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Impact of a Strength Training Exercise Program on Body Composition and Cardiovascular Risk Factors in a Group of Obese Schoolchildren by Pubertal Stage

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Abstract The purpose of this study was to evaluate the impact of a strength training exercise intervention on body composition and cardiovascular risk factors in obese children, by pubertal stage. The sample included 60 obese schoolchildren of both genders, aged 8 to 13 years, recruited from a school in the city of Santiago (Chile). The intervention included physical exercise (strength training 3 times per week), during 3 months. Multi-compartmental body composition was estimated using isotopic dilution, plethysmography, radiographic absorptiometry and 4C model as the gold standard. Presence of metabolic syndrome was diagnosed according to Cook criteria and cardiovascular risk factors were determined using anthropometric and biochemical indicators. We found differences in schoolchildren in pubertal stages III & IV. Compared to girls, boys showed significant reductions in body fat in kg and percentage (4-Component model) and isotopic dilution in kg ($p < 0,05$). Likewise, we observed an increase in the fat-free mass in kg, in the 4-Component Model ($p < 0,01$). In all groups, the prevalence of metabolic syndrome decreased from baseline to 3 months, but the reduction was significant only among boys of Tanner I & II ($p = 0.03$). Only this group showed a significant reduction in the prevalence of cardiovascular risk factors from baseline to 3 months ($p = 0.02$). This study provides evidence on the positive impact of a strength training physical exercise program on reductions of body fat, metabolic syndrome, and cardiovascular risk factors, supporting the use of exercise as a treatment for obesity and its comorbidities in schoolchildren.

Keywords: *obese schoolchildren, strength training exercise, metabolic syndrome, cardiovascular risk factors*

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1. Introduction

Over the last decades, the prevalence of obesity has increased dramatically worldwide, reaching epidemic proportions and becoming a source of huge concern since the negative health consequences begin early in childhood. [1] In Chile, obesity in schoolchildren quadrupled from 1986 (4%) to 1998 (17%). In the 2000s, he prevalence of obesity among children entering the school system increased from 19,4% in 2006 to 22,1% in 2011. [2,3] To a great extent, the obesity epidemic is the result of changes in diet and activity patterns due to explosive economic growth, the so-called nutritional transition [4,5]

Consequences of childhood obesity include an increased risk of developing the Metabolic Syndrome (MS) (abdominal obesity, dyslipidemia, high blood pressure, and glucose intolerance), cardiovascular diseases, type 2 diabetes (DM2), non- alcoholic fatty liver disease, obstructive sleep apnea/hypoventilation, polycystic ovarian syndrome, infertility, asthma, orthopedic complications, psychiatric disease, and increased rates of cancer, among others [6,7].

The excessive accumulation of BF is deleterious to an individual's health, negatively affecting its physical and metabolic condition and contributing to insulin resistance and a chronic inflammatory state. Longitudinal studies show that MS in childhood quadruples the risk of DM2 and MS in adulthood. [8] These abnormalities may persist into adulthood without early interventions to prevent or treat obesity and restore cardiovascular and metabolic homeostasis. [9,10] The beneficial effect of physical exercise on the metabolism of lipids and carbohydrates, cardiovascular health, endothelium, and prevention and treatment of many metabolic, cardiovascular, and osteomuscular disorders associated with overweight has been well documented. [11] Dosed physical exercise (both aerobic and strength training) modify body composition, contributing to a conservation or increase in muscle mass and reductions of subcutaneous, visceral, and intramuscular fatty tissue. [12] Strength training physical exercise has been used to prevent and treat insulin

resistance, as enhancement in muscular function improves glucose capture and transport as well as lipid oxidation [13,14,15,16].

Contractile activity initiates a series of molecular, physiological, and biochemical events in skeletal muscle cells, activating kinases and phosphates that produce multiple signal transduction events favoring metabolic homeostasis. [17,18] Furthermore, this type of exercise produces less cardiovascular overload, and the intermittent nature of strength training is familiar and compatible with the play and movement of schoolchildren. [19] The aim of this study was to evaluate the impact of a strength training exercise intervention on body composition and CVRF of obese children, by pubertal stage.

2. Materials and Methods

2.1. Subjects

The sample was made up of 60 obese (BMI $\geq$ 95th percentile, according to CDC-NCHS charts) children of both sexes, aged 8 to 13, [20] recruited from an Elementary school in Macul, a district in Central East Santiago, Chile. The selection of establishment was by convenience, based on the school's proximity to the research center and professionals performing the intervention. Other inclusion criteria included full day attendance to the educational establishment, assent of the student to participate in the study, and consent form signed by the parent or legal guardian. Students were excluded if they had been diagnosed with a psychomotor disorder; used medications that alter body composition, physical activity, dietary intake, and/or biochemical parameters; or had physical abnormalities that would prevent them from participate in the exercise program. The study was approved by the institutional review board of the Institute of Nutrition and Food Technology (INTA), University of Chile, which meets national and international certification standards.

2.2. Description of Intervention

The exercise intervention took place within the educational establishment. Children were required to attend 45 minutes session, 3 times per week on non-consecutive days, for a period of 3 months (30 sessions in total). The intervention focused on localized strength training, using exercises that worked 6 muscle groups to fatigue: biceps (left and right), shoulders (left and right), pectorals (left and right), abdominals, calves (left and right), and thighs (left and right). The exercises used weighted arm bands for the arm exercises and body weight for the lower body exercises. The objective of the training was to rehabilitate muscle function, including both functional and working capacity, that had been lost due to physical inactivity. [21,22,23] The training circuit used the "1x2x3" method, which consists of 1 minute of exercise designed to fatigue the isolated muscle group, followed by 2 minutes of rest, repeated 3 times [23].

