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# Physical fitness, cardiometabolic risk and heart rate recovery in Chilean children

## *Condición física, riesgo cardiometabólico y frecuencia cardiaca de recuperación en escolares chilenos*

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## Abstract

**Objective:** To evaluate the association of physical fitness (PF) and cardiometabolic risk (CMR) with heart rate recovery time (ΔHRR) in Chilean school aged children.

**Methods:** Cross-sectional study in 478 6-9 years old children participants. We measured weight, height and abdominal circumference. Fitness was measured using the 6MWT, grip strength and leap forward without impulse tests; PF z-scores were calculated. Heart rate (HR) was monitored and recorded during the 6MWT. ΔHRR was calculated as the difference between HR before and one minute after test; blood glucose, insulin, triglycerides and HDL-cholesterol were measured. Waist circumference, CMR-z and HOMA were calculated.

**Results:** Absolute ΔHRR and CMR-z measures in normal weight children were lower than in obese children ($p < 0.05$ and $p < 0.01$, respectively). In obese children, ΔHRR was also associated with grip strength/weight ($r = -0.6$, $p < 0.01$) and PF-z ($r = -0.6$, $p = 0.04$). Insulin and HOMA were significantly related to ΔHRR ($r = 0.3$, $p < 0.001$), especially in overweight and obese children. ΔHRR values were not associated with CMR-z.

**Conclusions:** A significant relationship between ΔHRR with fitness and insulin sensitivity in overweight and obese school children was found. We consider that these results support the need to measure these variables in overweight and obese children, in order to strengthen the need for early prevention.

**Key words:**

Fitness. Cardiometabolic risk. Heart rate recovery time. School children obesity.

## Resumen

**Objetivo:** establecer la asociación entre la condición física (CF) y el riesgo cardiometabólico (RCM) con el tiempo de recuperación de la frecuencia cardiaca (ΔFCR) en escolares chilenos.

**Métodos:** estudio trasversal de 478 escolares de 6 a 9 años de ambos sexos. Se evaluó peso, talla y perímetro abdominal. Se midió CF global mediante T6M, fuerza de agarre y salto hacia adelante sin impulso; se calculó z-CF. Se midió frecuencia cardiaca (FC) con sensor durante el T6M. Calculamos ΔFCRecup como la diferencia entre la FC en reposo y la FC al minuto de finalizado el test, glicemia, insulinemia, trigliceridemia y colesterol-HD. Perímetro de cintura, z-RCM y HOMA fueron calculados.

**Resultados:** los escolares normopeso tuvieron menor ΔFCRecup y z-RCM que los obesos ($p < 0,05$ and $p < 0,01$ respectivamente). En niños obesos, el ΔFCRecup se asoció a fuerza de agarre/peso ($r = -0,6$, $p < 0,01$) y z-CF ($r = -0,6$, $p = 0,04$). Un menor ΔFCRecup se relacionó con menores niveles de insulinemia y HOMA ($r = 0,3$, $p < 0,001$), especialmente en el grupo de escolares con sobrepeso y obesidad. El ΔFCRecup no fue asociado a z-RCM.

**Conclusión:** existe asociación entre el ΔFCRecup y la condición física y sensibilidad insulínica en escolares con sobrepeso y/u obesidad, lo que refuerza la necesidad de la medición de esta variable en niños con sobrepeso y obesidad para una prevención temprana.

**Palabras clave:**

Condición física. Riesgo cardiometabólico. Frecuencia cardiaca de recuperación. Obesidad escolar.

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## INTRODUCTION

The prevalence of sedentary life in adults and children continues to rise globally. At least 60% of the world population does not perform the necessary physical activity to prevent obesity and related non-communicable diseases (NCDs) (1). And Chile is not an exception. According to a 2012 report of physical fitness in schools, 70% of Chilean students in 8th grade had unsatisfactory aerobic fitness levels and lived predominantly sedentary lives (2), spending > 10 hours in activities of low energy expenditure and excessive time in front of a screen (television or computer) (3,4). Obesity and a sedentary lifestyle during childhood leads to poor physical fitness, increasing the risk for obesity, metabolic syndrome and cardiovascular disease in adulthood. These consequences have not been sufficiently studied in children. Thus we considered of interest to assess the association between physical fitness and cardiometabolic risk (CMR) to strengthen the call for more physical activity in children and adolescents. We further hypothesized that the evidence of prolonged heart rate recovery time in young children might motivate parents to act at an early stage, thus preventing further deterioration (5).

