Change in weight and body composition in obese subjects following a hypocaloric diet plus different training programs or physical activity recommendations

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Benito PJ, Bermejo LM, Peinado AB, López-Plaza B, Cupeiro R, Szendrei B, Calderón FJ, Castro EA, Gómez-Candela C on behalf of the PRONAF Study Group Change in weight and body composition in obese subjects following a hypocaloric diet plus different training programs or physical activity recommendations. J Appl Physiol 118: 1006–1013, 2015. First published February 26, 2015; doi:10.1152/japplphysiol.00928.2014.—The aim of the present study was to compare the effects of different physical activity programs, in combination with a hypocaloric diet, on anthropometric variables and body composition in obese subjects. Ninety-six obese (men: n = 48; women: n = 48; age range: 18–50 yr) participated in a supervised 22-wk program. They were randomized into four groups: strength training (S; n = 24), endurance training (E; n = 26), combined strength + endurance training (SE; n = 24), and physical activity recommendations (C; n = 22). In addition, all groups followed the same hypocaloric diet. At baseline and at the end of the intervention, dietetic and physical activity variables were assessed using validated questionnaires. Anthropometric variables were recorded along with body composition variables measured using dual-energy X-ray absorptiometry techniques. At the end of the intervention, significant improvements were seen within groups in terms of body weight (S: −9.21 ± 0.83 kg; E: −10.55 ± 0.80 kg; SE: −9.88 ± 0.85 kg; C: −8.69 ± 0.89 kg), and total fat mass (S: −5.24 ± 0.55%; E: −5.35 ± 0.55%; SE: −4.85 ± 0.56%; C: −4.89 ± 0.59%). No differences were seen between groups at this time in terms of any other anthropometric or body composition variables examined. All groups increased their total physical activity in metabolic equivalents (MET) per week during the intervention, but with no difference between groups (S: 976 ± 367 MET-min/wk; E: 954 ± 355 MET-min/wk; SE: 1329 ± 345 MET-min/wk; C: 763 ± 410 MET-min/wk). This study shows that, when combined with a hypocaloric diet, exercise training and adherence to physical activity recommendations are equally effective at reducing body weight and modifying body composition in the treatment of obesity (Clinical Trials Gov. number: NCT01116856).

physical activity; aerobic exercise; strength training; dietary modification; body composition

The majority of epidemiological studies indicate excess body weight during midlife to be associated with an increased risk of all-cause mortality (1, 9, 33). For example, people with a body mass index (BMI) of 25–28.9 have a relative risk of developing cardiovascular disease twice that of people with a BMI of <21 kg/m², while those with a BMI of ≥29 kg/m² are at almost three times the risk (36). Further, the results of the Framingham Heart Study show that being overweight at age 40 reduces life expectancy by 3 yr (24). In Spain, the prevalence of obesity in 2011 was 22.9% (24.4% in men and 21.4% in women) and about 36% of adults had abdominal obesity (32% of men and 39% of women) (11). Finding efficient treatments for midlife obesity should, therefore, be seen as a public health priority (4).

The treatment of obesity includes low-calorie, low-fat diets, increased physical activity, and lifestyle modification strategies (12, 18). Current evidence indicates that the best diet for prevention of weight gain, obesity, Type 2 diabetes, and cardiovascular disease is one low in fat and sugary beverages and high in carbohydrates, fiber, grains, and protein (3).

Physical activity is also widely recognized as a means of achieving the primary prevention of chronic diseases (10). Increasing physical activity, in addition to following a balanced diet, however, is crucial in any program designed to combat obesity (34). Despite the benefits of regular physical activity, the percentage of physically inactive adults in the world is high. The World Health Report of the World Health Organization (WHO) (2003) states that, worldwide, more than 60% of adults can be classified as inactive (10).

A combination of energy restriction and increased energy output by means of exercise has been proven as a means of treating obesity in the hospital setting (7). Indeed, the results have been quite conclusive with respect to the undertaking of aerobic exercise and the following of a very restrictive energy intake (i.e., <50% of that normally recommended) (15, 25). However, data are still scarce regarding the effect on weight loss of combining strength and aerobic training with a much less restrictive hypocaloric diet (15). Those trials that have been performed have varied in terms of intensity, delivery methods, target groups, and study components; the comparisons that can be made among them are, therefore, necessarily limited. It has now become essential that effective, physical activity interventions be developed on the basis of good scientific evidence (19, 21).

Within the framework of the Global Strategy on Diet, Physical Activity and Health, the WHO has stated that health...
should be protected and promoted by guiding the development of an enabling environment for sustainable actions at the individual, community, national, and global level, such that, when followed together, these might lead to reduced disease and death rates related to unhealthy diet and physical inactivity (35). Accordingly, the project “Nutrition and Physical Activity Programs for Obesity Treatment” (the PRONAF study according to its Spanish initials) was designed. Its main aim is to discover, via the undertaking of two randomized clinical trials, which physical activity protocol, in combination with a hypocaloric diet, is the most effective for the treatment of overweight and obesity. As part of this project, the present work compares the effects of different physical activity programs, in combination with a hypocaloric diet, on body weight and body composition in obese subjects.

