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ORIGINAL ARTICLE

Effect of a 12-week concurrent planification exercise program in overweight and obese children and adolescents

Efectos de una planificación de ejercicio concurrente de 12 semanas en niños, niñas y adolescentes con sobrepeso y obesidad

Erna Gálvez[a], Eduardo Cifuentes-Silva[a], Fernando González[a], Daniel Bueno[a], Phillip Foster[a], Mauricio Inostroza[a,b,c]

[a]Hospital Dr. Exequiel González Cortés. Santiago, Chile.
[b]Departamento de Kinesiología, Universidad Metropolitana de Ciencias de la Educación, Santiago, Chile.
[c]Núcleo Investigación Actividad Física y Salud (NIAS). Santiago, Chile.

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What do we know about the subject matter of this study?

It is known that concurrent training in overweight and obese children and adolescents impacts positively on aerobic capacity, muscle function, and metabolic control.

What does this study contribute to what is already known?

We present the results of the creation and implementation of a cost-effective and safe concurrent training planning for overweight and obese children and adolescents, which is a reproducible protocol applicable at all levels (primary, secondary, and tertiary) of public health.

Abstract

Objective: To determine the changes in a planned concurrent exercise protocol in overweight and obese children and adolescents who attend a cardiometabolic rehabilitation program at the Dr. Exequiel González Cortés hospital. **Patients and Method:** 32 patients were divided into two groups, the intervention group (INT) (n = 22; age: 12.9 ± 2.7), and the control group (CON) (n = 10; age: 12.6 ± 2.5). The INT performed 12 weeks of periodized concurrent training protocol, those who voluntarily left the program made up the CON. The measurements were made on three consecutive days; day 1: pre-participation cardiovascular evaluation and anthropometry, day 2: aerobic capacity and muscle function, and day 3: lipid profile and glycemic control. **Results:** The INT presented a decrease in the body mass index (BMI) (-0.77 ± 1.02 kilogram/meter^2; P=0.001), BMI z-score (-0.14 ± 0.20 Standard Deviation; P=0.002), waist circumference (-5.48 ± 6.42 centimeters; P = 0.0004), and waist to height ratio (-0.04 ± 0.04; P < 0.0001). Maximal oxygen consumption (2.24 ± **2.15 milliliters/kilogram/minutes; P** < 0.0001) and walked distance (104.55 ± 119.35 meters; P < 0.0001) improved in the INT. The push-ups 6.00 repetitions interquartile range (IQR) (4.00 - 11.00; P = 0.0001), standing

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Correspondence:
Mauricio Inostroza
mauricio.inostroza@umce.cl

Edited by:
Gerardo Weisstaub

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broad jump 16.00 centimeters IQR (8.00 - 21.25; P = 0.004), and prone plank 56,00 seconds IQR (38.00 - 73.00; P < 0.0001), improved in the INT, in addition to presenting a decrease in total cholesterol -11.00 milligram/deciliters IQR (-18.50 - 3.50; P = 0.02). Glycemic control did not change between both groups. **Conclusions:** A 12-week planned concurrent exercise protocol of twelve weeks is effective to improve anthropometry, aerobic capacity, muscle function, and total cholesterol in overweight and obese children and adolescents.

Introduction

In Chile, the prevalence of overweight in children has been increasing. 2017 data from the nutritional map of the National Board of School Aid and Scholarships (JUNAEB) show a prevalence of 28.6% of overweight, 23.1% of obesity, and 6.22% of severe obesity, resulting in 57.9% of Chilean schoolchildren with excess weight[1].

Physical exercise is essential in the reduction of body weight, although it should be accompanied by a nutritional intervention to achieve greater effectiveness[2]. Similarly, physical exercise alone demonstrates the ability to improve metabolic and cardiovascular parameters[3], also reducing mortality rates[4].

The positive effects of aerobic physical exercise[3,5] and strength[6,7] individually have been widely documented. Both types of physical exercise combined are denominated concurrent training, which has demonstrated potentiation of beneficial effects in aerobic capacity, muscular function[8], and metabolic parameters[9] than the modalities of aerobic and strength separately in obese children and adolescents.

Considering the above, it is necessary to generate concurrent training programs in the public health system. The objective of this study is to determine the effectiveness of a 12-week concurrent training program on anthropometry, muscle function, aerobic capacity, lipid profile, and glycemic control in children and adolescents consulting due to overweight and obesity in a sports medicine unit.