2.3. Biological Age

Pubertal development was classified using the Tanner scale according to female breast and male genital development [24].

Tanner stage was evaluated by visual inspection performed by a pediatric endocrinologist during the physical examination.

2.4. Anthropometry

Fasting weight and height were measured in early morning (7-8h). Children were just in underwear and stood on the scale, feet near the center, arms at their sides, and head neutral, so that the line from the corner of the eye to the origin of the ear was parallel with the floor. Weight was measured using an electronic precision scale (SECA® Model 767) with a sensitivity of 10 grams. Height was measured using a Holtain stadiometer (SECA) with a sensitivity of 0,1 cm. Both values were imported via Precision Hispana touch screen. Four skinfolds were measured (biceps, triceps, subscapular, and suprailiac) with a Lange caliper with millimetric precision (1 mm), using the technique described by Lohman et al., in triplicate. [25] All measurements (anthropometry, blood sampling) were performed in a single session.

2.5. Body Composition

2.5.1. Isotopic Dilution

Total body water was measured using deuterium dilution. The isotope was administered orally at a dose of 4 gr of deuterium oxide (99,8%), according to theparticipants' body weight. Body water values were derived from deuterium oxide concentrations, according to the Plateau method. Subjects fasted for a 3-hour equilibration period to minimize changes in total body water content. [26] A baseline saliva sample was taken (approximately 2 mL), and then the dose of deuterium was given, along with 20 ml of water. The post-dose saliva sample was taken after a 3-hour waiting period, during which the participants did not urinate or ingest other liquids or foods. The sample was frozen at a temperature of -20ºC. To analyze the deuterium content in the saliva, the sample was thawed and equilibrated with hydrogen gas, adding 5% platinum on alumina powder, for 3 days. The deuterium/hydrogen ratio in the resultant gas was analyzed using mass spectrometry (Hydra, Europa Scientific, Crewe, and Cheshire, UK).

2.5.2. Plethysmography

Body volume and density were measured using air-displacement plethysmography (BOD POD, mod 2000, Life Measurement, Inc, Concord, USA). Children were in underwear; only a swim cap covered their hair. Metalwork such as piercings and jewellry was removed. Children were weighed on a scale calibrated to a precision of 5g. This system first measures the pressure in the empty chamber and then measures the difference with the person inside using a 50-liter calibration cylinder, repeating the measurements 2-3 times. The total body volume calculated with this method is used as an input in the 4C equation.

2.5.3. Dual-energy X-ray Absorptiometry

Bone mineral density was estimated with dual-energy X-ray absorptiometry, using a latest-generation Ghc Lunar Prodigy DPX-NT (Lunar Radiology, WI, USA). This system evaluates the entire body in a five-minute cycle.

The children were positioned in supine on the exam bed, wearing underwear and covered with a sheet.

2.5.4. 2C Model

The 2C model divides the body into BF and FFM. Isotopic dilution, plethysmography, and DEXA were used to produce three estimates of body composition according to the 2C model.

2.5.5. 4C Model [27,28,29]

The 4C model divides the body into fat, water, protein, and minerals. Because the 4C model adjusts for mineral content, estimates of FFM hydration fraction and density are more precise as compared to the 3C model. The 4C model is considered the "gold standard" because it accounts for more of the sources of variability of its components. This equation has been validated previously in children of the same age group [30].

The 4C model uses the following equation:

$$\mathrm{BF}\ (\mathrm{Kg}) = [(2.747 * \mathrm{BV}) - (0.710 * \mathrm{TBW})] + [(1.460 * \mathrm{BMC}) - (2.050 * \mathrm{W})]$$

Where BV is body volume in liters (plethysmography), TBW is total body water in liters (isotopic dilution), BMC is bone mineral content in kg (DEXA), and W is body weight in kg.

2.6. Cardiovascular Risk Factors

Waist circumference in centimeters was measured using a non-stretch metric tape (SECA®) with automatic locking, measured over the border of the iliac crest, passing over the umbilicus. The methodology was based on that described by NHANES III in American population. [31] Diastolic (DBP) and systolic (SBP) blood pressure were measured in mmHg, using a mercury sphygmomanometer with an *ad hoc* sleeve, according to the standard methodology. [32] Cholesterol profile (HDL-Chol and TG in mg/dl) was determined using the dry analytic methodology (Vitros, Johnson & Johnson, Clinical diagnostics Inc.).

Baseline insulin in uUI/dl was measured using RIA (RIA DCP Diagnostic Products Corporation LA USA), with intra-assay CV of 5,1% and inter-assay CV of 7,1% for 14,4 uUI/ml, and a sensitivity of 1,2 uUI/ml. Glycemia was measured in mg/dl, with a commercial kit using the GOD-PAP enzymatic colorimetric method (Química Clínica Aplicada S.A.). Baseline insulin sensitivity was calculated using the HOMA method (fasting insulin (uUI/dl) * Fasting glycemia (mmol/L) / 22,5). [33] The biochemical profiles required an 8 hour fast. For its determination it took venous blood samples of 10 ml. Samples were analyzed in a laboratory at the Institute of Nutrition and Food Technology (University of Chile).

