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Caloric restriction and aerobic exercise in sarcopenic and non-sarcopenic obese women: an observational and retrospective study

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Abstract

Background Sarcopenic obese (SO) individuals are a unique subset of subjects that combines obesity and sarcopenia. Traditional weight loss programmes including aerobic exercises may worsen their condition by further reducing their lean mass. The objective of this observational and retrospective study was to verify the effect of a mixed weight loss programme combining caloric restriction and exercise on body composition, and lipid-lipoprotein profile of obese women according to their sarcopenic status.

Methods One hundred and forty-six obese women (body mass index $\geq$ 30 kg/m^2 and fat mass $\geq$ 40%) participated to the 3 week usual and institutionalized weight-reducing programme combining a dietary plan (1400 ± 200 kcal/day) and aerobic exercise (1 h/day, 6 days/week) of a specialized medical institution. The lean body mass index (LMI; lean mass/height^2) was calculated, and women in the lowest tertile of LMI were considered SO.

Results At baseline, SO women were older, and their body weight and LMI were lower than non-sarcopenic obese (N-SO) women ($p < 0.05$). N-SO and SO women similarly lost fat mass and improved their lipid-lipoprotein profile ($p < 0.05$), while differences in LMI between groups persisted at the end of the weight-reducing programme. Indeed, N-SO women lost lean mass ($p < 0.05$) while SO did not.

Conclusions These findings suggest that a short weight loss programme combining caloric restriction and aerobic exercise may significantly reduce fat mass and improve lipid-lipoprotein profile in obese women, independently of their sarcopenic status. Such programmes may have deleterious effects on lean mass in N-SO subjects, only.

Keywords Lean body mass; Aerobic exercise; Diet; Lipid-lipoprotein profile

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Introduction

As the prevalence of obesity increases dramatically, weight gain has become a major public health issue. Accordingly, 66.3% of adults in the United States are currently overweight and 35.5% are obese.[1] Similarly, 47.3% of French people aged 18 and over are overweight, and 15% of them are obese.[2] Obesity, mainly because of an increased visceral adipose tissue accumulation, was shown to be a predisposing factor of metabolic syndrome, cardiovascular diseases, type 2 diabetes, some cancers, and functional impairments.[3–5] Furthermore, obesity is known to reduce the length of life of

severely obese individuals by an estimated 5 to 20 years[6] and is suggested to negatively affect the future life expectancy of the population.[7] Diet, aerobic exercise, and especially the combination of both, are considered the cornerstone of obesity management.[8]

In France, 3 week weight loss programmes are available for overweight or obese individuals, once a year, by medical prescription. This 3 week period corresponds to the one covered by the French Medical Health Care System. These interventions developed by weight-loss centres and under medical supervision consist in modifying eating and physical activity habits and include psychological counselling. Physical activity usually includes aerobic exercises known to be more effective to reduce visceral fat,[9] but not necessarily resistance exercises, as the main objective of weight-reducing programmes focuses on weight loss rather than on increasing lean mass. Participants entering these programmes usually lose weight, but little is known on body composition and metabolic risk profile changes.

Sarcopenic obese (SO) individuals are a unique population that combines high fat mass and low muscle mass, both conditions being frequently observed with ageing.[10] SO individuals are exposed to greater risks for poor health-related outcomes (such as the cardiometabolic syndrome) and disability than individuals presenting either obesity or sarcopenia alone.[11–13] Even more than obese, SO individuals would benefit from a weight loss programme. However, treating all obese individuals with a 'one-size fits all' approach may be counterproductive, as the weight loss observed in weight-reducing programmes is usually because of losses of both fat mass and lean mass, which is susceptible to worsen the condition of SO individuals.[14] Yet, even when performed in a medical context, weight loss programmes do not include a systematic detection of sarcopenic individuals. The need to differentiate subgroups of obesity has already been illustrated by the example of the metabolically healthy but obese (MHO) individuals. Indeed, MHO exhibited cardioprotective traits despite having high levels of body adiposity.[15] However, programmes designed to improve their physical fitness have deteriorated their metabolic profile.[16,17]

Therefore, the main objective of this observational and retrospective study was to verify the effect of a short mixed weight loss programme (combining a dietary plan and aerobic activities) routinely performed in a medical institution, on the body composition and metabolic risk profile of obese women according to their sarcopenic status.