Patients and Method

Participants

Thirty-two participants entered the study. Table 1 shows their baseline characteristics. The participants were referred from primary health care centers from the South Metropolitan Health Service (SMHS) to the Sports Medicine unit, or by referrals from the medical specialties of the *Hospital Dr. Exequiel González Cortés* (HEGC). Inclusion criteria were children and adolescents with overweight [BMI z-score (BMI-z) > 1 standard deviation (SD)], obesity (BMI-z > 2 SD), and severe obesity (BMI-z > 3 SD), aged between 7 and 17 years. Exclusion criteria were moderate to severe cognitive impairment, a traumatic illness that prevents exercise, and severe cardiac disease that contraindicates exercise.

The participants were divided into an intervention group (INT) (n: 22; age 12.9 ± 2.7 years; 11 male and 11 female) and a control group (CON), which consisted of those users who entered the study and did not complete it, having voluntarily dropped out (n: 10; age 12.6 ± 2.5 years; 6 male and 4 female). To ensure the most optimal sample regarding the effect of exercise, the users of the CON group were evaluated three months after having voluntarily dropped out of the program. This study was approved by the SMHS ethics committee (code 55-21072021) following the guidelines of the Helsinki declaration.

Study design

Participants were evaluated by the HEGC Sports Medicine Unit team for 3 consecutive days, pre- and post-exercise program (INT group), or 3 months after voluntary dropout from the program (CON group) in the following order:

Day 1: Pre-participatory cardiovascular[10] and anthropometric assessment [weight, height, Body Mass Index (BMI), Body Mass Index calculated by z-score (BMI-z), waist circumference (WC), and waist-to-height ratio (WHtR).

Day 2: Muscle function evaluation (prone plank, elbow flexion-extension, standing broad jump, and aerobic capacity (20m shuttle run test).

Day 3: During a fasting period of 8-12 hours, lipid profile, glycemia, and insulin were measured at the HEGC.

Exercise planning

The INT group performed a 12-week concurrent training program, 3 times per week. The standard session consisted of a warm-up, running through each station of the aerobic circuit for 5 minutes continuously. Subsequently, aerobic exercise was continued for 30 minutes, ending with 30 minutes of strength exercise. The aerobic exercise was performed with functional movements: jogging, skipping, jumping jacks, lateral movements, and modified burpees.

During the first two weeks, 2 sets of 15 minutes with

5 minutes of rest between sets were performed at a rated perceived exertion (RPE) index of 5-6 on the infant perceived exertion scale (EPInfant)[11]. From week 3 to week 12, high-intensity interval exercise (HIIE) was performed in circuit mode with the verbal command to perform the exercises at maximum capacity [e.g., week 4, Monday, target: 20 sets of HIIE, divided into 4 rounds for each of the movements (jogging, skipping, jumping jacks, lateral movements, and modified burpees)]. Table 2 shows the exercise planning.

The strength exercise consisted of four types of exercise for the lower extremities (squats and lunges at 90°, long jumps, and maximum vertical jumps); two for the upper extremities (elbow flexion-extension with knee support and triceps dips with elbow and knee flexion at 90°) which correspond to isotonic exercises that include an eccentric and a concentric phase during their execution; and one for the trunk (prone plank) which corresponds to an isometric exercise since there is no change in muscle length during its execution. These exercises were performed with body weight at an intensity of 5-6 according to the OMNI-Resistance Exercise Scale (OMNI-RES). Table 3 shows the planning of the strength exercises.

Measurements

Laboratory tests

Venous blood samples were collected by a certified phlebotomist in the HEGC sampling laboratory, at rest after fasting between 8 - 12 hours. The analyses were performed by a medical technologist specialized in the area, using techniques with a high degree of validity such as the enzymatic determination method for total serum cholesterol and triglycerides, Friedewald equation for LDL cholesterol, direct measurement of polyethylene glycol for HDL cholesterol, electrochemiluminescence for basal insulin, and hexokinase for basal glycemia.

Anthropometry

Weight and height were measured using a beam balance scale with stadiometer (SECA®). The WC was measured with an inextensible tape measure, according to the protocol of Ruiz et al.[12] and then BMI, BMI-z, and WHtR were calculated with the data collected. The anthropometric measurements were made by the sports physician.