2.7. Definition of MS

MS was diagnosed according to the Cook phenotype, including three or more of the following abnormalities [34]: waist circumference (WC) $\geq$ 90th percentile, blood arterial pressure (BAP) $\geq$ 90th percentile, triglycerides (TG) $\geq$ 110 mg/dl, HDL- Cholesterol (HDL-Chol) $\leq$ 40 mg/dl, and fasting hyperglycemia (GI) $\geq$ 100 mg/dl.

2.8. Statistical Analysis

Descriptive statistics including minimum, maximum, and frequency distribution were derived for all variables. The Shapiro Wilk goodness-of-fit test and homogeneity of variance test were performed for continuous variables. Normal variables were expressed as mean ± standard deviation. Where normality criteria were not satisfied, variables are expressed as median and interquartile range. Two-way ANOVA was performed for [(2) sex x (2) pubertal stage] to compare physical characteristics, body composition and CVRF between groups. The comparison of the change (before-after) in the anthropometric variables, body composition and CVRF between the two groups was performed using the Student's *t* tests or the Wilcoxon test for independent samples. The McNemar test was used for the dependent samples to measure the change (before-after). The Symmetry test was used to evaluate the change of prevalence CVRF from baseline to 3 months.

The significance level was set at $p < 0,05$. Data were analyzed using STATA 12.0 (StataCorp. 2011. Stata Statistical Software: Release 12. College Station, TX: StataCorp LP.).

3. Results

Table 1 shows the physical characteristics, body composition and CVRF of the sample, by gender and pubertal stage. There were significant differences by gender and pubertal stage, although there were no interaction effects between the two variables. Age, weight, height, total body water, and bone mineral density were significantly higher in males. Likewise, values of BF (kg) and FFM (kg) in the 4C model, isotopic dilution, DEXA, plethysmography and systolic blood pressure were significantly higher among males, whereas females of breast III & IV had higher values for HOMA-IR. Regarding pubertal stage, both males and females in more advanced stages showed significantly higher values of age, weight, height, total body water, and bone mineral density. They also had significantly higher values of BF (kg) and FFM (kg) in the 4C model, isotopic dilution, DEXA, plethysmography, systolic blood pressure and diastolic blood pressure.

Table 2 compares the groups in terms of change in physical characteristics, body composition and CVRF from baseline to 3 months. We found differences in schoolchildren in pubertal stages III & IV. Comparing males and females, the former showed significant reductions in BF in kg and percentage (4C Model) and isotopic dilution in kg. Similarly, in this groups we observed an increase in the FFM in kg, in the 4C Model.

In Table 3 and Table 4, only boys of Tanner I & II showed a significant reduction from baseline to 3 months in the prevalence of CVRF ($p = 0,02$). In addition, we highlight the following reductions from baseline to three month post intervention: one participant with two MS components decreased to zero component; three children with two risk factors decreased to one; and six participants with three risk factors decreased to zero component.

Figure 1 shows the change in the prevalence of MS from baseline to 3 months. A reduction in the prevalence of MS was observed in all groups, however, the variation

was significant only among boys in Tanner stage I & II (p = 0,03).

Table 1. Physical characteristics, body composition and cardiovascular risk factors of the sample, by gender and pubertal stage

Variable	Boys		Girls	
	Genital I&II (n=19) Genital I (n=8) Genital II (n=11)	Genital III&IV (n=14) Genital III (n=8) Genital IV (n=6)	Breast I&II (n=5) Breast I (n=4) Breast II (n=1)	Breast III&IV (n=22) Breast III (n=15) BrIV (n=7)
Age (years)[1,2]	11,5 ± 1,1	13,6 ± 1,0	8,4 ± 0,8	11,5 ± 1,7
Weight (kg)[1,2]	60,9 ± 13,5	76,3 ± 11,7	38,5 ± 5,1	58,2 ± 14,3
Height (cm)[1,2]	149,4 ± 12,0	161,4 ± 4,8	131,1 ± 3,7	147,8 ± 8,0
Total body water (L)[1,2]	26,9 ± 5,5	35,6 ± 5,0	17,8 ± 2,1	25,6 ± 5,2
Bone mineral density (kg)[1,2]	1,8 ± 0,5	2,4 ± 0,3	1,2 ± 0,1	1,7 ± 0,4
4C Model				
BF (kg) [1,2]	25,3 ± 7,9	28,6 ± 9,3	14,4 ± 3,1	24,1 ± 8,5
BF (%)	41,2 ± 6,0	36,9 ± 7,9	37,2 ± 4,3	40,4 ± 6,2
FFM (kg)[1,2]	35,6 ± 7,7	47,7 ± 6,4	24,1 ± 2,6	34,1 ± 6,9
2C Model				
Isotopic dilution BF (kg)[1,2]	24,8 ± 7,8	28,4 ± 8,2	15,4 ± 2,9	24,4 ± 7,8
Isotopic dilution BF (%)	40,3 ± 5,7	36,8 ± 6,7	39,9 ± 3,6	41,3 ± 4,3
Isotopic dilution FFM (kg)[1,2]	36,1 ± 7,3	47,9 ± 6,8	23,1 ± 2,7	33,8 ± 7,1
DEXA BF (kg)[1,2]	25,6 ± 8,2	30,1 ± 8,8	14,8 ± 2,8	24,6 ± 8,0
DEXA BF (%)	41,5 ± 5,6	39,0 ± 7,0	38,3 ± 3,0	41,6 ± 4,7
DEXA FFM (kg)[1,2]	35,3 ± 6,7	46,2 ± 6,5	23,7 ± 2,6	33,6 ± 6,9
Plethysmography BF (kg)[1,2]	27,2 ± 8,3	30,6 ± 10,5	15,2 ± 3,6	25,5 ± 9,5
Plethysmography BF (%)	44,4 ± 6,7	39,2 ± 9,0	39,1 ± 6,1	42,6 ± 7,9
Plethysmography FFM (kg)[1,2]	33,7 ± 8,0	45,7 ± 5,9	23,3 ± 7,3	32,7 ± 7,0
Cardiovascular factors				
Waist circumference (cm)	91,8 ± 9,4	97,9 ± 9,3	77,3 ± 4,6	90,4 ± 11,3
Systolic blood pressure (mm Hg)[1,2]	106,3 ± 10,4	115,0 ± 11,5	92,5 ± 5,0	107,6 ± 11,9
Diastolic blood pressure (mm Hg)[2]	66,3 ± 7,2	69,6 ± 5,9	61,3 ± 2,5	66,9 ± 6,8
Glycemia (mg/dl)	93,4 ± 15,4	90,9 ± 8,9	88,4 ± 19,4	97,8 ± 17,1
HOMA-IR[1]	1,8 (1,2)	2,1 (1,2)	0,9 (1,6)	3,3 (2,5)
Total Cholesterol (mg/dl)	175,0 (38,0)	130,0 (20,0)	159,0 (67,5)	170,0 (57,0)
HDL-Cholesterol (mg/dl)	40,0 (14)	41,0 (16)	37,5 (12,5)	37,0 (8,0)
Triglycerides (mg/dl)	165,5 (69,0)	131,0 (75,0)	148,5 (192,0)	140,0 (74,0)

