Exercise Intervention in Childhood Obesity: A Randomized Controlled Trial Comparing Hospital-Versus Home-Based Groups

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Received for publication September 27, 2011; accepted March 6, 2012.

Abstract

Objective: The aim of this study was to compare the effect of a hospital clinic group- versus home-based combined exercise–diet program for the treatment of childhood obesity.

Methods: One hundred ten overweight/obese Spanish children and adolescents (6–16 years) in 2 intervention groups (hospital clinic group-based [n = 45] and home-based [n = 41]) and a sex-age-matched control group (n = 24) were randomly assigned to participate in a 6-month combined exercise (aerobic + resistance training) and Mediterranean diet program. Anthropometric values (including body weight, height, body mass index, BMI-Z score, and waist circumference) were measured pre- and post-intervention for all the participants. Percentage body fat was also determined with a body fat analyzer (TANITA TBF-410 M).

Results: Our study showed a significant reduction in percentage body fat and body mass index Z-score among both intervention-group participants (4%, 0.16, hospital clinic group-based; 4.4%, 0.23, home-based; $P < .0001$). There was also a significant reduction in waist circumference in the home-based group (4.4 cm; $P = .019$). Attendance rates at intervention sessions were equivalent for both intervention groups ($P = .805$).

Conclusions: The study findings indicate that a simple home-based combined exercise and Mediterranean diet program may be effective among overweight and obese children and adolescents, because it improves body composition, is feasible and can be adopted on a large scale without substantial expenses.

Keywords: adolescents; children; home-based treatment; obesity; physical activity

Academic Pediatrics 2012;■:1–7

What's New

The findings in this study indicate that this simple home-based program may be effective among overweight and obese children and adolescents because it improves body composition, is feasible, and can be adopted on a large scale without substantial expenses.

THE PREVALENCE OF overweight/obesity (OW/OB) among children and adolescents, 20% to 30%, has increased significantly in recent decades, becoming a serious public health concern in all industrialized countries.[1–3] This increase has immediate- and long-term health implications.[4–7] Although prevention is recognized as the primary and most efficient way to avoid obesity, many children and adolescents who are currently obese require treatment.

The progressive increase in adiposity is the result of a prolonged positive energy balance.[8] In children and adolescents, obesity correlates strongly with a progressive reduction in the level of physical activity (PA) and changes in food habits.[8,9] Essentially, the major objectives of a weight-reduction program are to change food and behavioral habits and to enhance PA. The addition of PA to dietary changes has proven to be beneficial in body composition in a large number of studies.[10–16] The rationale for prescribing exercise as an adjunct to dietary restriction is compelling given its potential to reduce OW/OB-related comorbidity and the hazards associated with dietary restriction alone.[17] Hypocaloric diets may slow down growth and induce reductions in resting metabolic rate in proportion to the decreases in fat-free mass,[18–20] which favors weight regain after cessation of the dietary treatment.[21,22] PA may reduce fat mass, preserve fat free mass, and improve cardiovascular fitness.[13–16,23–25] It has also been suggested that dietary modification alone has less impact on blood pressure than a combination of diet plus exercise.[26]

Although there is agreement within the scientific community that exercise is an empirically validated method of

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treating obesity, the optimal exercise modality that should be recommended for its treatment is unclear. Most studies have successfully treated OW/OB children and adolescents by means of group-based exercise programs conducted in health care facilities or university settings.[13,14,16] However, this modality does not always provide accessibility and convenience for families limited by work commitments, finances, location, or transportation.[27] A novel approach that has not been entirely explored is the home-based exercise programs. We hypothesize that a home-based intervention would achieve similar results to those held in a hospital environment.

Therefore, the aim of this study was to compare the effects on the BMI Z-score and body composition of a hospital clinic group- versus home-based combined exercise-diet program in OW/OB children and adolescents.

Subjects and Methods

White OW/OB children and adolescents of both sexes, ranging from 6 to 16 years of age, were recruited at the obesity and cardiovascular unit, Consorcio Hospital General Universitario, Valencia, Spain. Patients with secondary obesity syndromes or with acute illnesses were excluded from the study. Obesity was diagnosed when the body mass index (BMI; weight in kilograms divided by height in meters squared) exceeded the 95th percentile for age and sex. Subjects with a BMI ranging from the 85th to the 95th percentile of the BMI distribution were defined as being overweight. The extent of OW/OB was quantified with the use of Cole's LMS method, which normalizes BMI, and its skewed distribution, by expressing BMI as a standard deviation score.[28] Subjects with severe obesity (z score > 2.5) were excluded because individuals in this category require specific individualized programs to avoid potential orthopedic problems. None of the subjects were taking regular medication, nor did they display any clinical manifestations of illness. In all cases, informed consent was obtained from parents and participants before randomization. The study was approved by the Ethical Committee of the General Hospital, University of Valencia, Spain.