Table 1. Baseline Characteristics

Characteristics	Intervention group (n = 22)	Control group (n = 10)	p Value
Age (years)	12.9 ± 2.7	12. 6 ± 2.5	0.72
Weight (kg)	77.8 ± 24.6	77.71 ± 21.1	0.98
Height (cm)	155.7 ± 13.5	155.2 ± 8.6	0.91
BMI (kg/m2)	31. 3 ± 6.5	31.7 ± 5.9	0.87
BMI-z (standard deviation)	2.80 ± 0.75	2.90 ± 0.75	0.74
WC (cm)	100.7 ± 16.6	96.3 ± 11.6	0.45
WHtR	0.64 ± 0.1	0.62 ± 0.1	0.39
VO2max estimated by Shuttle 20m-run test (ml/kg/minute)	35.6 ± 5.6	35.6 ± 4.4	0.99
Distance runned in Shuttle 20m-run test (meters)	217.2 ± 139.1	190.0 ± 71.96	0.92
Elbow flexion - extension (repetitions).	0 (0 - 2)	0.5 (0 - 1.5)	0.78
Standing broad jump (cm)	138.5 (110.7 - 152.0)	118.5 (111.1 - 158.5)	0.74
Prone plank (seconds)	26.0 (18.0 - 35.0)	24.1 (17.1 - 48.1)	0.94
Total cholesterol (mg/dl)	147.0 (122.5 - 157.5)	157.0 (130.5 - 177.5)	0.40
Triglycerides (mg/dl)	102.0 (57.5 - 152.5)	88.5 (80.5 - 131.5)	0.51
LDL cholesterol (mg/dl)	82.5 ± 20.9	90.4 ± 32.6	0.42
HDL cholesterol (mg/dl)	39.1 ± 9.1	48.8 ± 8.8	0.11
Insulin (mU/L)	23.8 (18.2 - 39.0)	19.3 (12.4 - 24.4)	0.15
Glycemia (mg/dl)	96.0 (86.0 - 99.0)	92.0 (87.0 - 95.2)	0.53

Mean ± Standard deviation; Median (Inter Quartile Range); BMI: Body Mass Index; BMI – z: Body Mass Index by z – score; WC: Waist Circumference; WHtR: Waist to Height Ratio; VO2maximal: Maximal Oxygen Consumption; mg/dl: milligrams/deciliter; LDL: Low Density Lipoprotein; HDL: High Density Lipoprotein; mU/L: milliunits/liter.

20m shuttle run test

The test consisted of running 20 meters round trip at an initial incremental speed of 8.5 km/hr, increasing by 0.5 km/hr per minute[12]. Maximal oxygen consumption (VO2max) was estimated using the Leger et al equation[13]. VO2max in ml/kg/min and distance runned (m) during the test were used for data analysis.

Elbow flexion-extension

The participants were placed on a mat, supporting only feet and hands shoulder-width apart, and performed the maximum number of repetitions (rep) of

Table 2. Aerobic exercise planning.

Weeks		1			2			3	
Frequency (days)	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
Work RPE	5-6	5-6	5-6	5-6	5-6	5-6	8-9	8-9	8-9
Active pause RPE	/	/	/	/	/	/	5-6	5-6	5-6
HI:MI Relationship	/	/	/	/	/	/	1:4	1:4	1:4
WTT (min)	30	30	30	30	30	30	20	17.5	22.5
Bouts EIAI	/	/	/	/	/	/	16	14	18
Active TT (min)	30	30	30	30	30	30	4	3.5	4.5
Active pause TT (min)	/	/	/	/	/	/	16	16.5	15.5
Weeks		4			5			6	
Frequency (days)	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
Work RPE	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9
Active pause RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
HI:MI Relationship	1:3	1:3	1:3	1:3	1:3	1:3	1:3	1:3	1:3
WTT (min)	20	20	20	20	20	20	20	20	20
Bouts EIAI	20	20	20	20	16	24	20	16	24
Active TT (min)	5	5	5	5	4	6	5	4	6
Active pause TT (min)	15	15	15	15	16	14	15	16	14
Weeks		7			8			9	
Frequency (days)	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
Work RPE	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9
Active pause RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
HI:MI Relationship	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2	1:2
WTT (min)	20.25	20.25	20.25	20.25	18	22.5	20.25	18	22.5
Bouts EIAI	27	27	27	24	30	27	24	30	27
Active TT (min)	6.75	6.75	6.75	6.75	6	7.5	6.75	6	7.5
Active pause TT (min)	13.5	13.5	13.5	13.5	12	15	13.5	12	15
Weeks		10			11			12	
Frequency (days)	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
Work RPE	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9	8-9
Active pause RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
HI:MI Relationship	1:1	1:1	1:1	1:1	1:1	1:1	1:1	1:1	1:1
WTT (min)	20	20	20	20	17.5	22.5	15	15	15
Bouts EIAI	40	40	40	35	45	30	30	30	30
Active TT (min)	10	10	10	10	8.75	11.25	7.5	7.5	7.5
Active pause TT (min)	10	10	10	10	8.75	11.25	7.5	7.5	7.5