Data are presented as average ± standard deviation (SD) and mean (interquartile range)
[1]Significant difference by gender, p<0,05, [2]Significant different by pubertal stage, p<0,05.

Table 2. Change in physical characteristics, body composition and cardiovascular risk factors of the sample, by gender and pubertal stage

Variable		Girls	P value[1,2]	Boys	Girls	P value[1,2]
	Genital I &II (n=19) Genital I (n = 8) Genital II (n=11)	Breast I&II (n=5) Breast I (n=4) Breast II (n=1)		Genital III & IV (n=14) Genital III (n=8) Genital IV (n=6)	Breast III & IV (n = 22) Breast III (n = 15) BrIV (n = 7)	
Age (years)	0,3 ± 0,05	0,3 ± 0,05	0,28	0,3 ± 0,05	0,3 ± 0,04	0,74
Weight (kg)	1,9 ± 2,4	1,0 ± 1,6	0,50	0,8 ± 2,6	1,3 ± 3,5	0,68
Height (cm)	2,1 ± 1,1	2,0 ± 1,0	0,92	2,5 ± 1,2	1,9 ± 1,0	0,13
Total body water (L)	0,7 ± 0,9	0,5 ± 0,6	0,71	1,0 ± 1,1	0,5 ± 1,7	0,39
Bone mineral density (kg)	0,04 ± 0,07	0,05 ± 0,04	0,86	0,1 ± 0,1	0,09 ± 0,1	0,48
4C Model						
BF (kg)	0,8 ± 2,8	1,0 ± 1,2	0,87	-1,8 ± 2,8	0,2 ± 2,7	0,04
BF (%)	0,1 ± 3,9	1,6 ± 2,5	0,48	-2,8 ± 3,1	0,2 ± 3,9	0,03
FFM (kg)	0,9 ± 2,5	0,1 ± 1,4	0,47	2,6 ± 2,2	0,6 ± 2,8	0,03
2C Model						
Isotopic dilution BF (kg)	-9,4 ± 5,4	-7,1 ± 3,1	0,42	-20,4 ± 9,1	-9,0 ± 3,9	0,00
Isotopic dilution BF (%)	-0,2 ± 2,1	-0,6 ± 2,2	0,69	-1,2 ± 2,6	-0,5 ± 1,9	0,34
Isotopic dilution FFM (kg)	1,0 ± 1,5	0,8 ± 0,6	0,83	1,4 ± 1,4	0,7 ± 2,2	0,37
DEXA BF (kg)	0,4 ± 1,4	0,2 ± 1,5	0,75	-0,5 ± 2,8	0,3 ± 1,6	0,27
DEXA BF (%)	-0,6 ± 1,4	-0,5 ± 1,9	0,93	-1,1 ± 2,7	-0,2 ± 2,2	0,28
DEXA FFM (kg)	1,2 ± 1,5	0,8 ± 0,4	0,56	1,3 ± 1,6	0,5 ± 3,0	0,37
Plethysmography BF (kg)	0,9 ± 4,2	-0,06 ± 1,6	0,67	-1,5 ± 3,0	-0,2 ± 4,1	0,33
Plethysmography BF (%)	-0,1 ± 6,3	-1,3 ± 5,1	0,75	-2,3 ± 4,0	-0,3 ± 6,6	0,32
Plethysmography FFM (kg)	0,8 ± 3,6	1,0 ± 2,8	0,91	2,3 ± 2,9	1,0 ± 4,0	0,33
Cardiovascular factors						
Waist circumference (cm)	-0,4 ± 2,8	-1,3 ± 3,5	0,30	-0,9 ± 2,9	-0,8 ± 3,0	0,86
Systolic blood pressure (mm Hg)	-4,3 ± 7,4	0,0 ± 0,0	0,26	-4,2 ± 6,7	-3,3 ± 5,8	0,68
Diastolic blood pressure (mm Hg)	-1,3 ± 6,6	-1,3 ± 2,5	0,99	-2,7 ± 3,3	-2,6 ± 5,8	0,97
Glycemia (mg/dl)	-6,5 ± 14,6	2,1 ± 7,9	0,27	-6,5 ± 8,1	-12,5 ± 14,5	0,18
HOMA-IR	0,5 (1,0)	0,7 (1,4)	0,61	0,2 (1,8)	-0,3 (1,7)	0,35
Total Cholesterol (mg/dl)	2,5 (20,0)	-1,5 (22,5)	0,97	0,0 (16,0)	-4,0 (11,0)	0,05
HDL-Cholesterol (mg/dl)	1,0 (5,0)	3,5 (10,5)	0,46	2,0 (8,0)	1,0 (3,0)	0,96
Triglycerides (mg/dl)	-21,0 (69,0)	-57,5 (147,0)	0,93	-25,0 (40,0)	-17,0 (69,0)	0,51