Heart rate recovery (ΔHRR) reflects the functional capacity of autonomic nervous system (6) and perhaps could be considered a measure autonomic dysfunction (7). Additionally, adults with high cardiorespiratory fitness recover faster than adults with lower level physical fitness (8). Metabolic risk factors are inversely associated with ΔHRR in healthy children and adolescents (9). The physiological mechanism underlying heart rate recovery after exercise in children operates faster than in adults; smaller heart size, relative muscle mass, perfusion distance and faster cardiorespiratory circulation time kinetics explain most of the difference (10). Simhaee et al. showed that children with high body mass index (BMI) have a longer heart rate recovery time and that those with faster recovery have more moderate to vigorous physical activity. Other studies show that there is a direct correlation between sedentary behavior and increased heart rate recovery (9). A cross-sectional study of 993 healthy adolescents of 12-19 years of age shows that heart rate recovery time was inversely related to metabolic risk factors (waist circumference, systolic blood pressure, plasma triglycerides, levels of C-reactive protein) and positively related to circulating HDL levels (11). Prolonged heart rate recovery time, which reflects a deteriorating physical condition, might be useful to detect children with elevated CMR. Thus, it is important to further investigate the link between heart rate recovery time and cardiovascular/metabolic risk in children (9). The aim of this cross-sectional study was to explore the association between physical fitness (6-minute walk test and muscle strength) and CMR, with heart rate recovery, in a group of Chilean schoolchildren aged 6-9 years.

## MATERIALS AND METHODS

### POPULATION

The study sample comprised 478 6-9 years-old children (n = 216 girls) participating in the Growth and Obesity Cohort Study (GOCS) conducted in Santiago, Chile. GOCS is a study of low-middle income Chilean children born in 2002-2003 (n = 1,196, ~ 50% girls), of normal gestation 37-42 weeks with birth weight ≥ 2,500 g (12). The study was approved by the Ethics Committee of the Institute of Nutrition and Food Technology, University of Chile. All parents/legal guardians agreed to the participation of their children by signing the free informed consent form.

### ASSESSMENT OF PHYSICAL FITNESS (PF)

Muscle strength was evaluated testing upper body strength (arms, handgrip strength) using a (Baseline 12-0286®) digital force gauge (13) and lower body strength (legs) was assessed by the standing long jump (14). Aerobic fitness was evaluated with the submaximal six minute walk test (6MWT) (15). Heart rate (HR) was measured and recorded with a heart rate monitor (Polar model FS1C): at rest before the test, then every three minutes, and finally one minute after test completion. Test results were expressed in meters traveled divided by the height of each child. The results of grip strength and jump were expressed in relative values, as the fat-free mass and length of stride of participants significantly modify the absolute values. We created an overall z-score of physical fitness (6MWTz/height + grip strength Z/weight + jump Z/height/3), and categorized "low" physical fitness as < -1 SD; "intermediate", between 1 and -1 SD; and "high", as > 1 SD.

### NUTRITIONAL ASSESSMENT

All children were measured in duplicate for weight (light clothing), standing at the center of a Tanita Body Composition Analyser BC-418, with 100 g precision and 220 kg capacity; height (Frankfurt methodology using a portable SECA, 222 stadiometer with upper range 200 cm and divisions of 1 mm) (16); and waist circumference, with an automatic locking tape (SECA) measured above the rim of the iliac crest, through the navel (17). Average height and weight measurements were used to determine BMI.

### BODY COMPOSITION

In a sub-sample of 122 boys and 92 girls, fat-free mass was estimated by total body water with bioelectrical impedance using Tanita BC-418MA, eight-electrode, hand-to-foot system, manufactured by Tanita Corporation (Tokyo, Japan) (18). We observed a high correlation between body weight and fat free mass ($r = 0.95$, $p < 0.001$).

