Health benefits of endurance training alone or combined with diet for obese patients over 60: a review

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Health benefits of endurance training alone or combined with diet for obese patients over 60: a review

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SUMMARY

Background: The prevalence of obesity is rapidly increasing in older patients and it is ubiquitous in many developed countries. Obesity is related to various negative health outcomes, making it a major public health target for intervention. Purpose: The aim of this study was to explore and summarise the literature that addresses endurance training alone or combined with nutrition interventions to combat obesity in obese patients over age 60. Methods: We searched online electronic databases up to September 2014 for original observational and intervention studies published between 1995 and 2014 on the relationship between endurance training alone or combined with a diet in obese patients over 60 regarding health outcomes. Results: Twenty-six studies examined interventions aimed specifically at promoting endurance training alone or combined with diet for older obese patients over 60. These studies demonstrated a positive effect of this intervention on the primary prevention of cardiovascular disease, and a significant beneficial effect on the lipid profile. Improvement of body composition and insulin sensitivity, and a reduction in blood pressure were also well established. Conclusions: Overall, this review demonstrates a positive effect of endurance training alone or combined with diet on health outcomes and metabolic benefits in older adults. Clinicians can now use this evidence to formulate actions to encourage the older obese to profit from the health benefits of endurance training and diet. This will not only help reduce the dramatic increase in the number of older obese but also help prevent sarcopenic obesity, which is a complex challenge for healthcare professionals.

Introduction

Obesity is defined as a body mass index (BMI) ≥ 30 kg/m² (1), and is already a major public health problem, with the added risk of developing serious medical pathologies (2). In older adults, obesity is prevalent in many parts of the world and is associated with a variety of poor health outcomes. The prevalence of obesity has markedly increased in older patients (3), who continue to represent one of the fastest growing segments of the population in developed countries (4). The proportion of obese older adults has doubled in the last 30 years, and in 2010 their prevalence was estimated at 37.45% (5). This reflects both an increase in the total number of older people and in the percentage of older obese population (6). There is no doubt that unless actions are taken to reverse this trend, the growing number of obese older adults in the population will increase public health challenges (7). It is therefore perhaps surprising that more attention has not been paid to the problem of obesity in older adults, especially because obesity has quantitatively different effects on morbidity and mortality in older individuals than in younger individuals (8). Indeed, obesity has been shown to be related to diseases including diabetes mellitus, hypertension, dyslipidaemia, coronary artery disease and congestive heart failure (9,10). The risk of all of these diseases can be reduced by increased physical activity (11). Physical activity can prevent obesity-related diseases through two mechanisms, by improving weight control (prevention of weight gain, increased weight loss), and by improving the metabolic profile associated with obesity (12). It is well established that endurance exercise training is an effective strategy in older obese adults to reduce body fat mass (13,14), increase whole-body insulin sensitivity (13–15), and reduce the risk of cardiovascular disease (16). Aerobic exercise and dietary modifications are broadly recommended as first-line interven-
tions in the treatment of obesity, particularly in obese adults over 60 (17–19).

In contrast to many studies and reviews that examined the health benefits of endurance exercise training, separate from or combined with diet for the general obese population (12,20–22), only a few studies have specifically examined their health benefits in obese adults aged over 60 (7,23,24). The aim of this review was thus to assess the health benefits of endurance training alone (ET) or combined with diet (ETD) for obese people aged over 60.

**Methods**

**Literature search**

We made a systematic search for observational and intervention studies that examined the relation between endurance training alone (ET) or combined with diet (ETD) and health for older people published between December 1995 and July 2014. Published and peer-reviewed articles in English language journals were identified in electronic databases and on reference lists of articles available to the authors of this review.

The search terms ‘exercise training, endurance training or aerobic training and diet therapy, diet restriction or weight loss intervention, fat oxidation, body composition, and skeletal muscles, and health or health benefits and obese or obesity and older adults, elderly, much older/elderly, aged, ageing, oldest, old and over 60’ were combined for each of the eight electronic databases. The search resulted in a total of 3544 hits: PubMed Central 1247, Web of Science 657, Medline 619, Scopus 375, Embase 289, CINAHL Plus 277, Cochrane library 50, SportDiscus 30. We also searched for previous systematic reviews, websites and references therein.

