5 Finally, a medium tertile of cardiorespiratory fitness and a medium tertile of muscle strength resulted in a high CMR (OR=2.6 95% CI, 1.2 to 5.5; p=0.003).

Table 4
Combined effects of physical fitness parameters on high cardiometabolic risk

Cardiorespiratory fitness level	**Muscle strength**	**Cardiometabolic risk (OR and 95% CI)**
High	High	reference
	Medium	1.6 (0.8 to 3.3)
	Low	2.4 (0.9 to 4.9)
Medium	High	1.5 (0.7 to 3.1)
	Medium	2.6 (1.2 to 5.5)*
	Low	3.5 (1.4 to 8.8)*
Low	High	0.6 (0.2 to 2.0)
	Medium	4.1 (2.8 to 8.4)*
	Low	6.8 (3.4 to 13.9)*

OR significant * All data were compared to higher muscle strength and higher cardiorespiratory fitness.

Discussion

Our results show that both muscle strength and cardiorespiratory fitness are inversely associated with the CMR-z score. In another study in adolescents, it was stated that continuous CMR-z scores are practical tools and are accurate and easy to apply [45].This suggests that body composition is a critical determinant of metabolic health, as other studies have shown in adolescents [46,47]. On the other hand, children, who increase their adiposity levels as they enter puberty, despite remaining normal weight are at risk of developing cardiometabolic risk factors. [48].

Muscular strength has a relevant role in attenuating the association between physical inactivity and metabolic risk in children, in a comparison of active and sedentary children. Our results show that overweight children had greater hand grip strength than eutrophic children. Ervin et al, found a similar result in a sample of 1224 youth aged 6 to 15 years, wherein grip strength was significantly higher in obese children and adolescents than in normal nutritional status children. However, when hand grip strength was adjusted by weight, normal nutritional status children achieved better results, a fact that suggests that static hand strength correlates more with lean mass than with total weight or BMI [49].Children with low grip strength had higher systolic blood pressure, low-density lipoprotein cholesterol, higher metabolic syndrome score (0.36), compared with those with moderate/high grip strength [50]. Cohen et al, has shown that when analyses were stratified by sex, handgrip strength was negatively associated with cardiometabolic z-score in girls. Furthermore, young people in the lowest strength quartile were three times more likely to have elevated metabolic risk than those in the highest strength quartile [51].

No difference was found by sex or nutritional status for the 6MWT, but when the 6MWT was adjusted by height, the maximal distance was significantly different ($p <0.05$). This adjustment by height was done to minimize the bias that body size has on the walked distance (correlation $r = 0.17$) (data not shown). The test was validated by Li et al, where the correlation of the 6MWT with size had an $r = 0.45$ ($p <0.05$). The same author has shown that this test is valid, easy to perform and economical as an indicator of sub-maximum capacity, compared to cardiorespiratory fitness or other stressful tests [52]. Moura BP et al, found that light sedentary physical activity can be considered an effective alternative to reduce sedentary behavior as improves the cardiometabolic health indicators in the children [53].

The first multinomial logistic regression analysis revealed that higher muscle strength and cardiorespiratory fitness explained lower CMR. In the overweight group of schoolchildren, it was observed that children with better muscle strength and cardiorespiratory fitness had a lower CMR compared to other overweight children. These results coincide with other works in adolescents and adults, which were attributed to changes in muscle metabolism, as lower visceral fat mass provides protection [16, 54]. In similar studies, muscular strength has shown a stronger association with CMR score than cardiorespiratory fitness has [20,21]. Similar findings in previous work in children and adolescents have shown an independent association of muscle strength with insulin sensitivity [15] and metabolic disease risk [55]. Agostinis-Sobrinho et al [56], in another study in adolescents, indicated that persistent greater and increasing muscle strength is associated with lower levels of cardiovascular risk. The results of Schmidt et al [57] strengthen the findings that cardiorespiratory fitness has a strong association with CMR.

Several studies have shown that CMR is higher in overweight children and adolescents with low muscle strength [7, 49]. The results of this study suggest that muscle strength in schoolchildren may confer additional benefits attributed to cardiorespiratory fitness Most obese children are reluctant to participate in aerobic training; therefore, power exercise may be more attractive and better tolerated [58].

Hand grip strength and the standing long jump have proven to be a good validity criterion, compared to laboratory tests [34,59], suggesting that they are appropriate measures of muscle strength, especially in the first years of schooling.

Among the strengths of our study, we confirm that a risk score composed of metabolic risk factors can be used to investigate the cardiorespiratory fitness and muscle strength [16, 18, 30, 45]. Such variables indicators may better reflect the health status of participants than the assessment of individual risk factors [[60]].

Limitations

However, our results should be interpreted with care. The CMR score is specific to the sample under study and is based on the assumption that each component is equally weighted in the prediction of CMR. The 6MWT is a submaximal test to assess cardiorespiratory fitness, and it is not comparable with the standard aerobic test, i.e., the Course-Navette test. Finally, to evaluate muscle strength, only hand grip strength and standing long jump were measured, and other tests could have been chosen[36, 46]. However, these tests are easy to apply and well tolerated in children of young ages, whose results are reported in this study.