MATERIALS AND METHODS

Participants

Detailed information on the materials and methods used in the wider PRONAF study can be obtained from a previous paper (39). In the present work, participants were sought via advertisements posted in newspapers and announced on the radio, the Internet, and TV. The eligible sample population consisted of 120 obese subjects (59 women and 61 men; age range: 18–50 years; BMI: ≥30 to <34.9 kg/m²) living in the region of Madrid, Spain. All subjects were healthy adults with no history of important concomitant illness (heart, lung, or liver disease, or neoplasms). All were normoglycemic, nonsmokers, and took no medications or drugs, but all led sedentary lifestyles. All female subjects had regular menstrual cycles. The exclusion criteria covered all physical and psychological diseases that may have precluded the performance of the requested strength or endurance training, along with the taking of any medication known to influence physical performance or that might interfere with the interpretation of the results. Subjects with a background of systematic strength or endurance training (moderate to high-intensity training more than once a week) in the year before the study started were also excluded. In agreement with the guidelines of the Declaration of Helsinki regarding research on human subjects, all participants signed an institutionally approved document of informed consent. All subjects were carefully informed about the possible risks and benefits of the study, which was approved by the Human Research Review Committee of the La Paz University Hospital (PI-643). This trial was registered at clinicaltrials.gov as NCT01116856. http://clinicaltrials.gov/. Figure 1 shows the participant flowchart in the study.

Study Design

Subjects who fulfilled the inclusion criteria and passed a baseline physical examination were stratified by age and sex and assigned (using a randomization table) to a strength training group (S; n = 30), an endurance training group (E; n = 30), a combined strength + endurance training group (SE; n = 30), or a physical activity recommendations group (control group, C; n = 30).

Hypocaloric diets were prescribed individually for all participants. This study design was that of an intervention trial of 22 wk duration. Baseline measurements for all subjects were made before starting the intervention period. The final measurements were taken once the intervention period was over (within 48–72 h of the last training session for the exercise groups).

Exercise Programs

The different exercise training groups (E, S, SE) followed their corresponding training programs, which in all cases involved training 3 times/wk for 22 wk. All training sessions were carefully supervised by certified personal trainers.

The S group followed a circuit involving eight exercises: the shoulder press, squats, the barbell row, the lateral split, bench press, front split and biceps curl, and the French press for triceps. Running, cycling, or elliptical (self-selected) exercises were the main components of the session for group E, while group SE followed a combination of cycle ergometry, treadmill, or elliptical exercises intercalated with squats, rowing machine, bench presses, and front split exercises (15 lifts per set or 45 s for the SE endurance phase). The C subjects followed the hospital’s habitual clinical practice for achieving weight loss: dietary intervention—the same as followed by the exercise training groups—plus being made aware of the general recommendations of the American College of Sports Medicine regarding physical activity. Thus, the C subjects were advised to undertake at least 200–300 min of moderate-intensity physical activity per week (30–60 min on most, if not all, days of the week) (8). The C subjects were also advised to reduce their sedentary behavior (e.g., watching television or using the computer) and increase daily activities, such as brisk walking or cycling instead of using a car, or climbing stairs instead of using the elevator (32).

The exercise-training programs were designed to take into account each subject’s muscular strength (MS) and heart rate reserve (HRR as the difference between resting HR and maximal HR). MS was measured in the strength program subjects (S, SE) using the 15-repetition maximum (15 RM) testing method every other day during the week before the intervention period. The HRR was calculated to set the exercise intensity [(maximum heart rate-resting heart rate) 50–60%] for the E and SE subjects. The volume and intensity of the three training programs were equal and increased progressively during the study. In weeks 2–5, exercise was at an intensity of 50% of the 15 RM and HRR and lasted an overall 51 min and 15 s. In weeks 6–14, exercise was performed at an intensity of 60% of 15 RM and HRR, again with a duration of 51 min and 15 s. Finally, in weeks 15–22, exercise was performed at an intensity of 60% of 15 RM and HRR, with a duration of 60 min. Each training session for the S, E, and SE subjects commenced with a 5-min aerobic warm-up, followed by the main session exercises, and concluded with 5 min of cooling down and stretching exercises. In all sessions, the exercise rhythm was controlled by instructions recorded on a compact disk.