Methods

Study population

These secondary analyses were conducted from retrospective data obtained in 146 obese women (BMI $\geq$ 30 kg/m^2 and fat mass $\geq$ 40 %) referred by their personal physician to participate in a non-randomized short mixed weight-reducing programme at the Clinique du Château de Vernhes (Bondigoux, France) covered by the French Medical Health Care System.[18–20] As patients are subjected to the routine assays performed during the 3 week they spent at the Clinique du Château de Vernhes (i.e. anthropometry and body composition, lipid-lipoprotein, and haemodynamic measures), they only gave their written informed consent to the use of data collected. Thus, because of this specific design, this study could not be defined as a clinical trial per se but as a retrospective one. None of the women had identified disease (e.g. cardiomyopathy; endocrine disorders, which may cause irregular menstrual cycles; or orthopaedic limitations that could affect physical activity). Women on medication that could influence outcome—mainly β-blockers, sympathomimetic drugs, cholesterol-lowering drugs (including statins), antihypertensive drugs, and thyroxin, for which a dosage change occurred during the previous 6 months or was expected during the course of the institutionalized weight-reducing programme—were excluded from this observational and retrospective study. Premenopausal women using oral contraceptives and postmenopausal women on hormone therapy were also excluded. All women were sedentary (exercising no more than 30 min per week). The study was approved by the Local Ethical Committee of the Clinique du Château de Vernhes (Bondigoux, France).

Weight-reducing programme

The institutionalized weight-reducing programme combined dietary and physical activity instructions and psychological counselling 6 days/week, during 3 weeks. This short duration corresponded to the period covered by the French Medical Health Care System. During this period, all women had four meals per day (breakfast, lunch, snack, and dinner), and received a standardized dietary plan estimated as 1400 ± 200 kcal/day (mean ± standard deviation, SD) according to patients' usual caloric intake and hunger. The dietary plan was composed of 20–25% proteins, 25–30% lipids (saturated fatty acids being one third of total fatty acids), and 50–55% carbohydrates; no alcohol was allowed. Participants also followed a personalized physical training programme with cycle ergometer and walking 1 h/day, 6 days a week, for 3 weeks. The detailed physical training programme was previously described.[18–20] Subjects' heart rate (HR) was continuously monitored using a cardiofrequencemeter (Polar, FS1 type, Kempele, Finland), and intensity of exercise was set at 50% of their hypothetical maximal HR calculated from the following equation: 220 − age, where age is expressed in years. This intensity was fixed by the medical staff for safety reasons, and physical activity was performed under the supervision of medical staff.

Anthropometry and body composition

Body weight was measured to the nearest 0.1 kg using an electronic scale. Height was determined to the nearest 0.5 cm at head level, using a tape measure fixed to the wall. Fat mass and lean mass were measured by a standard electric bioimpedance technique (Bodystat 1500, Isle of Man, UK).[18–20] Measurements were performed in the early morning after an overnight fast, with participants lying down for 10 to 15 min prior to the measurement. The measurement of total body water by the Bodystat 1500 has been validated against tritium dilution techniques.[21] According to the European Working Group on Sarcopenia in Older People,[22] electric bioimpedance is suitable for research and clinical settings as measurements, under standard conditions, were highly correlated with MRI predictions.

Anthropometric and body composition measures were repeated twice and then averaged. Lean body mass index (LMI; kg/m^2) was calculated by dividing total lean mass (kg) by height squared (m^2). In the absence of threshold of sarcopenia with this method, women showing the lowest tertile of LMI ($n = 50$) were considered as SO, as previously reported when using bioelectrical impedance analysis,[23] and compared to women with the highest tertile considered as non-sarcopenic obese (N-SO; $n = 50$).

Lipid-lipoprotein and haemodynamic profiles

Blood samples were collected by the same nurse after a 12 h overnight fast and a 15 min rest period, during which patients were in a semi-recumbent position; patients had to remain inactive for 60 h before blood sampling to eliminate any acute effect of exercise on metabolic profile. Serum samples were stored at −80°C until use, and samples from each subject were analysed within a simple batch to minimize analytic variations. Fasting cholesterol, triacylglycerol, and high-density lipoprotein (HDL)-cholesterol levels were determined according to standardized laboratory procedures on a COBA MIRA PLUS automate (Roche Diagnostics). Fasting low-density lipoprotein (LDL)-cholesterol concentrations were estimated using the Friedewald equation.[24] Resting systolic and diastolic blood pressure (BP) were taken when subjects were lying down, with both arms relaxed and supported, after a rest period of at least 10 min, using an automated BP ambulatory unit (NAIS, Blood Pressure Unit).[18] Systolic and diastolic BP measurements were taken twice, at 5 min intervals, and the mean of the two measurements was used.