An open study design was used, and participants were randomly assigned (in a ratio of 2:2:1; hospital clinic group-based [GRX]/home-based [HOX]/control; n = 45:41:24) to participate in our 6-month combined exercise–diet program for the treatment of OW/OB. A schematic map of the study design is shown in Figure 1.

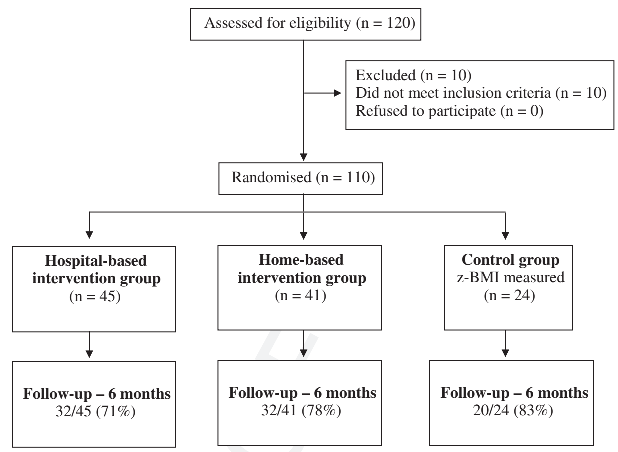

Figure 1. *A schematic diagram indicating the flow of study subject selection though the study and subject compliance (given as a fraction and percentage in the 'Follow Up' box).*

Patients were assigned to experimental groups on the basis of the day of the week in which they attended the outpatient clinic. Patients who attended on Mondays and Wednesdays were assigned to the GRX and those on Tuesdays and Thursdays to the HOX. Those who attended on Fridays were assigned to the control group. The pediatrician who attended these visits was blinded to group allocation criteria.

Study volunteers belonging to GRX and HOX groups and their parents jointly attended two 1-hour educational sessions conducted by 2 pediatricians at the Hospital. The topics covered included the importance of weight loss and its maintenance, a therapeutic nutritional approach to childhood obesity, and the role of PA in cardiovascular fitness. The dietary intervention focused on the promotion of the Mediterranean diet, a modern nutritional recommendation inspired by the traditional dietary patterns of southern Italy, Greece, and the Spanish Mediterranean coast (Levante), where this study took place. This diet, in addition to regular PA, emphasizes the consumption of abundant vegetables, fresh fruit for dessert, olive oil as the principal source of fat, regular consumption of dairy products (principally cheese and yogurt), fish and poultry consumed in low to moderate amounts, 0 to 4 eggs consumed weekly, and a reduced intake of red meat. This diet has been specifically devised for children by our nutritionist. Total fat in this diet is 25% to 35% of the caloric intake, with saturated fat at 8% or less of the total calories.

Families were provided with additional nutritional instruction, including interpretation of food labels and shopping, and were taught stimulus control to reduce access to high-calorie foods and increase access to healthy lower-calorie foods. Pre-planning was taught to facilitate decision making and problem solving for difficult eating and activity situations, such as parties, holidays, and school work functions.

Participants were also encouraged to reduce sedentary behavior, such as watching television, playing computer games, or playing board games. Academically relevant sedentary behaviors, such as homework or schoolwork, were not targeted for reduction.

Clinical Procedures

Body weight was recorded to the nearest 0.1 kg with the use of a standard beam balance scale with the subjects wearing light indoor clothing and no shoes. Height was recorded to the nearest 0.5 cm by a standardized wall-mounted height board. Percentage body fat (%BF) was determined by a body fat analyzer (TANITA TBF-410 M). Measurements were taken based on standard procedures.[29] This method for estimating %BF has a high correlation with dual-energy x-ray absorptiometry in children.[29] Waist circumference (WC) was measured to the nearest centimeter by a flexible tape half-way between the lower rib margin and the iliac crest. All outcome measures were recorded at baseline and at the end of the program by a trained nurse who was blinded to group allocation.

EXERCISE PROGRAMS

GRX subjects were provided with 5 supervised exercise sessions per week for 6 months (120 sessions). The participants and their parents were strongly advised to attend a minimum of 3 sessions per week (minimum attendance rate). Subjects were made to understand that "three" was the minimum required number of sessions per week to improve body composition.

Exercise training was conducted at the hospital by a physical education instructor. Parents were allowed to remain present during the sessions. Each session lasted 60 minutes, during which time 5 minutes were allocated for warming up and cooling down (stretching), 35 minutes were allocated to moderate aerobic activity, and 20 minutes to resistance training (low-load high-repetition exercises).