Hypocaloric Diet Program

Hypocaloric diets (between 5,028 and 12,570 kJ) were prescribed individually for all participants by expert dieticians at the Department of Nutrition, La Paz University Hospital, Madrid. The diet was designed to provide 30% less energy than the baseline total daily energy expenditure (DEE), as measured using a SenseWear Pro Armband accelerometer (BodyMedia, Pittsburgh, PA). Some 29–34% of energy came from fat, and 50–55% from carbohydrates, according to the recommendations of the Spanish Society of Community Nutrition [SENC, according to its Spanish initials, (29)], and 20% from protein (beyond that outlined in the above recommendations) to achieve the body composition benefits observed in different studies and examined in a recent meta-analysis (38).

The hypocaloric diet program was followed during the 22-wk intervention period. Dietary counseling was given at baseline and at 12 wk to resolve questions and to motivate participants sufficiently to comply with dietary advice. All subjects were instructed on how to record their dietary intake using a daily log and given recommended portion sizes and information on possible food swaps. In addition, nutrition education sessions were given by the dieticians. The goal was to equip the participants with the knowledge and skills necessary to achieve gradual but permanent behavior changes.
Responded to the advertisement  
n=751

Contacted and completed the second questionnaire  
n=432

Not interested after preliminary information  
n=319

Individual eligible for orientation visit  
n=120

Not eligible  
n=312

Excluded for pathologies  
n=49
Out of specified range of age  
n=12
Inadequate body mass index  
n=118
No sedentary behavior  
n=58
Smoker  
n=12
Metabolic syndrome  
n=34
Binge eating disorder  
n=18
Injuries and other reasons  
n=11

Randomized  
n=120

Assigned to S  
Men (n=16)  
Women (n=14)  
Completed n=24

Assigned to E  
Men (n=15)  
Women (n=15)  
Completed n=26

Assigned to SE  
Men (n=15)  
Women (n=15)  
Completed n=24

Assigned to C  
Men (n=15)  
Women (n=15)  
Completed n=22

Withdraw:  
3 Lost interest  
2 Job change  
1 Personal reasons

Withdraw:  
3 Lost interest  
1 Diet adherence

Withdraw:  
1 Personal reasons  
1 Job change  
2 Lost interest  
1 Diet adherence  
1 Diet and exercise adherence

Withdraw:  
8 Lost interest

Fig. 1. Participant flow diagram.
Analytical Methods, Measurement of Dietetic, Physical Activity, and Anthropometric and Body Composition Variables

The following analyses and measurements were made at baseline and at the end of the intervention period.

Dietetic study. All food and beverages consumed by the participants were recorded using a food frequency questionnaire and a “3-day food and drink record”, validated for the Spanish population (23) at the beginning and end of the intervention. Participants were instructed to record the weights of food consumed whenever possible and to use household measurements (tablespoons, cups, etc.) when not. The energy and nutritional content of the foods consumed were then calculated using DIAL software (2004; Alce Ingeniería, Madrid, Spain). The Healthy Eating Index (HEI) was calculated according to Kennedy et al. (17), taking into account the number of servings recommended for the Spanish population (29). Compliance with recommended intakes was assessed for the different food groups (cereals, vegetables/greens, fruits, dairy products, meat/fish/eggs, expressed in servings per day), and also from the point of view of meeting nutritional objectives (intake of lipids, saturated fatty acid, cholesterol, sodium, and dietary variety). Each of these 10 factors was awarded a maximum of 10 points when the intake was the same as that recommended and a minimum of 0 points when the difference was very great. Intermediate values were awarded proportionally. Diet quality was deemed “good” when more than 80% total points were scored, as “needing improvement” when the score was 51–80, and “poor” when 50 or below (17).

Physical activity variables. Physical activity was assessed using six items in the International Physical Activity Questionnaire-Short Form (IPAQ-SF), which asked about the frequency and duration of vigorous intensity activity, moderate intensity activity, and walking activity. The questionnaire was scored using established methods posted on the IPAQ website (www.ipaq.ki.se). The questionnaire took ~8 min to complete; a trained researcher assisted participants with answering.

These data were summarized to classify the subjects into high-, moderate-, and low-physical activity groups. Time spent in vigorous, moderate, and walking activity was weighted by the energy expended for these categories of activity, to produce the total metabolic equivalents per minute (MET-min) of physical activity per week. In addition, the IPAQ-SF contained an additional indicator item of time spent in sedentary activity: “During the last 7 days, how much time did you usually spend sitting on a weekday?” Sitting time/week was estimated taking into account the answers supplied.

Cardiovascular fitness was evaluated with a maximal stress test using the modified Bruce protocol, broadly used in overweight and obese population, on a computerized treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany). Peak oxygen consumption (VO2peak) was measured with the gas analyzer Jaeger Oxycon Pro (Erich Jaeger, Viasys Healthcare, Höchberg, Germany). The stress test was maintained until exhaustion, and the mean of the three highest measurements was used as VO2peak. Dinamometry (maximum handgrip strength testing) was assessed using the Tecsys Ttk5002 hand dynamometer (Tecsys, Barcelona, Spain) (range: 5–100 kg; precision: 0.1 kg). This test was performed twice with the dominant hand, and the maximum score was recorded in kilograms.