Statistical analysis

Data are expressed as the mean ± SD. A non-paired Student's *t*-test was used for the comparison between groups (N-SO vs. SO), at baseline and at the end of the 3 week programme. An analysis of variance (ANOVA) with repeated measures was used to detect changes in response to the treatment condition (pre- vs. post-weight reducing programme) and between groups. Analyses were performed using SPSS 17.0 (Chicago, IL). A p value of less than 0.05 was considered significant.

Results

Baseline participants' characteristics

Participants' characteristics before the weight-reducing programme are presented in *Table* 1. At baseline, SO women were older and had lower body weight, BMI, and LMI than N-SO women ($p < 0.05$). No between group-difference was observed regarding the lipid-lipoprotein and haemodynamic profiles.

Effects of the weight-reducing programme

Because of age differences at baseline, ANOVA was controlled for this variable. Body weight, BMI, and fat mass decreased in both N-SO and SO women ($p < 0.05$) in response to the weight-reducing programme. LMI significantly decreased in N-SO subjects ($-1.8 \pm 4.6\%$, $p < 0.01$) but not in SO women ($-0.5 \pm 2.1\%$, $p = 0.11$). Total cholesterol, HDL- and LDL-cholesterol levels, as well as systolic BP decreased in both groups ($p < 0.05$). Significant weight-reducing effect × group interactions were observed for body weight, BMI, and LMI. Relative changes in BMI, LMI, and fat mass are shown in *Figure* 1.

Alternative statistical analysis

Furthermore, as the body weight difference between groups may not be entirely because of differences in lean mass, ANOVA controlling for age and fat mass was also performed. However, results were similar to those obtained after control for age only (not shown).

Because postmenopausal women were more numerous in the SO than in the N-SO group (probably because SO women were older than N-SO ones), we also performed statistical analysis controlling for menopausal status instead of age, and found similar results. Finally no significant weight-reducing effect × menopausal status interaction was observed. Therefore, we did not decide to include menopausal status as a confounding factor, in our analyses.

Discussion

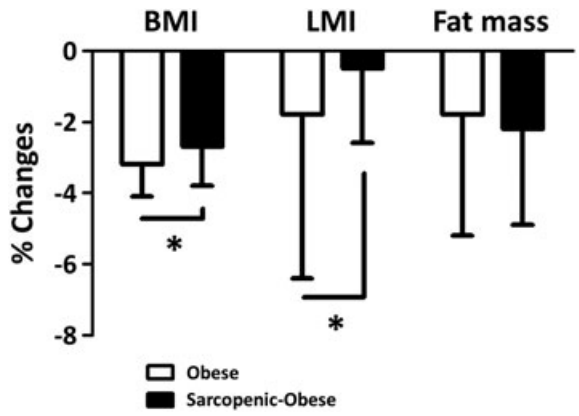
To the best of our knowledge, these are the first retrospective analyses to report the effects of a short institutionalized weight-reducing programme combining a dietary plan and aerobic exercise on the body composition and metabolic risk