Data are presented as average ± standard deviation (SD) and mean (interquartile range) [1]Student's *t* Test [2]Wilcoxon Rank sum Test

Table 3. Change in cardiovascular risk factors of boys at pubertal stages

Cardiovascular risk factors at baseline	Cardiovascular risk factors at 3-Month follow-up									
	Tanner 1[1,2]					Tanner 2[1]				
	0	1	2	3	4	0	1	2	3	4
0	0	0	0	0	0	1	0	0	0	0
1	0	0	1	1	0	1	2	0	0	0
2	1	3	0	0	0	0	2	1	0	0
3	0	1	6	2	0	0	0	1	3	1
4	0	0	0	3	1	0	0	0	1	1
Total	1	4	7	6	1	2	4	2	4	2

[1]Symmetry Test [2]p=0,02

Table 4. Change in cardiovascular risk factors of girls at pubertal stages

Cardiovascular risk factors at baseline	Cardiovascular risk factors at 3-Month follow-up										
	Tanner 1[1]					Tanner 2[1]					
	0	1	2	3	4	0	1	2	3	4	5
0	0	0	0	0	0	1	0	0	0	0	0
1	0	1	0	0	0	1	1	1	0	0	0
2	0	0	1	0	0	0	1	1	2	0	0
3	0	0	0	1	1	0	2	0	3	0	0
4	0	0	1	0	0	0	1	1	2	3	0
5	0	0	0	0	0	0	0	0	1	1	0
Total	0	1	2	1	1	2	5	3	8	4	0

[1]Symmetry Test

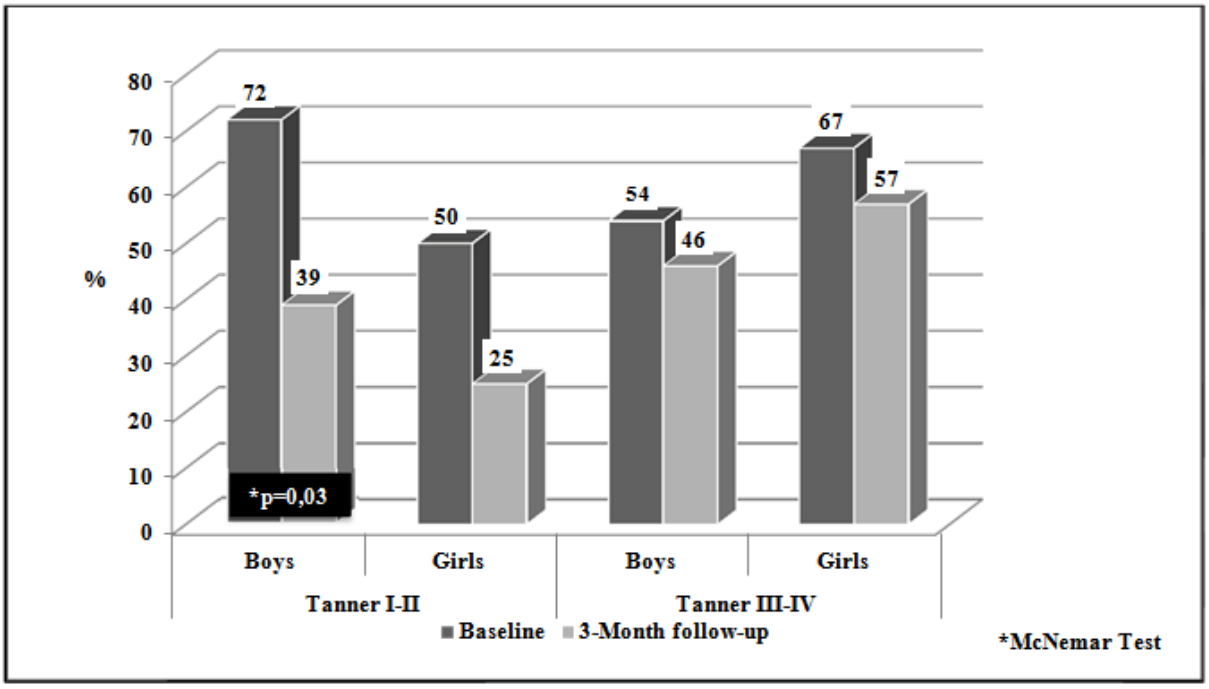

Figure 1. Change in prevalence of metabolic syndrome in boys and girls, from baseline to 3 months