Conclusion

Muscle strength and cardiorespiratory fitness are associated independently and inversely with CMR score. These results confirm the importance of stimulating physical activity to prevent metabolic risk at an early age, especially in sedentary children or those with high weights. In the future, longitudinal studies are needed to further find the independent and combined effects of cardiorespiratory fitness and muscle strength in the prevention of cardiovascular disease risk.

Abbreviations

BMI Body Mass Index

CMR Cardio-metabolic risk

6MWT Six-minute walk test

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Declarations

Ethics approval and consent to participate: Ethical approval: Research involving human participants. All procedures performed were in accordance with the ethical standards as laid down in the 1964 Helsinki declaration. Informed consent: Parents or guardians previously signed the informed consent forms approved by INTA's Committee for research in human subjects.

Consent for publication

- Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request
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- Authors' contributions

All authors have read and approved the manuscript

GW designed the study, review of the literature, writing and revised the manuscript, approval of the final manuscript

MAG review of the literature and statistical analysis the data, approval of the final manuscript.

AGH statistical analysis the data and approval of the final manuscript

GS supervise the data collection, review of the literature, writing and revised the manuscript, approval of the final manuscript.

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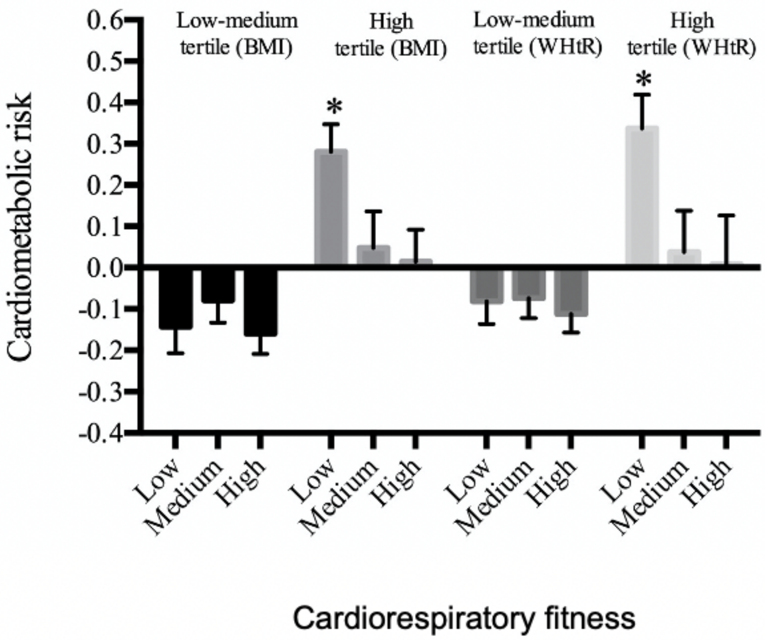
Figures

1a



1b

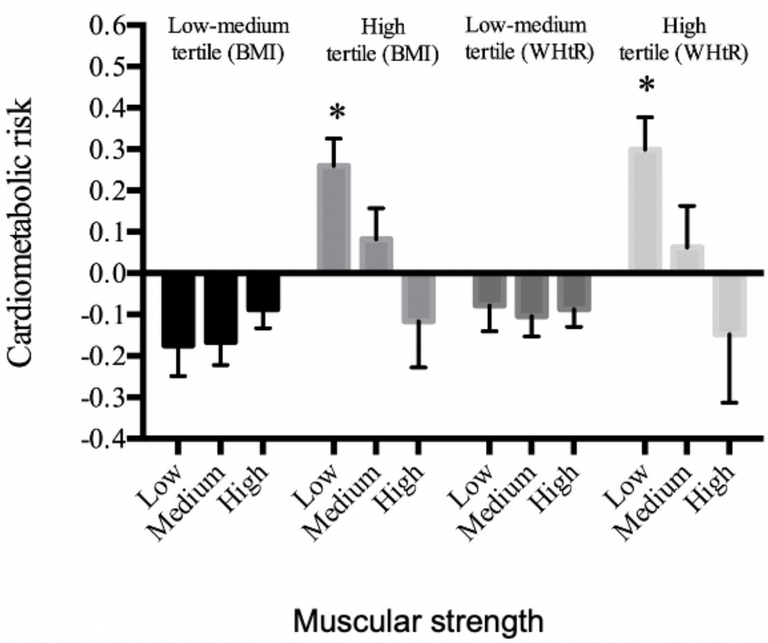


Figure 1

Cardiometabolic risk z-score by fat tertiles categories (a), cardiorespiratory fitness (b) and muscular strength * p<0.05 between high and low tertiles In subjects with low fat, there was no difference in the CMR risk as muscle strength tertiles; whereas in children with high fat, higher muscle strength showed lower CMR compared to other groups with lower muscle strength.