Table 1 Variables before and after the mixed weight-reducing programme

Variable	All ($n = 146$)		N-SO ($n = 50$)		SO ($n = 50$)	
	Pre	Post	Pre	Post	Pre	Post
Age (years)	53 ± 9		51 ± 11		57 ± 6 [a]	
Postmenopausal (%)	62.3		50		76 [a]	
Height (cm)	161.6 ± 6.8		163.3 ± 6.6		161.2 ± 6.2	
Weight (kg)	92.7 ± 11.9	90.1 ± 11.4 [c]	100.5 ± 11.1	97.3 ± 10.6 [c]	86.3 ± 8.9 [a]	84.0 ± 8.6 [b c d]
BMI (kg/m^2)	35.4 ± 3.3	34.4 ± 3.2 [c]	37.7 ± 3.0	36.5 ± 3.0 [c]	33.2 ± 2.4 [a]	32.3 ± 2.4 [b c d]
Fat mass (%)	47.6 ± 3.6	46.6 ± 3.7 [c]	47.4 ± 3.3	46.6 ± 3.5 [c]	48.0 ± 3.6	47.0 ± 3.9 [c]
Lean mass (kg)	48.3 ± 5.5	48.0 ± 5.6 [c]	52.8 ± 5.0	51.8 ± 5.6 [c]	44.6 ± 3.2 [a]	44.4 ± 3.4 [b d]
LMI (kg/m^2)	18.5 ± 1.2	18.3 ± 1.3 [c]	19.8 ± 0.8	19.4 ± 1.2 [c]	17.2 ± 0.6 [a]	17.1 ± 0.7 [b d]
Total cholesterol (mmol/L)	2.12 ± 0.36	1.80 ± 0.40 [c]	2.21 ± 0.28	1.83 ± 0.51 [c]	2.13 ± 0.33	1.85 ± 0.34 [c]
HDL-cholesterol (mmol/L)	0.52 ± 0.14	0.45 ± 0.13 [c]	0.53 ± 0.18	0.43 ± 0.11 [c]	0.53 ± 0.13	0.47 ± 0.11 [c]
LDL-cholesterol (mmol/L)	1.38 ± 0.36	1.14 ± 0.39 [c]	1.38 ± 0.32	1.11 ± 0.41 [c]	1.34 ± 0.28	1.11 ± 0.33 [c]
Triacylglycerol (mmol/L)	1.31 ± 0.51	1.13 ± 0.31 [c]	1.30 ± 0.48	1.07 ± 0.25	1.28 ± 0.49	1.12 ± 0.30 [c]
Systolic BP (mmHg)	129 ± 13	122 ± 13 [c]	126 ± 12	118 ± 15	131 ± 13	123 ± 13 [c]
Diastolic BP (mmHg)	75 ± 10	74 ± 9	74 ± 5	74 ± 10	74 ± 12	72 ± 8

Blood analysis was performed on 57 women, 12 of which are in the N-SO group, and 30 in the SO group.
BMI: Body mass index; LMI: Lean body mass index; BP: Blood pressure; N-SO: Non-sarcopenic-obese; SO: sarcopenic-obese.
[a]Differences between N-SO and SO at baseline ($p < 0.05$).
[b]Differences between N-SO and SO at the end of the weight-reducing programme ($p < 0.05$).
[c]Weight-reducing effect ($p < 0.05$).
[d]Weight-reducing effect × group interaction ($p < 0.05$) after controlling for age.

Figure 1 Relative changes (%) in BMI, LMI, and fat mass in non-sarcopenic-obese and sarcopenic-obese women following the mixed weight-reducing programme. Changes were calculated as relative differences between pre and post-weight loss values. BMI: Body mass index; LMI: Lean body mass index. *Differences between non-sarcopenic-obese ($n = 50$) and sarcopenic-obese ($n = 50$) women at $p < 0.05$, after control for age differences.



profile according to their sarcopenic status. Sarcopenic-obese individuals, even more than N-SO ones, would benefit from a fat mass reduction because negative effects of sarcopenia and obesity are cumulative. However, weight loss is also partially because of a loss of lean mass, which may worsen the condition of sarcopenic individuals whose functional capacity is already impaired by their initially low muscle mass. This issue is even more important as sarcopenic individuals are not screened when entering weight-loss programmes.

Separating obese women based on their LMI revealed other morphological differences. Obviously, lean mass was lower in SO than in N-SO patients. This difference in lean mass also contributed to differences observed in total body weight and BMI. Furthermore, that sarcopenic-obese women were older than N-SO ones, is in good accordance with the fact that sarcopenia is an age-related process. However, controlling analysis for these differences did not influence our observations, thus suggesting that the sarcopenic-obese phenotype was not an artefact.