### CMR-z

We evaluated CMR based on glucose, fasting insulin levels and lipid profile. CMR defined z ≥ 1.29 (90th percentile), from the score of the variables included in the equation (waist circumference-Z + glucose-Z + insulin-Z + triglycerides-Z – HDL-Z/5) (19). We used USA cut-offs for waist circumference (17) and plasma lipids (20), and blood glucose and insulin based on Chilean data (21). Insulin and HOMA were classified based on the centile distribution of Chilean children 6-15 years (22). The 75th centile for Tanner 1 (HOMA: 2.1) was used as a cut-off to diagnose insulin resistance.

## HEART RATE RECOVERY

We calculated a change in heart rate recovery (ΔHRR) as the difference between heart rate at the end of the 6MWT and after the one minute rest. Later, differences were classified in quartiles. The lowest quartile represented better recovery.

## STATISTICAL ANALYSIS

After analyzing the distribution of variables, data were expressed with means ± SD. Continuous variables were compared by sex and age range. To study the association between heart rate recovery and overall physical fitness (PF-z), insulin and HOMA, either Pearson or Spearman correlation coefficients were used. The associations between physical condition (lower, middle, top) and heart rate recovery (in quartiles) were evaluated with Chi-squared tests. Finally, the Student's t-test was used to compare the ΔHRR, according to presence or absence of insulin resistance, and ANOVA was used to assess whether heart rate recovery varied by nutritional status and CMR. A p value < 0.05 was considered to be statistically significant.

## RESULTS

The characteristics of the sample are summarized in table I. A total of 478 students (54.8% boys) of 8.3 ± 0.7 years were included in this study. When analyzing the results by sex, girls had lower resting HR, HR maximum and z-PF (p < 0.001), and the like ΔHRR (beats/minute) than boys. The prevalence of obesity was significantly higher in boys than in girls (15% and 7%, respectively; p < 0.01).

After calculating cut-offs for ΔHRR quartiles (< 41, 41-58, 58-80 and > 80), no differences were found by sex or age range, although we found a higher % of girls in the top two quartiles ΔHRR (60% girls *vs* 45% children). The ΔHRR was lower in schoolchildren with normal nutritional status compared with those who were obese (p = 0.03) (Fig. 1); no differences were found in analyzing the results by sex and age range.

The characteristics of the physical fitness tests are summarized in table II. In the jumping test, adjusted for height, boys jumped significantly more than girls (94 *vs* 84 cm, p < 0.01), a difference that was not maintained in tests of grip strength/weight and 6MWT/height. Studying the data by nutritional status, normal weight subjects scored better on tests of muscle strength and aerobic capacity than those who were overweight or obese (p < 0.001). In analyzing the results of physical fitness according to z-FP, 85% of schoolchildren had an intermediate fitness level (+/- 1 SD).

Table III shows the cardiovascular and metabolic profile and CMR score by sex and nutritional status. There were statistically significant differences in blood glucose and HDL-C by sex. Nutritional status, waist circumference, triglycerides, insulin and HOMA were also significantly different.

Thirteen and seventeen percent of schoolchildren had hyperinsulinemia and altered HOMA, respectively; 44% of them had high CMR scores (≥ z: 1.29); and no differences by sex or age were found. Children with overweight and obesity had higher CMR-z than normal children (Table III). However, no relationship between ΔHRR and CMR-z were observed, except for z value for insulin and HOMA, in this group. (r = 0.4; p < 0.001). When comparing schoolchildren with and without insulin resistance, we noted that this condition was associated with increased ΔHRR (72.4 *vs* 58.2 l/min; p < 0.001) (Fig. 2).

No statistical relationship was found between ΔHRR and -PF z (lower, middle or high). Instead, an association was observed if ΔHRR and strength grip/weight (r = -0.3; p < 0.01) were included, especially in 6-7 years old obese children (r = -0.6; p < 0.01). Finally, in the same group, higher ΔHRR was associated with a lower z-PF (r = - 0.6, p = 0.04).