4. Discussion

This study provides background on impact of exercise strength training interventions for obese schoolchildren carried out within the school system on body composition and CVRF, thus helping to increase the evidence available in both the country and the region. The 4C model quantifies BF and FFM more precisely than other methods because it directly measures mineral, water, and protein content rather than assuming a constant density of FFM. [35] In this research, it was chosen the 4C model as the reference standard to compare the sensitivity of other methods to estimate body composition (BF and FFM) in obese schoolchildren, by gender and pubertal stages. Concerning the impact on body composition (4 C model), the strength training intervention produced a significant reduction in BF (kg and %) and a significant increase in FFM (kg) in boys in Tanner stages III & IV, compared to girls girls. Instead, in the two-compartment model, a significant difference was also observed when comparing the reduction in BF (kg) in boys and girls, being higher in boys in Tanner III & IV. These findings are consistent with those provided by Ferguson et al. [36]. According to these authors, the effect of a 4 months of strength training exercise in obese children aged 7 to 11 years, reduced BF by 2,2% ($p < 0,001$). Similarly, a case-controlled intervention comprising strength training physical exercise intervention over ten weeks in overweight children aged 5 to 10 years

result in a significant reduction in BF in the intervention group ($p < 0,01$) [37]. A similar outcome was observed after a four-month exercise program for obese children aged 7 to 11 years; reductions in percentage of BF were higher than 2% in the intervention group ($p < 0,01$). [38] McGuigan et al. [39] studied the effect of an eight-week strength training program in children with overweight or obesity, finding a reduction in BF of 2,6% ($p = 0,003$).

The research in children show that this type of exercise significantly lowers central and total adiposity, increases lean mass, and improves muscular strength. [40,41] However, an extensive review of the literature on the effect of physical exercise on obese children conclude that the magnitude of change in BF and FFM after exercise is associated with initial BF as well as the intensity and type of exercise [42,43,44]

In Chilean children and adolescents, the prevalence of MS is proportional to excess body weight (6.5% and 40.3% in overweight and severe obese children, respectively), whereas abdominal obesity increases the risk of MS by 17 times. [45] In Figure 1, both groups (girls and boys Tanner I-IV) showed lower rates of of MS, although the reduction was significant only among boys in Tanner I & II ($p = 0,03$). In the same groups we also observed a significant reduction in the number of risk factors after the intervention ($p = 0,02$) (Table 3), (Table 4). All groups achieved a reduction in abdominal obesity and hypertriglyceridemia, as well as a decrease in fasting hyperglycemia in boys in Tanner I-IV and girls in Tanner III & IV

Also, a decrease in total cholesterol in girls in Tanner I-IV along with an increase in HDL-Colesterol in boys and girls of Tanner I-IV were observed.

Similar results were reported in a research, in which a physical exercise intervention over a 6 weeks period led to a reduction in abdominal obesity ($p < 0,02$) and total cholesterol levels ($p < 0,05$). [6] Doyle et al. [37], whose intervention consisted of high- intensity physical exercise as well as nutritional and dietary education for children and their parents over 10 weeks, found a significant decrease in triglyceride levels in the intervention group as compared to the controls ($p = 0,0467$). Chang et al. [47] showed a decrease in the prevalence of fasting hyperglycemia, from 23,5% before intervention to 9% at 3 months and 0% at 9 months in the intervention group, vs. an increase from 23,1% at baseline to 29,4% at 12 months in the control group.

National and international studies concur that children's compliance rates with obesity treatment programs provided within the health care system are low. [48,49] The studies described above used conventional, individual treatment, in which the child is required to attend monthly or weekly sessions at a health care center. This design may partly explain the high attrition rate.

A strength of this study was that the program was provided in a group setting and targeted to obese schoolchildren. This design improved compliance and maintenance rates of the strength training exercise program over time.

A potential limitation is that the exposure-response relationship for the variable could not be analyzed due to the quasi- experimental design, resulting in a quality of evidence categorized as moderate rather than high as compared to randomized studies. [50] Thus, our results, although valid in our sample, cannot be generalized to the target population (obese school children aged 8 to 13). To achieve this type of findings, we recommend an effectiveness study.

5. Conclusions

This research measures the positive impact of a strength training physical exercise program on reductions of BF, MS, and CVRF. This program was provided in a group setting and designed especially for obese schoolchildren, which improved compliance and maintenance rates of the strength training exercise program. However, this kind of training in should be provided to all children within the school system, regardless of their nutritional status, to allow sustainability over time.

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Statement of Competing Interest

None of the authors had a conflict of interest.

List of abbreviation

Metabolic Syndrome: MS Cardiovascular
Risk Factors: CVRF Body Fat: BF
Fat-Free Mass: FFM
Dual-energy X-ray Absorptiometry: DEXA
4-Component Model: 4C Model
2-Component Model: 2C Model

References

[1] Global Health Observatory (GHO): Obesity 2008. World Health Organization 2013. [Online]. Available from: URL: http://www.who.int/gho/ncd/risk_factors/obesity_text/en/index.html. [Accessed Dec. 10, 2013].

[2] Muzzo S, Cordero J, Ramirez I, Burrows R. Trend in nutritional status and stature among school age children in Chile. *Nutrition.* 2004; 20 (10):867-973.

[3] National Council for School Assistance. Map Nutritional 2010. [Online]. Available from: URL: http://bpt.junaeb.cl:8080/MapaNutricionalGx/. [Accessed Jan. 23, 2014].