RPE: Rated Perceived Exertion; HI:MI: High Intensity / Moderato Intensity; WTT: Work Total Time; HIIE: Hight Intensity Interval Exercise; TT: Total Time; 1:4: 15 seconds of high intensity by 60 seconds of moderate intensity; 1:3: 15 seconds of high intensity by 45 seconds of moderate intensity; 1:2: 15 seconds of high intensity by 30 seconds of moderate intensity; 1:1: 15 seconds of high intensity by 15 seconds of moderate intensity.

trunk lift with 90º arm flexion[14]. These repetitions were considered for data analysis.

Standing broad jump

The subject stood behind the jump line, with feet shoulder-width apart, and then jumped as far as possible landing with both feet at the same time. Three attempts were performed and the best score in centimeters (cm) was considered for data analysis[12].

Prone plank

Only the elbows and toes were allowed to be in contact with the mat, maintaining the isometric position for as long as possible. The total time recorded in seconds (s) was used for data analysis[15].

Infant Perceived Exertion Scale (EPInfant)

The perceived exertion scale is used to quantify the sensation caused by metabolic changes during aerobic exercise. It has numerical descriptors (0 to 10), verbal descriptors, and a set of illustrations depicting a child running at increasing intensities along a bar scale of incremental height[11].

OMNI-Resistance Exercise Scale

Perception of exertion scale applied to strength exercises. It has numerical descriptors (0 to 10), verbal descriptors, and a set of illustrations representing a child lifting weight at increasing intensities along a bar scale of incremental height[16].

Statistical analysis

The normality of the sample was determined through the Shapiro-Wilk test. Student's t-tests for unpaired samples and Mann-Whitney tests were used to determine possible differences in the baseline characteristics of variables with normal and non-normal distribution between the INT and CON groups.

Intra-group changes experienced by both INT and CON groups from baseline and post-exercise were compared by two-way analysis of variance (ANOVA) or the Kruskal-Wallis test depending on the assumption of normality. If the ANOVA or Kruskal-Wallis test showed a significant difference, a Fisher's LSD *post-hoc* test for multiple comparisons was used to determine whether there were changes between the INT and CON groups after the exercise.

An effect size (ES) analysis was performed for normally and non-normally distributed variables[17,18], in-

Table 3. Strength training planning

Weeks	1			2			3		
Frequency (days)	Monday	Wednesday	Friday	Monday	Wednesday	Friday	Monday	Wednesday	Friday
Work RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
Isotonic volume exercises (series x repetitions)	2 x 6	2 x 6	2 x 6	2 x 6	2 x 6	2 x 6	2 x 6	2 x 6	2 x 6
Isometric volume exercises (series x seconds)	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30
Weeks	4			5			6		
Frequency (days)	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes
Work RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
Isotonic volume exercises (series x repetitions)	2 x 10	2 x 10	2 x 10	2 x 10	2 x 10	2 x 10	2 x 12	2 x 12	2 x 12
Isometric volume exercises (series x seconds)	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 30	2 x 60	2 x 60	2 x 60
Weeks	7			8			9		
Frequency (days)	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes
Work RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
Isotonic volume exercises (series x repetitions)	2 x 12	2 x 12	2 x 12	2 x 12	2 x 12	3 x 12	3 x 12	3 x 12	3 x 12
Isometric volume exercises (series x seconds)	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60
Weeks	10			11			12		
Frequency (days)	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes	Lunes	Miércoles	Viernes
Work RPE	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6	5-6
Isotonic volume exercises (series x repetitions)	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12	3 x 12
Isometric volume exercises (series x seconds)	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60	2 x 60

RPE: Rated Perceived Exertion.

terpreted as < 0.1 trivial, ≤ 0.1 to < 0.3 small, ≤ 0.3 to < 0.5 medium, and ≥ 0.5 as large. Statistical analysis was performed using GraphPad® PRISM 8.0 (California, USA). Statistical significance was set at $P \leq 0.05$. Data are presented as means and standard deviation (mean ± SD) or median and interquartile range (IQR).