**Table I.** Basic characteristics of the sample

| | Boys (n = 262) | | Girls (n = 216) | | *p* |
|---|---|---|---|---|---|
| | 6-7 years (n = 84) | 8-9 years (n = 178) | 6-7 years (n = 78) | 8-9 years (n = 138) | |
| Age (years) | 7 .5 ± 0.3 | 8.7 ± 04 | 7.5 ± 0.3 | 8.5 ± 0.4 | b,c |
| Weight (kg) | 26.2 ± 4.7 | 33.0 ± 7.7 | 26.7 ± 6.6 | 31.9 ± 7.5 | b,c |
| Height (m) | 1.2 ± 0.07 | 1.3 ± 0.07 | 1.2 ± 0.7 | 1.3 ± 0.8 | b,c |
| BMIz | 0 .9 ± 1.1 | 1.1 ± 1.2 | 0.7 ± 1.0 | 0.8 ± 1.1 | a |
| Resting heart rate (l/min) | 80.4 ± 8.3 | 77.7 ± 7.8 | 81.6 ± 8.5 | 81.5 ± 9.7 | a,b |
| Max heart rate (l/min) | 162.7 ± 18.2 | 142.6 ± 18.8 | 166.1 ± 18.1 | 157.0 ± 20.0 | a,b,c |
| ΔHRR (b/min) | 42.4 ± 19.2 | 71.0 ± 23.6 | 45.5 ± 16.5 | 67.1 ± 26.4 | b,c |
| Physical fitness-Z score | 0.2 ± 0.7 | 0.1 ± 07 | -0.16 ± 0.6 | -0.09 ± 0.6 | a |
| CMR-z score | 1.2 ± 0.1 | 1.1 ± 0.09 | 1.2 ± 0.1 | 1.4 ± 0.1 | NS |

*p < 0.01. BMI: body mass index; ΔHRR: change in heart rate recovery; a: differences by sex; b: differences by age range in boys; c: differences by age range in girls.*

**Table II.** Physical fitness characteristics by sex and age range

| | Boys (n = 262) | | Girls (n = 216) | | p |
|---|---|---|---|---|---|
| | 6-7 years (n = 84) | 8-9 years (n = 178) | 6-7 years (n = 78) | 8-9 years (n = 138) | |
| Jump (cm) | 113.7 ± 16.4 | 124.3 ± 19.1 | 110.0 ±14.3 | 102.3 ± 17.2 | a,b,c |
| Jump/height (cm) | 93.0 ± 14.5 | 94.4 ± 15.1 | 83.5 ± 12.1 | 84.1 ± 13.8 | a |
| Grip strength (kg) | 11.3 ± 2.3 | 12.5 ± 2.3 | 10.6 ± 2.0 | 12.0 ± 2.6 | a,b,c |
| Grip strength/weight (kg) | 0.4 ± 0.1 | 0.3 ± 0.1 | 0.4 ± 0.08 | 0.3 ± 0.09 | b, c |
| 6MWT (m) | 617.0 ± 50.0 | 624.3 ± 47.3 | 604.3 ± 49.7 | 625.5 ± 45.2 | c |
| 6MWT/height (m) | 504.0 ± 44.1 | 474.0 ± 44.5 | 491.0 ± 47.1 | 477.0 ± 42.0 | b,c * |

*$p < 0.01$; *p 0.02. 6MWT: 6 minute walking test; a: differences by sex; b: differences by age range in boys; c: differences by age range in girls.*