Weight and body composition variables. Height was measured using a SECA stadiometer (range: 80–200 cm). Body weight was measured using a TANITA BC-420MA balance (Bio Lógica Tecnología Médica S.L., Barcelona, Spain). The BMI was calculated as [body weight (kg)/height (m)²]. Waist circumference (WC) was measured using a SECA stadiometer (range: 80 –200 cm). Body weight was measured twice with the dominant hand, and the maximum score was recorded in kilograms.

Adherence to Diet and Exercise

Adherence to diet was calculated as the estimated kilocalorie intake divided by the real kilocalorie intake [(estimated kilocalories of diet/real kilocalorie intake)-100]. Complete adherence = 100%. Higher values reflect greater dietary restriction, while lower values reflect lesser restriction. Those participants who failed to meet 80% adherence to the diet were excluded from further analysis.

Adherence to exercise was calculated as the number of sessions completed with respect to the theoretical maximum [(sessions performed/total sessions)-100]. An adherence of 90% was demanded.

Statistical Analysis

The Kolmogorov-Smirnov test was used to determine whether or not the data were normally distributed: all variables reported in this article met this condition. Means and SDs were calculated for continuous variables. MANOVA or two-way ANOVA for repeated measures were used to determine differences among the four interventions groups and between baseline and post-training values. Multiple ANOVA comparisons were made employing the Bonferroni post hoc test. The Chi-square test was used to examine the relationship between quantitative variables.

The sample size of the present study was calculated to detect any effect of training and diet on TFM% (with 80% statistical power, and with significance set at P < 0.05, assuming a correlation of 0.80 between repeated measures and assuming an estimated drop out of 20%). All analyses were performed using SPSS v. 17.0 software (SPSS, Chicago, IL.). Significance was set at α = 0.05.

RESULTS

Baseline Characteristics

The baseline characteristics of the present subjects were reported in a previous article (39). The results provided here are for the 96 participants (48 women and 48 men; mean age: 39.27 ± 7.80 yr), who completed the study (S: n = 24; E: n = 26; SE: n = 24; C: n = 22). No significant differences in baseline characteristics were seen between groups.

Diet

Adherence to diet was adequate (S: 103 ± 31%; E: 103 ± 34%; SE: 100 ± 26%; C: 98 ± 21%), and acceptable compliance was achieved over the 22-wk diet intervention period (Table 1). All groups significantly reduced their energy intake compared with baseline (P < 0.001), with no significant differences between groups. According to their energy profiles, all subjects approached the recommendations of the dietary intervention, increasing significantly the percentage of energy provided by carbohydrate (P < 0.01) and protein (P < 0.05), and decreasing significantly the percentage of energy provided by fat (P < 0.01). The cholesterol intake decreased significantly by the end of the intervention period in all groups (P < 0.01). At baseline, all subjects had a diet “needing improvement”, but by the end all had significantly improved their HEI index and their dietary quality was “good” (S: 60.7 ± 14.6 to 78.0 ± 10.5, P < 0.001; E: 55.1 ± 13.2 to 82.6 ± 8.9, P < 0.01; SE: 58.1 ± 12.6 to 76.3 ± 16.1, P < 0.001; and C: 58.5 ± 10.1 to 73.5 ± 19.2, P < 0.001).

Physical Activity

Table 2 shows the subjects’ physical activity variables. Adherence to the training programs was adequate (S: 90.0 ± 7.0%; E: 90.0 ± 8.0%; SE: 90.0 ± 5.0%). The time spent...
sitting per week decreased significantly after the intervention in all groups (S: $-142.0 \pm 32.9$; E: $-100.0 \pm 34.0$; SE: $-98.8 \pm 31.9$; C: $-100.0 \pm 38.4$ min/wk; no significant differences between groups). In addition, all groups increased significantly their total physical activity per week during the intervention (S: $1,314 \pm 708$ to $2,290 \pm 982$ MET-min/wk, $P < 0.01$; E: $1,428 \pm 727$ to $2,884 \pm 1,707$ MET-min/wk, $P < 0.001$; SE: $1,637 \pm 862$ to $2,966 \pm 1,556$ MET-min/wk, $P < 0.001$; C: $1,366 \pm 861$ to $2,128 \pm 1,083$ MET-min/wk, $P < 0.05$), with no differences between groups.

The change in the percentage of “high physical activity” subjects increased in all groups after the intervention, more so in the exercise training groups (S: $73.3\%$; E: $56.3\%$; SE: $70.6\%$; C: $25.0\%$).