The aerobic activities were designed primarily to encourage enthusiasm and participation of the subjects. Activities such as sports or games were modified to minimize breaks. Resistance training consisted of different low-load high-repetition exercises (abdominal curl-ups, prone hip extensions, wall push-ups, shoulder abductions and extensions, squats and biceps curls) involving the major muscle groups. Each of the activities and exercises were increased in intensity throughout the 120 sessions of the program. The exercise was tailored to the physical characteristics of each adolescent. Heart rate was continuously monitored using Sport testers (Polar S610i). During the sessions, a positive environment was created to achieve a positive feeling and attitude towards PA. The participants and their parents were also advised to practice the physical activities during the weekend.

HOX group participants were instructed to complete all exercises in their home environment. Their program also consisted of 5 sessions per week (6 months, 120 sessions). The duration of each session was approximately 60 minutes and involved both resistance and aerobic training exercises (circuit training; Fig. 2).

The subjects received a demonstration of how to perform the exercises and each patient was given detailed written instructions, including images of the exercises, the number of repetitions, and/or duration required. All participants were provided with a daily exercise log book for 6 months and were instructed to complete it for each exercise session, including date and duration. The participants and their parents were also specifically advised to perform at least three sessions per week (minimum attendance rate).

The resistance training included two sets of ten low-load-high-repetition (LLHR) exercises involving the major muscle groups. The exercises were performed in the following order: 1—abdominal curl-ups, 2—prone hip extensions, 3—skipping in place, 4—wall push-ups, 5—squats, 6—biceps curls, 7—running in place buttock-kicks, 8—shoulder horizontal abductions, 9—vertical jumps, and 10—shoulder extensions. Exercises 6, 8, and 10 were performed with barbells (0.5 kg). Exercise duration was progressively increased (number of repetitions) from month 1 to month 6, as shown in Figure 2. The aerobic activity was intercalated with each LLHR exercise and contained two kinds of exercise (brisk walking [months 1–3] and scissor jumps [months 4–6]).

Special attention was paid to the speed of the aerobic exercises, especially for brisk walking, which was instructed to be performed indoors (ie, in the corridor) to minimize breaks between LLHR and aerobic exercises. After the first circuit, the participants performed 5 minutes of brisk walking and thereafter repeated the circuit (2 circuits $\times$ 30 minutes).

GRX and HOX exercise participants were classified in 2 categories (treatment completers vs treatment noncompleters) according to the number of sessions attended by the end of the program ($>$20 vs $\leq$20 sessions, respectively). Attendance rates were calculated in both intervention groups. These rates were also calculated when excluding the treatment noncompleters.

Control group participants were instructed about diet and other lifestyle changes during their regular visits to the hospital, but neither received the exercise nor the nutrition educational sessions as for the intervention groups. Control group participants maintained their usual levels of daily activity, with no additional exercise components.

SAMPLE SIZE AND STATISTICAL ANALYSIS

To achieve a statistically significant 0.25-point BMI Z-score reduction between the estimated mean and the sampling mean with a statistical power equal to 80% and an alpha risk of 0.05, a sample size of 20 patients per group was necessary. The sampling size was increased to compensate for possible alterations in the statistical significance of the results caused by possible dropouts in the intervention groups. In addition and, on the basis of our experience (dropouts in a previous pilot study), we intentionally allocated an unequal number of participants to each group.

The statistical analysis was performed according to intention-to-treat. To compare the success of randomization, preliminary analyses of variance or chi-squared tests were used to determine baseline differences between groups. A Mann-Whitney U test was used to compare the attendance rates between both intervention groups.

Two-way mixed ANOVA tests were used to compare the study effects on height, body weight, BMI, BMI Z-score, % BF and WC between groups, with exercise period serving as the within-group factor and intervention type as the between-group factor. Data are presented as mean $\pm$ SD. Statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, Ill). $P < .05$ was considered statistically significant.