**Table III.** Cardiometabolic profile, HOMA and CMR-z score by sex and nutritional status

| | Boys (n = 262) | | | | Girls (n = 216) | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal (n = 122) | Overweight (n = 57) | Obese (n = 74) | P | Normal (n = 113) | Overweight (n = 61) | Obese (n = 35) | p |
| WC (cm) | 57.3 ± 3.4 | 62.8 ± 3.9 | 73.4 ± 6.5 | b,c* | 56.9 ± 4.1 | 65.7 ± 4.6 | 72.5 ± 5.5 | b,c |
| Triglycerides (mg/dl) | 81.3 ± 37.5 | 88.2 ± 29.4 | 106.2 ± 52.5 | b,c* | 86.1 ± 32.6 | 93.2 ± 45.8 | 129.9 ± 65.9 | b,c |
| Insulinemia (uUI/ml) | 7.0 ± 2.3 | 7.2 ± 3.2 | 8.5 ± 3.6 | b,c* | 6.8 ± 2.4 | 7.7 ± 2.8 | 8.7 ± 3.1 | b,d** |
| HDLc (mg/dl) | 51.5 ± 13.3 | 50.0 ± 11.9 | 48.5 ± 10.7 | d** | 48.3 ± 12.3 | 44.5 ± 11.4 | 44.8 ± 10.6 | d** |
| Glicemia (mg/dl) | 90.5 ± 6.3 | 91.1 ± 6.3 | 92.3 ± 6.8 | d** | 86.8 ± 6.7 | 87.8 ± 6.8 | 89.9 ± 8.1 | d** |
| HOMA | 1.6 ± 0.6 | 1.6 ± 0.8 | 2.0 ± 0.9 | b,c | 1.5 ± 0.5 | 1.7 ± 0.7 | 2.0 ± 0.8 | b** |
| CMR-z | 0.6 ± 1.0 | 1.1 ± 0.8 | 2.1 ± 1.2 | a,b,c | 0.8 ± 0.8 | 1.7 ± 1.0 | 2.8 ± 1.1 | a,b,c |

*$p < 0.01$; *p = 0.04; **$p < 0.001$. WC: waist circumference; CMR-z: cardiometabolic risk score; a: differences between normal weight and overweight; b: differences between normal weight and obese; c: differences between overweight and obesity; d: differences by sex.*

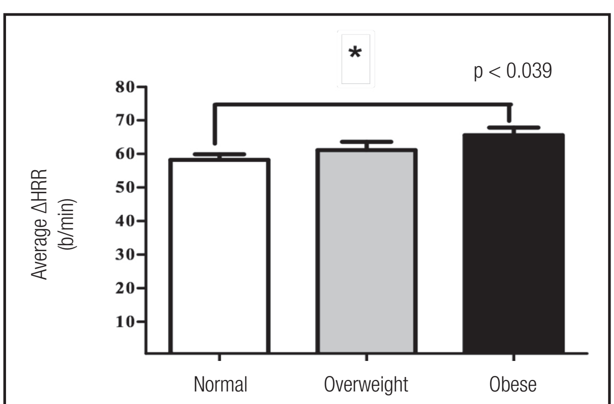


**Figure 1.**

Mean ΔHRR by nutritional status in schoolchildren aged 6-9 years. Anova, Bonferroni. p value represents trend between groups. Average ΔRHR: normal (58.2 ± 25.8 l/min), overweight (61.2 ± 26.8 l/min), obesity (66.0 ± 23.4).

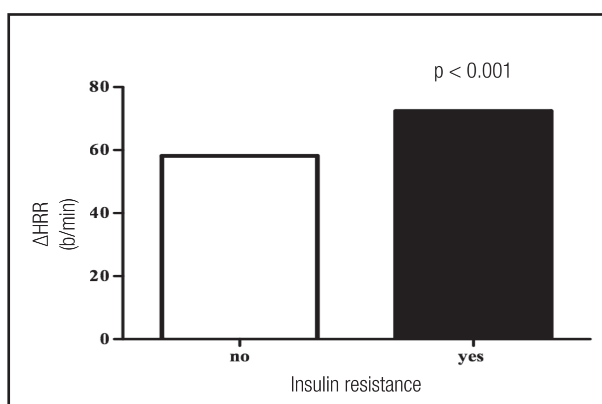


**Figure 2.**

ΔRHR and insulin resistance in schoolchildren aged 6 to 9 years. Student's t-test. *p* value represents trend between groups.

## DISCUSSION

Our study showed that overall PF-z, grip strength, HOMA and insulinemia were significantly associated with ΔHRR in overweight and obese children.