Peak oxygen consumption improved only in SE ($3,103 \pm 692$ to $3,405 \pm 907$, $P = 0.001$). Strength measured by dynamometry showed no differences in any groups.

Weight and Body Composition

A significant reduction in body weight, BMI, WC, TFM, AF, and AF/GF, and a significant increase in LM, was detected in all groups after the intervention, with no significant differences between groups (Table 3).

### TABLE 1. DIETETIC VARIABLES AT BASELINE AND AFTER 22 WK OF INTERVENTION

<table>
<thead>
<tr>
<th>Group/Characteristics</th>
<th>S n = 24</th>
<th>E n = 26</th>
<th>SE n = 24</th>
<th>C n = 22</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake, kcal/day</td>
<td></td>
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</tr>
<tr>
<td>Baseline</td>
<td>2,918 ± 909</td>
<td>3,007 ± 1,257</td>
<td>2,555 ± 873</td>
<td>2,691 ± 740</td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td>1,971 ± 634***</td>
<td>1,787 ± 696***</td>
<td>1,734 ± 471***</td>
<td>1,752 ± 340***</td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>-946 ± 183</td>
<td>-1,221 ± 180</td>
<td>-820 ± 191</td>
<td>-939 ± 206</td>
<td>NS</td>
</tr>
<tr>
<td>Proteins, %EI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>17.78 ± 2.84</td>
<td>16.29 ± 2.79</td>
<td>17.87 ± 3.14</td>
<td>16.37 ± 2.49</td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td>20.29 ± 3.03**</td>
<td>19.87 ± 2.02***</td>
<td>20.12 ± 2.53**</td>
<td>20.34 ± 2.90***</td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>2.52 ± 0.71</td>
<td>3.58 ± 0.69</td>
<td>2.25 ± 0.74</td>
<td>3.96 ± 0.79</td>
<td>NS</td>
</tr>
<tr>
<td>Carbohydrates, %EI</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>38.38 ± 6.05</td>
<td>37.27 ± 6.40</td>
<td>36.52 ± 4.96</td>
<td>37.67 ± 7.87</td>
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</tr>
<tr>
<td>Final</td>
<td>40.58 ± 4.97*</td>
<td>43.14 ± 4.39***</td>
<td>43.10 ± 6.73***</td>
<td>40.85 ± 7.35*</td>
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</tr>
<tr>
<td>Change</td>
<td>2.20 ± 1.50</td>
<td>5.87 ± 1.47</td>
<td>6.58 ± 1.57</td>
<td>3.18 ± 1.69</td>
<td>NS</td>
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<td>Lipids, %EI</td>
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<td></td>
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</tr>
<tr>
<td>Baseline</td>
<td>39.45 ± 6.44</td>
<td>42.20 ± 6.44</td>
<td>42.14 ± 5.66</td>
<td>42.00 ± 6.32</td>
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</tr>
<tr>
<td>Final</td>
<td>35.41 ± 5.20**</td>
<td>33.62 ± 5.04***</td>
<td>33.72 ± 6.02***</td>
<td>35.62 ± 6.83***</td>
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<tr>
<td>Change</td>
<td>-4.05 ± 1.53</td>
<td>-8.59 ± 1.50</td>
<td>-8.42 ± 1.60</td>
<td>-6.38 ± 1.72</td>
<td>NS</td>
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<tr>
<td>Alcohol, %EI</td>
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<tr>
<td>Baseline</td>
<td>2.56 ± 3.07</td>
<td>2.65 ± 5.18</td>
<td>1.72 ± 1.91</td>
<td>2.32 ± 3.57</td>
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<tr>
<td>Final</td>
<td>1.31 ± 2.57*</td>
<td>0.66 ± 1.24**</td>
<td>0.60 ± 1.37*</td>
<td>0.65 ± 1.67*</td>
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<tr>
<td>Change</td>
<td>-1.25 ± 0.77</td>
<td>-1.99 ± 0.75</td>
<td>-1.12 ± 0.80</td>
<td>-1.67 ± 0.86</td>
<td>NS</td>
</tr>
<tr>
<td>Fiber, g/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>25.01 ± 10.95</td>
<td>23.79 ± 8.01</td>
<td>21.20 ± 6.25</td>
<td>21.93 ± 6.05</td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td>23.57 ± 8.15</td>
<td>23.22 ± 7.43</td>
<td>19.87 ± 4.92</td>
<td>22.12 ± 6.94</td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>-1.44 ± 1.80</td>
<td>-0.58 ± 1.77</td>
<td>-1.32 ± 1.88</td>
<td>0.20 ± 2.03</td>
<td>NS</td>
</tr>
<tr>
<td>Cholesterol, mg/day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>369.5 ± 118.2</td>
<td>444.6 ± 201.0</td>
<td>449.7 ± 192.3</td>
<td>415.3 ± 134.4</td>
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</tr>
<tr>
<td>Final</td>
<td>291.1 ± 109.8**</td>
<td>262.8 ± 97.8***</td>
<td>278.7 ± 104.0***</td>
<td>273.9 ± 102.8***</td>
<td></td>
</tr>
<tr>
<td>Change</td>
<td>-78.3 ± 31.1</td>
<td>-181.8 ± 30.5</td>
<td>-171.0 ± 32.5</td>
<td>-141.3 ± 35.0</td>
<td>NS</td>
</tr>
</tbody>
</table>