RESULTS

A total of 110 white children and adolescents were included in the study, of which 45 (41%) were in the GRX intervention, 41 (37%) were in the HOX intervention,

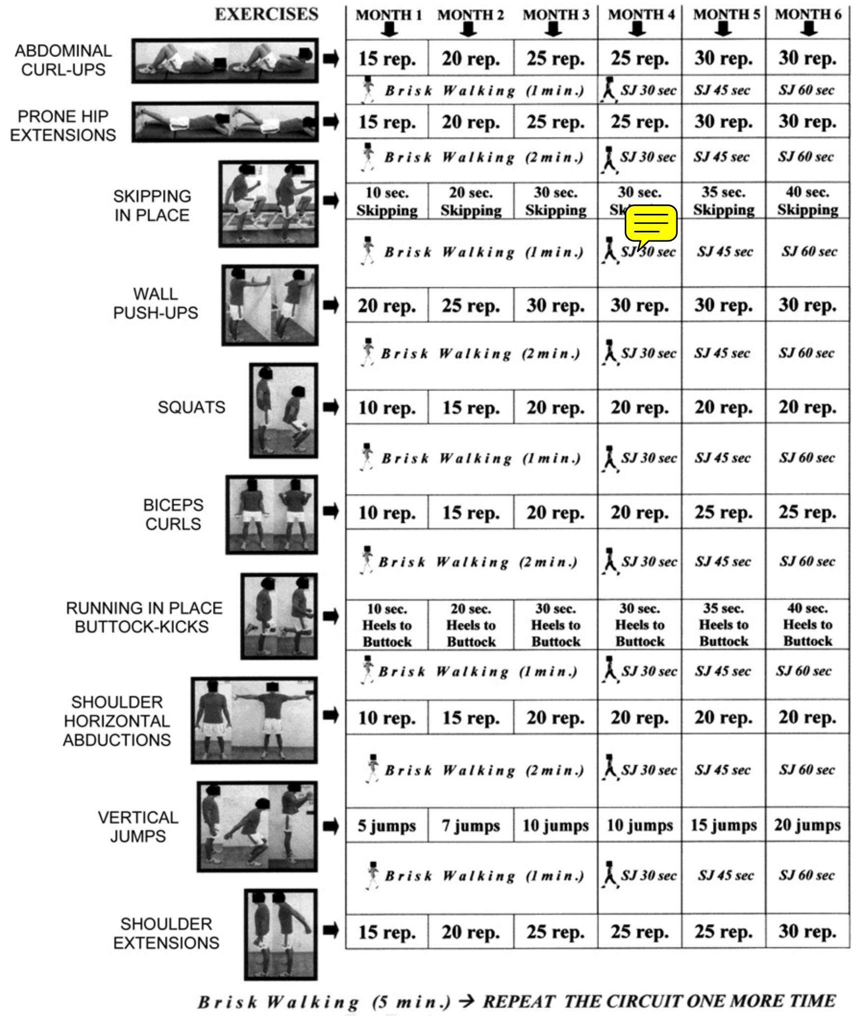

Figure 2. *Detailed description of the complete home-based exercise program as explained to the study subjects. The arrows at the top of the image clearly indicate the increase in exercise duration and repetition required during the 6 months of the study. Note: Detailed descriptions of exercise methodology as explained to the study subjects, along with abbreviations used in this figure appear below.*
SJ = *SCISSOR JUMPS: Stand with one leg out in front of you and the other leg extended behind you. Kneel down into a quarter squat position and jump up into the air. Before you land, switch your leg positions and repeat the movement.*
ABDOMINAL CURL-UPS: Lying on the ground with hips and knees bent, curl until your upper back is off the floor. Return to the starting position.
PRONE HIP EXTENSIONS: Keeping both legs straight at all times, lift one at a time without arching your back. Return it to the ground and repeat with the other leg. SKIPPING IN PLACE: Run in place raising knees upwards as high as possible.
WALL PUSH-UPS: Lean the body towards the wall and then push your body back with your hands until you achieve the standing position.
SQUATS: Squat down with the hands placed on the waist until the knees are bent at 90 degrees. Return to the starting position.
BICEPS CURLS: With elbows held tightly to your sides, raise both forearms to shoulder height. Return to the start position.
RUNNING IN PLACE BUTTOCK KICKS: Run in place kicking with both feet so as to make contact between the heels and the buttocks.
SHOULDER HORIZONTAL ABDUCTIONS: Raise the arms horizontally behind your body, clasping your hands together, until your elbows reach shoulder height. Return to the starting position.
VERTICAL JUMPS: Squat down until the knees are bent at 90 degrees and jump as high as possible (swinging the arms forward).
SHOULDER EXTENSIONS: Raise the arms back up to 25–30 degrees. Return to the starting position.

and 24 (22%) were controls. The general characteristics of the study population are shown in Table 1. No differences in terms of age, sex, degree of obesity, %BF, proportion of OW/OB, or WC were observed among groups at baseline.