An important point to consider when interpreting the results of this study is the large variability in HR by age. This variability is due to a progressive maturation of the autonomic nervous system between three and six years old children. During this period, there is a tendency to increase sympathicotonia (23-25). Over-activation of the sympathetic nervous system in obesity, hypertension and hyperinsulinism (26,27) could be explained by an increase in free radicals, a decrease in nitric oxide, and an increase in both tubular sodium reabsorption and arterial vasoconstriction (28). Our results showed fluctuations in heart rate at rest and after the 6MWT by sex and age range, and an association between insulin levels, HOMA and waist circumference with ΔHRR in children with overweight/obesity. Wilks et al. reported that lifestyle changes for four to six weeks in children and adolescents with overweight/obesity would produce a significant improvement in heart rate recovery, although this recovery would not be associated with an improvement in cardiometabolic risk factors (29).

We find that higher ΔHRR was associated with a lower overall physical fitness (z-PF) in obese children aged six to seven years, a difference that was not observed in other children. This could be possibly explained by the fact that this group is more susceptible to develop sympathicotonia due to the lower age range. Furthermore, the nutritional state of these children is associated with greater cardiovascular and metabolic risk (9). The association is not expressed in the same way when analyzing separately the ratio of heart rate recovery with different fitness tests. In our study, ΔHRR was associated only with better grip strength/weight. This result is consistent with the fact that a better physical fitness in children is usually associated with greater muscle strength. Artero et al. found, in a sample of 709 adolescents, that muscle strength was associated with better physical condition and lower cardiometabolic risk (30). In this regard, this finding and our work complement previous studies in which the results showed that heart rate recovery was a marker of aerobic fitness, not related with muscle strength (31). On the other hand, the lack of association with the 6MWT could be because the latter would have a low correlation with maximum oxygen consumption ($VO_2$max), assessing functional capacity and not fitness aerobic. Morinder et al. found a low correlation between the traveled distance by the 6MWT and $VO_2$max in 8-16 years obese children (32). Other authors obtained similar results in obese children and adolescents by comparing the correlation of 6MWT and Cooper tests with $VO_2$max (33).

In analyzing our results related to ΔHRR, nutritional status and cardiometabolic risk, it is important to consider that 23% of subjects were obese, similar to that reported by the Board of School Aid and Scholarships Chile (34). Nearly half (48%) of our sample had CMR, close to the prevalence of insulin resistance (53%) described in Chilean children and adolescents between four and 16 years (35). In our study, children with insulin resistance had significantly higher ΔHRR, results similar to those of KuoHsu-Ko et al. in a sample of adolescents and adults with insulin resistance (36).

The differences found in ΔHRR by nutritional status were similar to those described in American obese schoolchildren (9). Another study in healthy adolescents and adults between 12 and 49 years showed that those who had slower heart rate recovery had higher BMI (36).

A lack of association was found between ΔHRR and CMR, which is consistent with other studies. In a sample of US adolescents (NHANES III), Liny el al. found, after a test of aerobic submaximal fitness, that heart rate recovery per minute was not associated with overall CMR, even if it was associated with some components of the metabolic syndrome (11). This result could be explained because the low demand of the submaximal test does not generate an increase of maximum heart rate or a change in ΔHRR, so it cannot detect individuals with higher CMR. In a sample of 1,395 children of both sexes, aged 9-12 years old, evaluated with a maximal test of short duration (three minutes), Laguna M. et al. found a significant association between blood pressure and ΔHRR in younger subjects and no association with global CMR (37).

One limitation of this study was the choice of the 6MWT. Future research should consider using the Navette test, an instrument with strong evidence to determine aerobic capacity in children and adolescents (38). Further, the lack of previous data related to the physical fitness of Chilean children could have influenced the overall classification and analysis of PF-z, and thus the absence of an association with heart rate recovery. In addition, not having measured blood pressure could partly explain the lack of association between CMR and ΔHRR, which however was associated with levels of insulin and HOMA. These findings support the need to improve efforts to reduce the high prevalence of overweight and obesity in schoolchildren aged 6-7 years. We can conclude that in overweight and obese children, ΔHRR could be a sensitive method for evaluating physical fitness and metabolic risk.

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