Values are expressed as means ± SD. S, strength group; E, endurance group; SE, combined strength + endurance group; C, control group; EI, energy intake; HEI, healthy eating index. *$P < 0.05$, significantly different compared to baseline. **$P < 0.01$, significantly different compared to baseline. ***$P < 0.001$, significantly different compared to baseline. $P$ denotes significant difference for the comparison of mean change after the intervention between treatments, with baseline values as covariates. NS, not significant.

### DISCUSSION

To our knowledge, this is the first clinical trial designed to examine the effect of different physical activity interventions, in combination with a hypocaloric diet, on body weight and composition variables in obese Spanish people. Maintaining a hypocaloric diet and regular physical activity, independent of the type followed, improved the anthropometric and body composition variables by the end of the 22-wk intervention period.

Our knowledge of the efficacy of physical activity as part of obesity prevention is based on a very small number of studies (19, 21). Some of these report a positive impact on BMI and body weight, but the heterogeneity in terms of study design, theoretical underpinning, and target population, make it difficult to draw any firm conclusions regarding which interventions are most effective. The PRONAF study, of which the present work is part, was designed as a clinical trial to clarify the importance of physical activity in the treatment of obesity.

The information currently available suggests that the best type of diet for treating obesity is one low in fat and sugary beverages, and high in carbohydrates, fiber, grains, fruits and vegetables, and proteins (3). According to the recommendations of the SENC (29), a balanced diet should provide 30–
56.3 ± 56.3
39.1 ± 2.66
33.1 ± 2.74
50.0 ± 290

Values are expressed as means ± SD. VO_{2peak}, peak oxygen consumption; L: low physical activity group; M: moderate physical activity group; H: high physical activity group. *P < 0.05, significantly different compared to baseline. **P < 0.01, significantly different compared to baseline. ***P < 0.001, significantly different compared to baseline. P denotes significant difference for the comparison of mean change after the intervention between treatments, with baseline values as covariates.

35% of energy from fat, 15–18% from protein, and 50–55% from carbohydrates. A recent meta-analysis showed that a hypocaloric, high-protein, and low-fat diet provides modest benefits in terms of body composition variables compared with a standard-protein, low-fat diet (38). On the basis of this evidence, a hypocaloric balanced diet was designed for use in the present study (30% of energy from fat, 20% from protein, and 50% from carbohydrates). All subjects reduced their energy intake by 10.22 ± 0.33 kCal/day.

Table 3. Anthropometric and body composition variables before and after 22 wk of intervention by group