Changes in height, weight, BMI, BMI Z-score, %BF, and WC in controls and in each intervention group are shown in Table 2. As expected in a pediatric population, an increase of height was observed with growth in the 2 intervention groups as well as in controls. In each intervention group a significant reduction in BMI Z-score and %BF was observed. In contrast, no changes were observed in the control group. BMI and WC were significantly reduced in the HOX group, and there was a nonsignificant tendency towards a reduction in the GRX group. The data analysis showed a significant time × intervention interaction effect across the variables (Table 2). When the effects of the 2 different interventions (GRX, HOX) were compared, no statistical differences were found for any outcome. Differences in BMI Z-score and %BF between groups are shown in Figures 3 and 4.

Table 1. Characteristics of the Study Participants at Baseline

	Control (n = 24)	HOX* Intervention (n = 41)	GRX Intervention (n = 45)	*P*
Age	11.2 ± 2.1	11.9 ± 2.2	12.3 ± 1.9	.264
Boys/girls	13/11	21/20	22/23	.969
Height, cm	152 ± 14	157 ± 10	152 ± 10	.241
Weight, kg	69.2 ± 18.3	74 ± 16.2	67.2 ± 17.3	.417
BMI, kg/m^2	29.2 ± 3.9	29.7 ± 3.7	28.5 ± 3.8	.557
BMI Z-score	2.23 ± 0.21	2.10 ± 0.26	2.11 ± 0.33	.213
BF, %	39.8 ± 6.8	39.1 ± 5.9	37.8 ± 6.0	.745
WC, cm	94.7 ± 10.3	95.5 ± 11.4	94.7 ± 9.3	.775
OW/OB	1/23	6/35	7/38	.383

The values are mean ± standard error.
*HOX = home based; GRX = hospital clinic group based; BMI = body mass index; BF = body fat; WC = waist circumference; OW/OB = overweight/obese; *P* = statistical significance of the differences among groups.

The number of treatment completers was similar comparing across the GRX and HOX intervention groups (22 of 45; 21 of 41, respectively). Overall, attendance rates at intervention sessions from baseline to month 6 were equivalent for the GRX and HOX intervention groups (1.32 ± 1.05 and 1.62 ± 1.72 sessions per week, respectively; $P = .805$). This equivalence did not change when excluding nontreatment completers (2.04 ± 0.88 and 2.7 ± 1.43; $P = .110$).

DISCUSSION

In the present study, the main finding was that GRX and HOX exercise formats combined with Mediterranean diet recommendations appeared similarly effective in the reduction of BMI Z-score and %BF. To our knowledge, this is the first study that compares the effectiveness of two exercise modalities (home- vs hospital clinic group-based) in OW/OB children and adolescents. Our findings showed that the BMI Z-score and %BF values were very similar between the 2 intervention groups in the postprogram measurements. However, although the GRX program was equally successful in treating OW/OB children and adolescents when compared with the HOX program, the relative expense of the GRX program was substantially higher than the HOX program.

PA programs for OW/OB children and adolescents have traditionally been conducted in health care facilities or university settings and have consisted mostly of structured, group-based exercise. Although such programs can be effective, their public health impact is limited because they only serve families with sufficient resources and motivation to attend on a long-term basis, curtailing their adoption on a large scale. For an intervention to be adopted on a large scale and to have the greatest impact over the longest period of time it must be sustainable. In addition, costs are an important aspect of sustainability. Home-based programs offer significant advantages in terms of structural and financial sustainability.[27] They provide accessibility and convenience for families limited by work commitments, finances, location or transportation.

The home-based exercise format offers flexibility and privacy for the participants. It may have particular application among families who are socially and economically disadvantaged, especially low-income families that may face lack of safe places for PA.[30] In addition, it engages parent–child contact in the home environment. It is still surprising that relatively few home-based intervention programs are available for OW/OB children and adolescents. Our home-based intervention program was primarily designed to maximize health benefits without increasing the demand on resources or personnel.

Drop-out rates, which were similar across the 3 study groups, were fairly considered in powering the sample population. The attendance rates at the exercise sessions in the GRX and HOX intervention groups did not show statistical differences. These rates were lower than the advised minimum attendance rates. The statistical analysis included the treatment noncompleters, characterized by low attendance rates, a phenomenon that was considerably increased in treatment completers. This observation reinforces the effectiveness of both interventions in terms of

Table 2. Significance by ANOVA* of the Main Effects of Period, Intervention, and Period × Intervention Interaction (P × I): Intragroup Comparisons (Pre vs Postintervention) for the Studied Variables