[4] Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. *Int J Obes Relat Metab Disord.* 2004; 28 Suppl 3:S2-S9.

[5] Popkin BM. An overview on the nutrition transition and its health implications: the Bellagio meeting. *Public Health Nutr.* 2002; 5 (1A):93-103.

[6] Bastien M, Poirier P, Lemieux I, Després JP. Overview of epidemiology and contribution of obesity to cardiovascular disease. *Prog Cardiovasc Dis.* 2014; 56 (4):369-381.

[7] Kelsey MM, Zaepfel A, Bjornstad P, Nadeau KJ. Age-Related Consequences of Childhood Obesity. *Gerontology*. 2014. [Epub ahead of print].

[8] Sun SS, Liang R, Huang TT, Daniels SR, Arslanian S, Liu K, Grave G, Siervogel R. Childhood obesity predicts adult metabolic syndrome: the Fels Longitudinal Study. *J Pediatr*. 2008; 152 (2):191-200.

[9] Hills AP, King NA, Armstrong TP. The contribution of physical activity and sedentary behaviors to the growth and development of children and adolescents: implications for overweight and obesity. *Sports Med.* 2007; 37 (6):533-545.

[10] Stein CJ, Colditz GA. The epidemic of obesity. *J Clin Endocrinol Metab*. 2004; 89 (6):2522-2525.

[11] Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits?. *Med Sci Sports Exerc*. 2001; 33 Suppl 6:S379-S399.

[12] Saris WH. The role of exercise in the dietary treatment of obesity. *Int J Obes Relat Metab Disord*. 1993; 17 Suppl :S17-S21.

[13] Hawley JA. Exercise as a therapeutic intervention for the prevention and treatment of insulin resistance. *Diabetes Metab Res Rev*. 2004; 20 (5):383-393.

[14] Hawley JA, Lessard SJ. Exercise training-induced improvements in insulin action. *Acta Physiol (Oxf)*. 2008; 192 (1):127-135.

[15] Shaibi GQ, Cruz ML, Ball GD, Weigensberg MJ, Salem GJ, Crespo NC, Goran MI. Effects of resistance training on insulin sensitivity in overweight Latino adolescent males. *Med Sci Sports Exerc*. 2006; 38 (7):1208-1215.

[16] Watts K, Beye P, Siafarikas A, O'Driscoll G, Jones TW, Davis EA, Green DJ. Effects of exercise training on vascular function in obese children. *J Pediatr*. 2004; 144 (5):620-625.

[17] Diaz E, Saavedra C. Physical exercise and obesity, concepts and metabolic cellular level. In: Cruchet S, Rozowsky J. Editors. Obesity: A Comprehensive Approach. Santiago: Nestlé Chile SA, 2007, pp 51-63.

[18] Hood DA. Invited Review: contractile activity-induced mitochondrial biogenesis in skeletal muscle. *J Appl Physiol*. 2001; 90 (3):1137-1157.

[19] Faigenbaum AD. State of the art reviews: resistance training for children and adolescents: are there health outcomes?. *AJLM*. 2007; 1 (3):190-200.

[20] National Center for Health Statistical (NCHS) - Centers for Disease Control and Prevention (CDC). [Online]. Available from: URL:http://www.cdc.gov/GrowthCharts/. [Accessed Jan. 16, 2014].

[21] Chile. Ministry of Health. Program on Healthy Eating and Physical Activity for Chronic Disease Prevention in Women, Children, Adolescents and Adults 2008. [Online]. Available from: URL:http://webhosting.redsalud.gov.cl/minsal/archivos/alimentosynutricion/estrategiaintervencion/orientacionespas af2008.doc. [Accessed Jan. 16, 2014].

[22] Diaz E, Saavedra C. Exercise and metabolic restoration. Nutrition, health and wellness. Magazine for health professionals (12), 26-40. 2008. Santiago: Nestlé Chile SA.

[23] Diaz E, Saavedra C, Meza J. Paper prepared for Ministry of Health. Contemporary Guide to exercise and health, 2007.

[24] Tanner JM. Fetus into man. Physical growth from conception to maturity. 2nd ed Harvard University Press, 1989.

[25] Lohman TG, Boileau RA, Slaughter RA. Body composition in children. In: Lohman TG. Editor. Human body composition. New York: Human Kinetics, 1984, pp 29-57.

[26] Schoeller DA. Hydrometry. In: Roche A, Heymsfield S, Lohman TG, editors. Human body composition. New York: Human Kinetics, 1996:25-43.

[27] Fuller NJ, Jebb SA, Laskey MA, Coward WA, Elia M. Four-component model for the assessment of body composition in humans: comparison with alternative methods, and evaluation of the density and hydration of fat-free mass. *Clin Sci (Lond).* 1992; 82 (6):687-93.

[28] Bellisari A, Roche A. Anthropometry and Ultrasound. In: Heymsfield S, Lohman T, Wang Z, Going S. Editors. Human Body Composition. 2nd ed. United States: Human Kinetics, 2005, pp 109-128.

[29] Sopher A, Shen W, Pietrobelli A. Pediatric Body Composition Methods. In: Heymsfield S, Lohman T, Wang Z, Going S. Editors. Human Body Composition. 2nd ed. United States: Human Kinetics, 2005, pp 129-139.