<table>
<thead>
<tr>
<th>Group/Characteristics</th>
<th>S n = 24</th>
<th>E n = 26</th>
<th>SE n = 24</th>
<th>C n = 22</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight, kg</td>
<td>96.35 ± 10.20</td>
<td>93.50 ± 9.10</td>
<td>98.01 ± 13.50</td>
<td>92.32 ± 13.03</td>
<td>92.32 ± 13.03</td>
</tr>
<tr>
<td>Final</td>
<td>87.13 ± 9.97***</td>
<td>82.95 ± 8.91***</td>
<td>88.13 ± 13.29***</td>
<td>83.63 ± 13.30***</td>
<td>83.63 ± 13.30***</td>
</tr>
<tr>
<td>Change</td>
<td>-9.21 ± 0.83</td>
<td>-10.55 ± 0.80</td>
<td>-9.88 ± 0.85</td>
<td>-8.69 ± 0.89</td>
<td>-8.69 ± 0.89</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>33.28 ± 1.81</td>
<td>33.56 ± 2.54</td>
<td>33.91 ± 2.66</td>
<td>33.11 ± 2.74</td>
<td>33.11 ± 2.74</td>
</tr>
<tr>
<td>Final</td>
<td>30.15 ± 2.26***</td>
<td>29.57 ± 2.85***</td>
<td>30.49 ± 2.78***</td>
<td>30.04 ± 2.99***</td>
<td>30.04 ± 2.99***</td>
</tr>
<tr>
<td>Change</td>
<td>-3.13 ± 0.32</td>
<td>-3.99 ± 0.30</td>
<td>-3.42 ± 0.32</td>
<td>-3.08 ± 0.34</td>
<td>-3.08 ± 0.34</td>
</tr>
<tr>
<td>WC, cm</td>
<td>103.25 ± 7.33</td>
<td>101.69 ± 7.14</td>
<td>102.91 ± 7.8</td>
<td>103.79 ± 7.97</td>
<td>103.79 ± 7.97</td>
</tr>
<tr>
<td>Final</td>
<td>94.42 ± 7.57***</td>
<td>91.85 ± 6.38***</td>
<td>94.59 ± 7.94***</td>
<td>94.52 ± 9.22***</td>
<td>94.52 ± 9.22***</td>
</tr>
<tr>
<td>TFM, %</td>
<td>41.89 ± 5.56</td>
<td>42.89 ± 5.77</td>
<td>44.08 ± 6.38</td>
<td>41.38 ± 5.58</td>
<td>41.38 ± 5.58</td>
</tr>
<tr>
<td>Final</td>
<td>36.65 ± 6.59***</td>
<td>37.55 ± 6.47***</td>
<td>39.23 ± 7.46***</td>
<td>36.49 ± 6.76***</td>
<td>36.49 ± 6.76***</td>
</tr>
<tr>
<td>Change</td>
<td>-5.24 ± 0.55</td>
<td>-5.35 ± 0.55</td>
<td>-4.85 ± 0.56</td>
<td>-4.89 ± 0.59</td>
<td>-4.89 ± 0.59</td>
</tr>
<tr>
<td>AF, %</td>
<td>49.80 ± 4.80</td>
<td>50.30 ± 5.55</td>
<td>51.92 ± 6.15</td>
<td>49.74 ± 5.55</td>
<td>49.74 ± 5.55</td>
</tr>
<tr>
<td>Final</td>
<td>40.21 ± 10.37***</td>
<td>42.79 ± 7.14***</td>
<td>45.43 ± 8.72***</td>
<td>42.38 ± 7.73***</td>
<td>42.38 ± 7.73***</td>
</tr>
<tr>
<td>Change</td>
<td>-9.59 ± 1.27</td>
<td>-7.51 ± 1.27</td>
<td>-6.50 ± 1.30</td>
<td>-7.36 ± 1.36</td>
<td>-7.36 ± 1.36</td>
</tr>
<tr>
<td>AFGF, %</td>
<td>1.19 ± 0.18</td>
<td>1.14 ± 0.19</td>
<td>1.18 ± 0.20</td>
<td>1.22 ± 0.21</td>
<td>1.22 ± 0.21</td>
</tr>
<tr>
<td>Final</td>
<td>1.16 ± 0.20***</td>
<td>1.11 ± 0.18***</td>
<td>1.17 ± 0.22***</td>
<td>1.17 ± 0.23***</td>
<td>1.17 ± 0.23***</td>
</tr>
<tr>
<td>Change</td>
<td>-0.03 ± 0.01</td>
<td>-0.03 ± 0.01</td>
<td>-0.01 ± 0.01</td>
<td>-0.04 ± 0.02</td>
<td>-0.04 ± 0.02</td>
</tr>
<tr>
<td>LM, %</td>
<td>56.29 ± 5.25</td>
<td>55.46 ± 5.67</td>
<td>54.12 ± 5.92</td>
<td>56.53 ± 5.27</td>
<td>56.53 ± 5.27</td>
</tr>
<tr>
<td>Final</td>
<td>61.21 ± 6.15***</td>
<td>60.34 ± 6.09***</td>
<td>58.76 ± 7.02***</td>
<td>61.25 ± 6.34***</td>
<td>61.25 ± 6.34***</td>
</tr>
<tr>
<td>Change</td>
<td>4.92 ± 2.78</td>
<td>4.99 ± 1.85</td>
<td>4.54 ± 2.55</td>
<td>4.52 ± 2.77</td>
<td>4.52 ± 2.77</td>
</tr>
</tbody>
</table>

Values are expressed as mean values ± SD. BMI, body mass index; WC, waist circumference; TFM, total fat mass; AF, android fat; AFGF, android/gynoid fat ratio; LM, lean mass. ***P < 0.001, significantly different compared to baseline. P denotes significant difference for the comparison of mean change after the intervention between treatments, with baseline values as covariates.
ergy intake and showed good compliance with the protein and fat intake recommendations. However, the percentage of energy supplied by carbohydrate did not increase enough to attain the goal set out. Similar findings have been reported in other interventional studies in which the dietary recommendations were based on the same criteria (2, 22). However, different studies suggest that diets supplying 40–50% of total energy from carbohydrate may be effective alternatives to those insisting on >50% of energy coming from this macronutrient, since similar weight losses were achieved (14, 28, 38).

It is important to note that all subjects in the present study enjoyed considerably improved dietary quality after the intervention; all groups had a diet “needing improvement” at baseline and at the end all had a “good” HEI index. The dieticians made sure they informed the subjects on the most important aspects of diet quality during the nutrition education sessions. It might be essential to equip participants with the knowledge and skills necessary to achieve gradual but permanent behavior changes.