	Control			GRX Intervention			HOX Intervention			Main Effects (*P* Values)		
	Baseline	6 Months	*P* Value	Baseline	6 Months	*P* Value	Baseline	6 Months	*P* Value	Period	Intervention	*P* x I
Height, cm	152	157	<.0001	157	159	<.0001	152	155	<.0001	<.0001	.245	<.0001
Weight, kg	69.2	77.0	<.0001	74.0	75.2	.082	67.2	66.9	.621	<.0001	.164	<.0001
BMI, kg/m^2	29.2	30.8	<.0001	29.7	29.3	.104	28.5	27.3	<.0001	.911	.094	<.0001
BMI Z-score	2.23	2.22	.882	2.10	1.94	<.0001	2.11	1.88	<.0001	<.0001	.024	.002
BF, %	39.8	40.7	.353	39.1	35.1	<.0001	37.8	33.4	<.0001	<.0001	.04	<.0001
WC, cm	94.7	97.4	.066	95.5	94.8	.59	94.7	90.3	.019	.345	.611	.012

*ANOVA = analysis of variance; GRX = hospital clinic group based; HOX = home based; BMI = body mass index; BF = body fat; WC = waist circumference; *P* = statistical significance of the differences among groups.

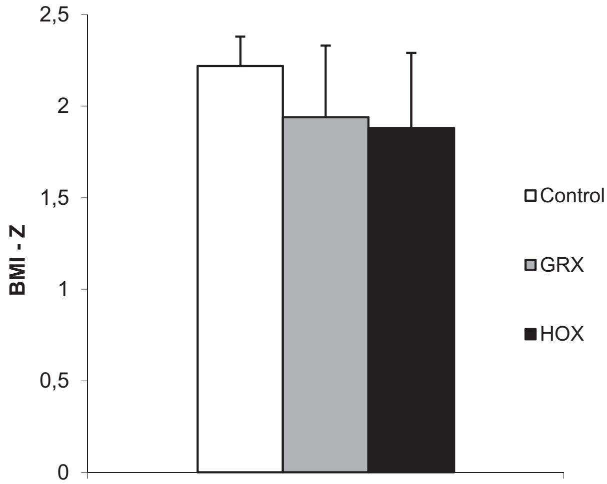

Figure 3. *A comparison of the BMI Z-score values after intervention between the 3 study groups. Control vs GRX (hospital clinic;* P = *.024), Control vs HOX (home-based;* P = *.004), and GRX vs HOX (p = 1). Bars show the mean ± SD.*

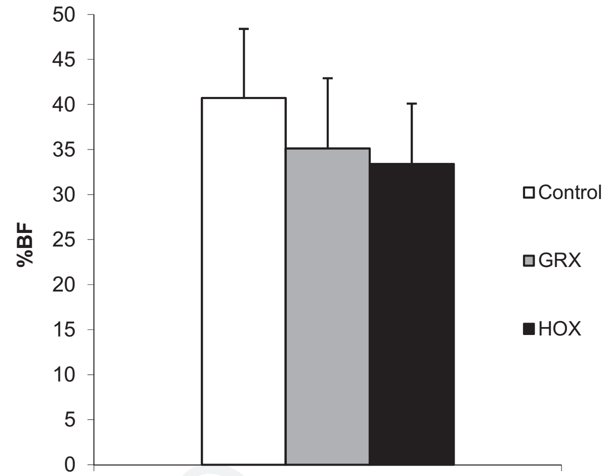

Figure 4. *A comparison of the percent body fat (%BF) values post-intervention for the three study groups; Control vs GRX (hospital clinic;* P = *.023), Control vs HOX (home-based;* P = *.002) and GRX vs HOX (*P = *1). Bars show the mean ± SD.*

improvements in body composition, and suggests that significant effects on %BF are achievable with a lower dose of prescribed exercise -when combined with Mediterranean diet-than that currently recommended. A nonstatistically significant tendency towards a greater attendance rate was also reported in the HOX versus GRX treatment completers. The greater convenience and flexibility of home-based exercise may result in higher levels of exercise participation.

Previous research indicates that exercise programs using a longer duration (minutes) and training length (weeks) and a combination of exercise modes (aerobic exercise plus resistance training) showed the greatest treatment effects and emerged as major predictors of %BF at the one year follow up assessment.[31,32] The amount of exercise, expressed as duration by intensity, is the major determinant of energy spent on exercise[33] and was similar in both intervention groups. Moderate PA is preferable because it can be sustained for a longer time (60 minutes), it increases fat oxidation, is suitable to enjoyable activities like modified sports or games (GRX intervention), and can be used in obese children with limited aerobic and anaerobic capacities.[32,34]

The results of this study are subject to limitations. First, even though the follow-up of the diet was assessed during the regular visits to the Hospital, the participants did not keep daily food records. Thus, we cannot discount the possibility that some subjects may have increased or decreased dietary intake, which would have confounded the effects of exercise. Nevertheless, randomization may minimize this effect if it had been produced.