Results

Anthropometry

There were no differences in multiple comparisons between the INT and the CON groups for weight, height, BMI, BMI-z, WC, and WHtR. Weight decreased in the INT group compared with the CON group (-0.80 ± 2.74 kg vs. 2.97 ± 1.87 kg; p = 0.007; ES: 0.17). Height increased in the INT group compared with the CON group (1.26 ± 1.48 cm vs. 2.30 ± 1.53 cm; p = 0.001; ES: 0.05). BMI decreased in the INT group compared with the CON group (-0.77 ± 1.1 kg/m^2 vs 0.33 ± 1.08 kg/m^2; p = 0.001; ES: 0.11). BMI-z decreased in the INT group compared with the CON group (-0.14 ± 0.20 SD vs 0.02 ± 0.22 SD; p = 0.0026; ES: 0.19) (Figure 1B). WC decreased in the INT group compared with the CON group (-5.48 ± 6.42 cm vs 2.10 ± 2.63 cm; p = 0.0004; ES: 0.34) (Figure 1C). WHtR decreased in the INT group compared with the CON group (-0.04 ± 0.04 points vs 0.01 ± 0.02 points; p < 0.0001; ES: 0.44) (Figure 1D).

20m shuttle run test

Multiple comparisons of the INT versus CON group presented no differences for VO2max, evidencing differences in meters run during the test (P = 0.05). The VO2max was increased in the INT group compared with the CON group (2.24 ± 2.15 ml/kg/min vs -0.27 ± 0.87 mg/kg/min; P < 0.0001; ES: 0.41) (Figure 1A). In addition, the INT group increased the distance runned during the test compared with the CON group (114.95 ± 119.35 m vs -22.00 ± 48.49 m; p < 0.0001; ES: 0.65) (Figure 2B).

Muscle function

Multiple comparisons of the INT versus CON group showed differences for the variables of elbow flexion-extension (p = 0.004) and prone plank (p < 0.0001), finding no differences for the standing long jump. The elbow flexion-extension test increased in the INT group compared with the CON group [6.00 rep (IQR 4.0 - 11.0) vs 1.00 rep (IQR 0.00 - 2.50); p = 0.001; ES: 0.97]. There were positive changes in the INT group compared with the CON group in the standing long jump [16.00 cm (IQR 8.00 - 21.25) vs -2.00 cm (IQR -7.75 - 5.25); p = 0.004; ES: 0.72]. The prone plank improved in the INT group compared with the CON group [56.00 s (IQR 38.00 - 73.00) vs 6.85 s (IQR -6.53 - 17.15); p < 0.0001; ES: 0.98].

Lipid profile

Multiple comparisons of the INT group versus the CON group presented no differences in total cholesterol, triglycerides, and LDL and HDL cholesterol. Total cholesterol decreased in the INT group compared with the CON group [-11.00 mg/dl (IQR -18.50 - 3.50) vs -6.50 mg/dl (IQR -23.25 - 11.00); p = 0.02; ES: 0.51). There was a decrease in HDL cholesterol in the CON group compared with the INT group (-3.40 ± 4.35 mg/dl vs 0.10 ± 5.36 mg/dl; p = 0.03; ES: 0.37). Triglycerides and LDL cholesterol showed no changes for both the INT and CON groups.

Glycemic control

Multiple comparisons of the INT versus CON group showed no differences for plasma insulin and glycemia variables. There were no changes in plasma insulin and glycemia in both the INT and CON groups.

Discussion

The 12-week concurrent training program was shown to improve anthropometric values, estimated VO2max, muscle function, and total cholesterol in overweight and obese children and adolescents. Therefore, the results are partially in line with the hypothesis initially proposed.