[30] Wells J, Fuller N, Dewit O, Fewtrell M, Elia M, Cole T. Four-component model of body composition in children: density and hydration of fat-free mass and comparison with simpler models. *Am J Clin Nutr*. 1999; 69 (5):904-12.

[31] Fernandez J, Redden D, Pietrobelli A, Allison D. Waist circumference percentiles in nationally representative samples of African-American, European-American, and Mexican-American children and adolescents. *J Pediatric*. 2004; 145 (4):439-444.

[32] National high blood pressure education program working group on hypertension control in children and adolescents. Update on the 1987 task force report on high blood pressure in children and adolescents: a working group report from the national high blood pressure education program. *Pediatrics*. 1996; 98 (4 Pt 1):649-658.

[33] Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 1985; 28 (7):412-419.

[34] Cook S, Weitzman M, Auinger P, Nguyen M, Dietz WH. Prevalence of a Metabolic Syndrome Phenotype in Adolescents: Findings From the Third National Health and Nutrition Examination Survey, 1988-1994. *Arch Pediatr Adolesc Med*. 2003; 157 (8):821-827.

[35] Wells JCK, Fuller NJ, Dewit O, Fewtrell MS, Elia M, Cole TJ. Four-component model of body composition in children: density and hydration of fat-free mass and comparison with simpler models. *Am J Clin Nutr*. 1999; 69 (5):904-912.

[36] Ferguson MA, Gutin B, Le NA, Karp W, Litaker M, Humphries M, Okuyama T, Riggs S, Owens S. Effects of exercise training and its cessation on components of the insulin resistance syndrome in obese children. *Int J Obes Relat Metab Disord.* 1999; 23 (8):889-895.

[37] Doyle-Baker PK, Venner AA, Lyon ME, Fung Tn. Impact of a combined diet and progressive exercise intervention for overweight and obese children: the B.E. H.I.P. study. *Appl Physiol Nutr Metab*. 2001; 36 (4):515-525.

[38] Owens S, Gutin B, Allison J, Riggs S, Ferguson M, Litaker M, Thompson W. Effect of physical training on total and visceral fat in obese children. *Med Sci Sports Exerc*. 1999; 31 (1):143-148.

[39] McGuigan MR, Tatasciore M, Newton RU, Pettigrew S. Eight weeks of resistance training can significantly alter body composition in children who are overweight or obese. *J Strength Cond Res.* 2009; 23 (1):80-85.

[40] Yoshioka M, Doucet E, St-Pierre S, Almeras N, Richard D, Labrie A, Despres JP, Bouchard C, Tremblay A. Impact of high-intensity exercise on energy expenditure, lipid oxidation and body fatness. *Int J Obes Relat Metab Disord*. 2001; 25 (3):332-339.

[41] Benson AC, Torode ME, Fiatarone Singh MA. The effect of high-intensity progressive resistance training on adiposity in children: a randomized controlled trial. *Int J Obes.* 2008; 32 (6):1016-1027.

[42] LeMura LM, Maziekas MT. Factors that alter body fat, body mass, and fat-free mass in pediatric obesity. *Med Sci Sports Exerc.* 2002; 34 (3):487-496.

[43] Nemet D, Barkan S, Epstein Y, Friedland O, Kowen G, Eliakim A. Short- and long-term beneficial effects of a combined dietary-behavioral-physical activity intervention for the treatment of childhood obesity. *Pediatrics.* 2005; 115 (4): e443-e4499.

[44] Sacher PM, Chadwick P, Wells JC, Williams JE, Cole TJ, Lawson MS. Assessing the acceptability and feasibility of the MEND Programme in a small group of obese 7-11-year-old children. *J Hum Nutr Diet.* 2005; 18 (1): 3-5.

[45] Burrows R, Leiva L, Weisstaub G. Metabolic syndrome in children and adolescents: association with insulin sensitivity and magnitude and distribution of obesity. *Rev Med Chil.* 2007; 135 (2):174-181.

[46] Woo KS, Chook P, Yu CW, Sung R, Qiao M, Leung S, Lam C, Metreweli C, Celermajer D. Effects of diet and exercise on obesity-related vascular dysfunction in children. *Circulation.* 2004; 109 (16):1981-1986.

[47] Chang C, Liu W, Zhao X, Li S, Yu C. Effect of supervised exercise intervention on metabolic risk factors and physical fitness in Chinese obese children in early puberty. *Obes Rev.* 2008; 9 Suppl 1:135-141.

[48] Barja S, Nuñez E, Velandia S, Urrejola P, Hodgson MI. Adherence and effectiveness in the medium term treatment of childhood obesity. *Rev Chil Pediatr.* 2005; 76 (2):151-158.

[49] Pinelli L, Elerdini N, Faith MS, Agnello D, Ambruzzi A, De Simone M, Leggeri G, Livieri C, Monetti N, Peverelli P, Salvatoni

A, Seminara S, Uasone R, Pietrobelli A. Childhood obesity: results of a multicenter study of obesity treatment in Italy. *J Pediatr Endocrinol Metab*. 1999;12 Suppl 3:795-799.

[50] Atkins D, Briss P, Eccles M, Flottorp S, Guyatt GH, Harbour RT, Hill S, Jaeschke R, Liberati A, Magrini N, Mason J, O'Connell D, Oxman AD, Phillips B, Schünemann H, Edejer TT, Vist GE, Williams JW Jr; GRADE Working Group. Systems for grading the quality of evidence and the strength of recommendations II: Pilot study of a new system. *BMC Health Serv Res*. 2005; 5 (1):25.