Second, in the present study it was not possible to independently assess the impact of physical exercise or diet on anthropometric parameters. Although we assumed that the differences between the control and intervention groups can be attributed to the physical exercise, an additional alternative component of diet adherence could not be excluded.

It should also be criticized that exercise intensity was neither individually monitored nor tailored in the HOX exercise group. In addition, self-reports of exercise in obese individuals tend to be inflated,[35] and the validity of the self-reported exercise may have been lower in the home than in the group condition (only the GRX participants completed their exercise under observation by staff). However, the significant differences in body composition variables between HOX and control groups indicate that the target intensities and the reported exercise were correct for attaining the training goals in this intervention group. Moreover, tailoring is rarely combined with interventions to be adopted on a large scale.

Finally, although imaging modalities such as computed tomography and magnetic resonance imaging are considered the gold standard method to quantify abdominal fat distribution, WC measure is a feasible clinical tool to evaluate abdominal obesity and is uniformly included in the diagnosis of the "metabolic syndrome" in both children and adults.[36] The results in this study showed WC reduction in both intervention groups, being statistically significant in the home-based group ($P = .019$). These results agree with those previously obtained in children[37] and adults,[38] which show that reductions in central obesity can be seen following combined aerobic and resistance training exercise.

Although our study has shown 2 effective treatment approaches for pediatric obesity in the short-term, long-term outcome data for successful treatment approaches is required. The time limitations of our study did not allow us to determine whether any increase in PA is maintained in the long term. Nevertheless, it has been shown that combined programs offer the opportunity to diversify exercises to maintain the motivation of adolescents for training and PA and therefore tend to be more effective because beneficial modifications are maintained in the long term.[39]

In summary, the findings in this study indicate that this simple home-based program may be effective among overweight and obese children and adolescents, because it improves body composition, is feasible, and can be adopted on a large scale without substantial expenditure.

ACKNOWLEDGMENTS

This work was supported by grants from the Comunidad Valenciana Government (GV06/227). No conflict of interest was declared. Trial registration: Clinicaltrials.gov NCT01503281.