The exercise protocol proposed in the research generated good adherence (67%) and attendance (76.64 ± 13.46 sessions). This is because the HIIE protocols generate greater enjoyment compared with the moderate-intensity continuous training protocols (MICT)[19] since they resemble developmental play activities[20]. Similarly, the proposed strength exercise meets important conditions for adherence and safety, such as full-body, high-volume, low-intensity, and motorically challenging exercises[7].

Concurrent training has demonstrated improvements in anthropometric values in overweight and obese children and adolescents, specifically in BMI (-5.0%)[21] and WC (-7.2)[22]. On the other hand, WHtR has been little studied and/or reported in concurrent training studies. Only one study reported results on this variable, finding no significant differences after a 24-week HIIE protocol[23].

The results of the INT group are in line with other studies[21,22] regarding improvements in BMI (-2.5 ± 3.4%), BMI-z (-4.78 ± 10.33%), and WC (-5.2 ± 6.1%). It is noteworthy that the WHtR, a variable that has been little reported and with great predictive value for cardiovascular disease in the pediatric population[24], decreased by 0.04 ± 0.04 points (-6.1 ± 6.0%). The improvements of the INT group

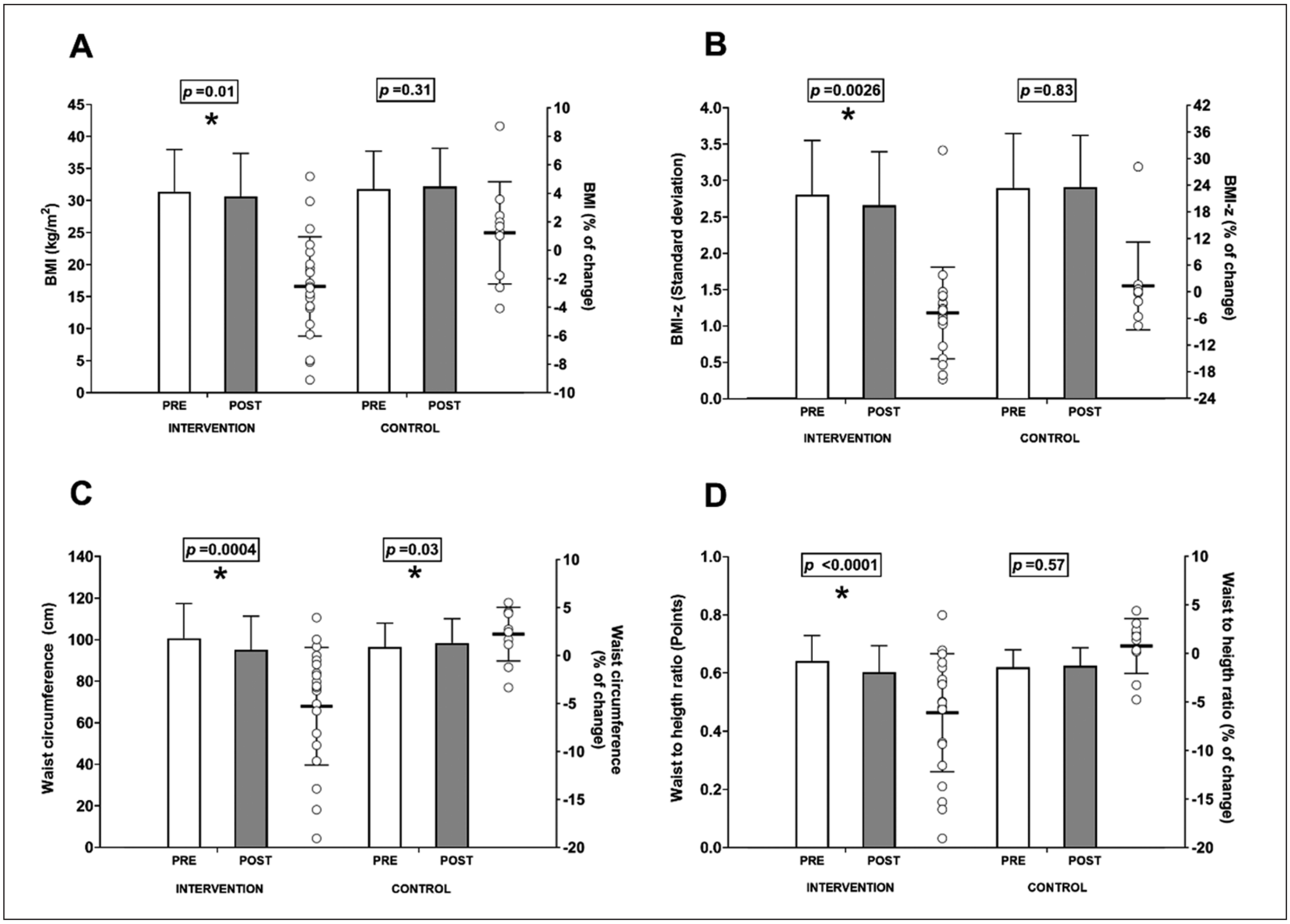

Figure 1. Changes of body mass index (A), body mass index by z – Score (B), waist circumference (C), waist to height ratio (D) of the participants plus mean ± standard deviation after (PRE) and before (POST) of 12 weeks of concurrent training in the INTERVENTION and CONTROL group. Percent of change from the PRE – POST of the individualized and their mean ± standard deviation. *Significative difference between PRE to POST.