Two important points have to be highlighted. First, SO women did not significantly lose lean mass, as reflected by their maintained LMI, in contrast to N-SO ones. Second, SO and N-SO women showed similar fat mass losses and improvements in their lipid-lipoprotein profile. The reason why SO women preserved their LMI is unclear but several factors may have contributed to this observation: (1) one may hypothesize that the intervention was too short to significantly decrease LMI. As illustrated in *Figure* 1, SO women showed a non-significant decrease of LMI (of 0.5%) that should have been more pronounced with a longer intervention; (2) the dietary plan was rather hyperproteinized, as the 20–25% of proteins reported in the present study is higher than the 15% content recommended by the French Agency for Food Safety for sedentary individuals, and (3) SO women had less muscle to lose, compared with N-SO ones. In our design, the SO group has a lower LMI than the N-SO one. One may thus hypothesize that SO women have a very low muscle mass to perform physical activity and that the physical activity programme (even if composed of aerobic exercises, at a relatively low intensity) was sufficient to maintain their muscle mass above this threshold.

As illustrated by the recent systematic review and meta-analysis of Schwingshackl *et al.*,[25] aerobic exercises are more efficient than resistance exercises in reducing body weight, waist circumference, and fat mass in overweight and obese

individuals. This observation is in good accordance with our results and fully justifies the integration of aerobic exercises in weight-loss programmes. However, regarding lean mass, aerobic exercises are well known to be less suitable than resistance ones.[25] This is also concordant with the loss of lean mass observed in the whole cohort, and more particularly in N-SO women. This is the reason why it was necessary to verify that such weight-reducing programme was appropriate for sarcopenic individuals whose muscle mass is already low. Therefore, although SO women did not significantly lose lean mass in the present study, our results are consistent with the need to integrate resistance exercise to weight loss programmes in SO individuals, from a preventive clinical standpoint.[26,27] Results of Schwingshackl *et al*.[25] also provide strong evidence that a combined weight-reducing programme is the most promising tool for the management of overweight and obesity. The combination of aerobic and resistance exercises appears to be more powerful in reducing anthropometric risk factors such as body weight or fat mass when compared to resistance exercises alone and more effective in raising lean mass when compared to aerobic exercises alone.[25] This is crucial when SO individuals are involved.

The second important point of this study is the similar fat mass loss and lipid-lipoprotein profile improvement observed in SO and N-SO women. Both groups experienced similar decreases in total cholesterol, LDL-cholesterol, and triacylglycerol levels, as well as in systolic and diastolic BPs. Unexpectedly, HDL-cholesterol also decreased in both groups, but to a lesser extent than LDL-cholesterol, leading to a small improvement in the HDL-/LDL-cholesterol ratio. HDL-Cholesterol concentrations usually increase with weight loss programmes.[28] However, controversial findings similar to those observed in the present study, are sometimes reported,[29] and more particularly during short and mostly active weight-loss periods.[28] During acute energy restriction, lipoprotein lipase activity was already reported to decrease by 50–80%. Because of its reduction, TG-rich lipoprotein synthesis is likely diminished and VLDL-cholesterol catabolism impaired. Therefore, transfer of lipids to HDL-cholesterol is limited, resulting in decreased HDL-cholesterol concentrations.[28]

The main limit of our observational and retrospective study is the short duration of the institutionalized weight-reducing programme. Indeed, the financial coverage offered by French Medical Health Care System for such programme is limited to a maximum of 3 weeks, leading physicians to propose efficient strategies within this time scale. A second limit of our study is the large standard deviation we observed for caloric intake although the dietary plan was standardized. This was mainly explained by the fact that participants did not always totally eat their meals, depending on their hunger. Although the exact caloric content ingested by each patient was not measured, it seems reasonable to assume that (1) the food consumed was similar (in terms of proportion) to the one prepared and (2) there was no preference of a nutrient over another according to the participants' group. Indeed, it seems unlikely that N-SO should have decreased their protein intake more than SO women, thus leading to a reduced LMI in the formers than in the latters.

However, our study also has several strengths. Energy intake and expenditure were well-controlled (diet being standardized throughout the 3 weeks and exercise being performed under supervision and continuously monitored through HR measurements). Furthermore, no woman dropped out, probably because of the continuous medical supervision.

In conclusion, a short weight-reducing institutionalized programme including a dietary plan and aerobic exercise allows SO women to lose fat mass and improve their lipid-lipoprotein profile, but does not deteriorate their sarcopenic status. However, identifying SO individuals who entered such weight loss interventions and adding resistance exercise activities to aerobic ones can only be benefic.

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Conflict of interest

All authors declare having no conflicts of interest.

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