In addition to increased obesity, a sedentary lifestyle during adulthood may also be associated with increased mortality. Physical activity is important for overall good health (8, 35). In the present study, all of the physical activity programs (C group recommendations included) contributed toward increasing the total physical activity and reducing inactivity in all subjects. All of the groups reduced their sitting time, and the percentage of people classified as showing “high physical activity” increased. This was especially true for the exercise-training groups, with no significant differences observed between them. However, improvement in VO2peak was observed only in the combined training group. Motivational factor could be responsible for this difference, since combined training is less monotonous than continuous aerobic training that can be more effective in obese people (6).

The scientific evidence suggests that the combination of dietary modification and exercise is the most effective behavioral approach for achieving weight loss (5, 7, 32); hence, the reason why the present study was designed combining both for all groups. Different authors have also indicated the urgent need to design large, effective, evidence-based programs based on exercise interventions to clarify the role of physical activity in obesity prevention (19, 21).

After the present interventions, all subjects saw improvements in their anthropometric and body composition variables, with no significant differences detected between any of the groups. Other authors have concluded that dietary restriction combined with endurance exercise training is effective in achieving weight loss and reducing fat mass in obese subjects (15, 25, 31). However, few studies have compared the effects of similar amounts of aerobic and resistance training on body mass and fat mass in obese people. In the recent STRRIDE AT/RT (Studies of a Targeted Risk Reduction Through Defined Exercise) study, (37) aerobic training (AT), resistance training (RT), and a combination of the two, were compared to determine the optimum mode of exercise for obesity reduction over an 8-mo intervention period. The authors concluded that a program of combined AT/RT did not result in significantly greater fat mass or body mass reduction over AT alone. In fact, balancing time commitments against health benefits, AT would appear to be the optimal mode. A program, including RT, is best if increased muscle mass and strength are sought. It should be remembered, however, that the STRRIDE AT/RT study did not include a dietary intervention, and the weight lost over the 8 mo was much less than in the present study (RT: 0.83 ± 2.32 vs. S: −9.21 ± 0.83; AT: −1.76 ± 3.00 vs. E: −10.55 ± 0.80; AT/RT: −1.63 ± 3.17 vs. SE: −9.88 ± 0.85 kg). Certainly, other authors have indicated that exercise programs alone are less efficient than those combined with diet control for achieving good weight management (13, 30). In addition, the STRRIDE AT/RT study did not include a control group; the impact of following physical activity recommendations was, therefore, not determined.

The present study shows that, when adhered to alongside a hypocaloric diet, different exercise training programs (endurance, strength, or their combination) or the following of physical activity recommendations are equally efficient in terms of improving body weight and body composition variables in obesity management. The lack of efficiency of the training programs may be attributable to a compensatory reduction in daily physical activity (13). Alternatively, it may be due to a lack of continuity in their undertaking: while the C group practiced regular physical activity daily, the S, E, and SE groups practiced exercise on only 3 days/wk. These results back up the exercise recommendations in the European Clinical Practice Guidelines for the Management of Obesity in Adults (32). These explain that the objective should be to reduce sedentary behavior and increase daily activities (e.g., walking or cycling instead of using a car, climbing stairs instead of using the elevator, etc.).

Subjects should be advised and helped in undertaking (or increasing) physical activity. Exercise advice must be tailored to a person’s ability and health, and focus on a gradual increase with levels that are safe. Current recommendations suggest that people of all ages should undertake 30–60 min of physical activity of moderate intensity (such as brisk walking) on most, if not all, days of the week (16, 26, 27). In fact, it is important to look for exercise interventions that can easily be integrated into daily life and that are not associated with an increased risk of trauma. Most importantly, patients should enjoy the proposed kind of physical exercise (20).

Many authors have concluded that the inclusion of an exercise training program in the treatment of obesity is important for maintaining long-term weight control (13, 30). The ongoing PRONAF study, therefore, plans to evaluate the effect of the present programs at 6 mo and 3 yr after the intervention. The data collected will be presented in a future article.

In conclusion, the present study shows that, when combined with a hypocaloric diet, the adherence to physical activity recommendations is just as effective as exercise training programs in the improvement of body weight and body composition in obese subjects.

GRANTS

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AUTHOR CONTRIBUTIONS

interpreted results of experiments; P.J.B. and L.M.B. prepared figures; P.J.B. and L.M.B. drafted manuscript; P.J.B., L.M.B., A.B.P., B.L.-P., R.C., B.S., F.J.C., E.A.C., and C.G.-C. edited and revised manuscript; P.J.B., L.M.B., A.B.P., B.L.-P., R.C., B.S., F.J.C., E.A.C., and C.G.-C. approved final version of manuscript.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

REFERENCES