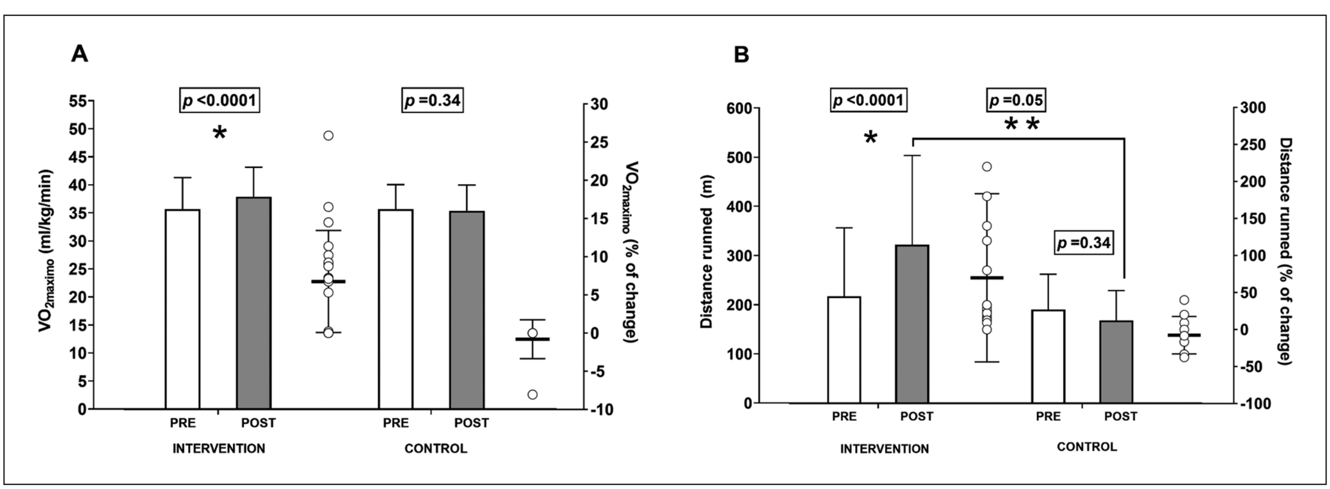

Figure 2. Changes of maximal oxygen consumption (A), distance runned (B) of the participants plus mean ± standard deviation after (PRE) and before (POST) of 12 weeks of concurrent training in the INTERVENTION and CONTROL group. Percent of change from the PRE – POST of the individualized participants and their mean ± standard deviation. *Significative difference between PRE to POST. **Significative difference between POST.

in WC and WHtR can be explained by the increase in lipolytic hormones such as growth hormone[25] and catecholamines[26], after a session of HIIE. The positive changes in BMI and BMI-z, occur due to the maintenance and/or decrease in weight (16 of 22 patients), in addition to an increase in height (1.26 ± 1.48 cm; p = 0.0003). After the above, the hypothesis that concurrent training is a cost-effective therapeutic tool in the improvement of BMI, BMI-z, WC, and WHtR in overweight and obese children and adolescents is reaffirmed.

The values obtained for VO2max estimated by the 20m shuttle run test (2.24 ± 2.15 ml/kg/min; 6.7 ± 6.6%) and meters run (104.55 ± 119.35 m; 69.8 ± 13.6) are in line with those reported in the literature. Grisalez et al.[27] after a 16-week HIIE protocol 3 times per week in overweight and obese schoolchildren, improved VO2max by 3.6 ml/kg/min.