REFERENCES

1. Rocchini AP. Childhood obesity and a diabetes epidemic. *N Engl J Med*. 2002;346:854–855.
2. Hedley AA, Ogden CL, Johnson CL, et al. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999–2002. *JAMA*. 2004;291:2847–2850.
3. Lissau I, Overpeck MD, Ruan WJ, et al. Body mass index and overweight in adolescents in 13 European countries, Israel, and the United States. *Arch Pediatr Adolesc Med*. 2004;158:27–33.
4. Must A, Jacques PF, Dallal GE, et al. Long-term morbidity and mortality of overweight adolescents. A follow-up of the Harvard Growth Study of 1922 to 1935. *N Engl J Med*. 1992;327:1350–1355.
5. Chu NF, Rimm EB, Wang DJ, et al. Clustering of cardiovascular disease risk factors among obese schoolchildren: the Taipei Children Heart Study. *Am J Clin Nutr*. 1998;67:1141–1146.
6. Wabitsch M. Overweight and obesity in European children: definition and diagnostic procedures, risk factors and consequences for later health outcome. *Eur J Pediatr*. 2000;159(suppl 1):S8–S13.
7. Baker JL, Olsen LW, Sorensen TI. Childhood body-mass index and the risk of coronary heart disease in adulthood. *N Engl J Med*. 2007;357:2329–2337.
8. Weinsier RL, Hunter GR, Heini AF, et al. The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity. *Am J Med*. 1998;105:145–150.
9. Janssen I, Katzmarzyk PT, Boyce WF, et al. Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev*. 2005;6:123–132.
10. Reybrouck T, Vinckx J, Van den Berghe G, et al. Exercise therapy and hypocaloric diet in the treatment of obese children and adolescents. *Acta Paediatr Scand*. 1990;79:84–89.
11. Epstein LH, Valoski AM, Vara LS, et al. Effects of decreasing sedentary behavior and increasing activity on weight change in obese children. *Health Psychol*. 1995;14:109–115.
12. Eliakim A, Kaven G, Berger I, et al. The effect of a combined intervention on body mass index and fitness in obese children and adolescents—a clinical experience. *Eur J Pediatr*. 2002;161:449–454.
13. Deforche B, De Bourdeaudhuij I, Debode P, et al. Changes in fat mass, fat-free mass and aerobic fitness in severely obese children and adolescents following a residential treatment programme. *Eur J Pediatr*. 2003;162:616–622.
14. Nemet D, Barkan S, Epstein Y, et al. Short- and long-term beneficial effects of a combined dietary-behavioral-physical activity intervention for the treatment of childhood obesity. *Pediatrics*. 2005;115: e443–e449.
15. Chen AK, Roberts CK, Barnard RJ. Effect of a short-term diet and exercise intervention on metabolic syndrome in overweight children. *Metabolism*. 2006;55:871–878.
16. Savoye M, Shaw M, Dziura J, et al. Effects of a weight management program on body composition and metabolic parameters in overweight children: a randomized controlled trial. *JAMA*. 2007;297: 2697–2704.
17. Atlantis E, Barnes EH, Singh MA. Efficacy of exercise for treating overweight in children and adolescents: a systematic review. *Int J Obes (Lond)*. 2006;30:1027–1040.
18. Dulloo AG, Jacquet J. Adaptive reduction in basal metabolic rate in response to food deprivation in humans: a role for feedback signals from fat stores. *Am J Clin Nutr*. 1998;68:599–606.
19. Maffeis C, Schutz Y, Pinelli L. Effect of weight loss on resting energy expenditure in obese prepubertal children. *Int J Obes Relat Metab Disord*. 1992;16:41–47.
20. Tounian P, Frelut ML, Parlier G, et al. Weight loss and changes in energy metabolism in massively obese adolescents. *Int J Obes Relat Metab Disord*. 1999;23:830–837.
21. Schwingshandl J, Borkenstein M. Changes in lean body mass in obese children during a weight reduction program: effect on short term and long term outcome. *Int J Obes Relat Metab Disord*. 1995;19:752–755.
22. Schwingshandl J, Sudi K, Eibl B, et al. Effect of an individualised training programme during weight reduction on body composition: a randomised trial. *Arch Dis Child*. 1999;81:426–428.
23. Gutin B, Owens S, Slavens G, et al. Effect of physical training on heart-period variability in obese children. *J Pediatr*. 1997;130: 938–943.
24. Bernhardt DT, Gomez J, Johnson MD, et al. Strength training by children and adolescents. *Pediatrics*. 2001;107:1470–1472.
25. Ness AR, Leary SD, Mattocks C, et al. Objectively measured physical activity and fat mass in a large cohort of children. *PLoS Med*. 2007; 4:e97.
26. Watts K, Jones TW, Davis EA, et al. Exercise training in obese children and adolescents: current concepts. *Sports Med*. 2005;35: 375–392.
27. Conwell LS, Trost SG, Spence L, et al. The feasibility of a home-based moderate-intensity physical activity intervention in obese children and adolescents. *Br J Sports Med*. 2010;44:250–255.
28. Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000;320:1240–1243.
29. NIH Technol Assess Statement Online: Bioelectrical Impedance analysis in body composition measurements. *NIH Technol Assess Statement Online*. 1994;12–14.
30. Oreskovic NM, Kuhlthau KA, Romm D, et al. Built environment and weight disparities among children in high- and low-income towns. *Acad Pediatr*. 2009;9:315–321.
31. Maziekas MT, LeMura LM, Stoddard NM, et al. Follow up exercise studies in paediatric obesity: implications for long term effectiveness. *Br J Sports Med*. 2003;37:425–429.
32. LeMura LM, Maziekas MT. Factors that alter body fat, body mass, and fat-free mass in pediatric obesity. *Med Sci Sports Exerc*. 2002; 34:487–496.
33. Hill JO, Wyatt HR. Role of physical activity in preventing and treating obesity. *J Appl Physiol*. 2005;99:765–770.
34. Maffeis C, Castellani M. Physical activity: an effective way to control weight in children? *Nutr Metab Cardiovasc Dis*. 2007;17:394–408.
35. Lichtman SW, Pisarska K, Berman ER, et al. Discrepancy between self-reported and actual caloric intake and exercise in obese subjects. *N Engl J Med*. 1992;327:1893–1898.
36. Cruz ML, Goran MI. The metabolic syndrome in children and adolescents. *Curr Diab Rep*. 2004;4:53–62.
37. Woo KS, Chook P, Yu CW, et al. Effects of diet and exercise on obesity-related vascular dysfunction in children. *Circulation*. 2004; 109:1981–1986.
38. Park SK, Park JH, Kwon YC, et al. The effect of combined aerobic and resistance exercise training on abdominal fat in obese middle-aged women. *J Physiol Anthropol Appl Human Sci*. 2003;22: 129–135.
39. Lazzer S, Boirie Y, Poissonnier C, et al. Longitudinal changes in activity patterns, physical capacities, energy expenditure, and body composition in severely obese adolescents during a multidisciplinary weight-reduction program. *Int J Obes (Lond)*. 2005;29:37–46.