The changes in VO2max resulting from HIIE are due to both central and peripheral adaptations. Evidence indicates that a 12-week HIIE protocol in a pediatric population with obesity[28] generates changes at the cardiac level, evidenced by an increase in ejection fraction (4.3%) and stroke volume index (6.1 ml/m^2). Similarly, an 8-week concurrent training protocol[29] improved flow-mediated vasodilation (endothelial function marker) by 3.5%. HIIE protocols can influence mitochondrial biogenesis through PGC-1α expression[30] which has been demonstrated in the study by Little et al.[31], who after 6 sessions over 2 weeks of HIIE showed increases in nuclear PGC-1α concentrations. Also, the addition of strength exercises to HIIE protocols will increase PGC-1α expression at the muscle level, more so than an HIIE protocol alone[32].

In a meta-analysis, García-Hermoso et al.[33] compared the efficacy of different HIIE exercise protocols versus MICT protocols in improving VO2max, showing that the pediatric population with obesity benefits more from HIIE protocols increasing their VO2max by 2.62 ml/kg/min vs. the 0.70 ml/kg/min increase of MICT protocols. Thus, the proposed 12-week HIIE program would achieve both molecularly and clinically supported changes in VO2max.

Muscle function showed improvements in the elbow flexion-extension test of 6.00 rep (IQR 4.00 - 11.00), prone plank 56.00 s (IQR 38.00 - 73.00), and standing broad jump 16.00 cm (IQR 8.00 - 21.25). Only two studies in a pediatric and normal-weight population[34,35] have reported improvements in the elbow flexion-extension test (6.08 rep)[34] and standing long jump (17.1 and 9.7 cm)[34,35], which are similar to ours, with exercise plans that progress exclusively in volume.

Regarding core exercise improvements, Chang et al.[36] intervened 52 healthy subjects for 6 weeks in two different groups, one group performed specific core exercises with body weight, and the other general physical exercise. The results established that only the group that performed specific core exercises with body weight improved their performance by 56 seconds (46%) during the prone plank test. However, there is little evidence available on concurrent training planning with the characteristics presented in this study, which enhances our positive results on muscle function in overweight and obese children and adolescents.

The positive changes experienced in muscle function by our population and other studies[34-36] could be directly related to neuromuscular rather than hypertrophic factors. Ozmun et al.[37] showed after a strength exercise protocol for 16 children between 9 - 12 years old, 3 times per week, for 8 weeks, improvements in upper extremity strength, but not arm circumference, reinforcing the thesis that at early ages the neuromuscular factor of strength production is above the hypertrophic factor.

Our results regarding lipid profile only show significant changes in total cholesterol [-11.00 mg/dl (IQR -18.50 - 3.50)] (P = 0.02) in the INT group with no significant changes in the rest of the variables in both the INT and CON groups. This could be explained by the fact that our experimental design does not include nutritional intervention, which, together with exercise, has shown the best results in improving the lipid profile[38,39].

Our exercise protocol did not generate a positive impact on glycemic control. A meta-analysis including 4021 participants from 12 studies showed that, compared with exercise-only interventions, diet and exercise interventions showed a significant effect on lowering fasting plasma glucose levels[40]. Therefore, the addition of a supplemental nutritional plan to the exercise protocol is essential.

There are some limitations of the study. First, we did not have a plan and/or follow-up of the nutritional pattern of the participants, which could have interfered with the anthropometric results. In addition, it is reflected in the results of lipid profile and glycemic control, so nutritional control continues to position itself as a fundamental ally of physical exercise in positive changes in body composition and metabolic control. The second is the quantification of the chronological age of the participants, setting aside the stratification of the maturation state (biological age), thus obviating in the process the differences that exist between pre-pubertal, pubertal, and post-pubertal subjects. On the other hand, the strength of this research is the delivery of a detailed plan with wide applicability in public health centers of the country, mainly due to the safety and cost-effectiveness of the intervention in cardiometabolic rehabilitation of overweight and obese children and adolescents.

Conclusion

A 12-week concurrent training plan is effective in improving anthropometry, aerobic capacity, muscle function, and total cholesterol in overweight and obese children and adolescents.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

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