**Inclusion criteria and selection process**

Based on the article titles and available abstracts, the reports were initially evaluated for inclusion using the following criteria.

Original research, articles written in English, observational or intervention studies published in peer-reviewed journals with outcomes based on combining endurance training with diet (energy restriction) in adults (aged 60 and over, with a mean BMI ≥ 30 kg/m²), independently reported effect of endurance training alone for older obese patients, quantitative measures of endurance training separate from or combined with diet for any purpose among older obese patients, measures of mortality or morbidity (including disease risk factors) and/or measures of health and metabolic function through endurance training separate from or combined with diet.

Altogether 3451 articles were excluded because of uncontrolled studies with outcomes based on resistance training, cross-sectional studies focused on middle-aged populations, and studies evaluating ET or ETD in older but not obese adults.

Ninety-three potentially relevant papers were selected. Two authors independently evaluated them based on the inclusion criteria. This resulted in the additional exclusion of 63 studies. Thirty of the originally eligible studies were selected for detailed evaluation of the full text. After exclusion of four more papers based on the unanimous judgment of the two authors, 26 studies were selected for review (see Figure 1).

**Data extraction**

The selected studies were sorted according to authors and year, sample, age, BMI, study design, purpose, protocol type and outcomes. The studies were divided into two groups: ET (Table 1) and ETD (Table 2).

**Results**

**General findings**

In this review, we evaluate the impact of endurance training alone (ET) or combined with diet (ETD) in obese patients over 60 on health. This age group often presents significant chronic conditions or geriatric syndromes such as cardio-respiratory risk factors, metabolic disorder and alteration in body composition.

Twenty-six recent controlled trial studies (10 studies for ET and 16 studies for ETD) were identified for the review (Tables 1 and 2, respectively).

**Effects of endurance training alone or combined with diet on health outcomes**

**Effects on cardio-respiratory fitness**

Obesity is related to an increased risk of many chronic diseases, especially cardiovascular heart diseases (12). Indeed, there is compelling evidence that aerobic fitness in older obese people reduces mortality as well as cardiovascular disease (CVD) and improves health status (25). In fact, the maximum volume of oxygen (VO₂max) declines with ageing and a value of 15–18 ml/kg/min must be maintained to be independent for daily activity (26). Thus, the benefit of ET or ETD on the VO₂max among older obese patients is well established.

Concerning the effect of ET, 8 of 10 studies were conducted. In these studies, older obese subjects had to be able to participate in a high intensity endurance programme. Thus, they were in some regard
selected accordingly, and were generally healthy and well-motivated people without significant orthopaedic diseases and comorbidities. Indeed, Katzel et al. (27) noted after moderate endurance programme a 17% increase in the VO\textsubscript{2max}. Similarly, Gillett and Caserta (28) reported in older obese patients an increase of 34% of VO\textsubscript{2max} after 48 exercise sessions of endurance training. Older obese subjects with a lower baseline VO\textsubscript{2max} appear to have the greatest improvement in VO\textsubscript{2max} (21%, p < 0.001) after ET, as shown by Savage et al. (29). Moreover, some data suggest that ET in obese people over 60 results in a 14% increase in the VO\textsubscript{2max} (17). In two small studies, Coker et al. (30,31) observed a respective increase of 14% and 21% in VO\textsubscript{2max} as the result of ET programme. Snijders et al. (32) also observed an 11% increase in VO\textsubscript{2max} in obese patients with type 2 diabetes (T2D), after walking or cycling ET. Conversely, only Kirwan et al. (33), reported no significant change on VO\textsubscript{2max} in older obese patients with T2D after a short term of ET.

Concerning the effect of ETD, 15 of 16 studies were conclusive in this review. Indeed, a recent study conducted by Hays et al. (34) reported that with
### Table 1  Summary of endurance training for older obese patients

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Sample</th>
<th>Mean age (years)</th>
<th>Mean BMI (kg/m²)</th>
<th>Study design</th>
<th>Purpose</th>
<th>Protocol type</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Gillett and Caserta, 1996 (28)</td>
<td>164</td>
<td>64.4 ± 3.0</td>
<td>32.0 ± 4.0</td>
<td>Randomised controlled trial</td>
<td>Test the effects of aerobic training on aerobic power, and body composition, of older, obese women</td>
<td>Exercise training on cycle ergometer 60–70% of HRR, 12 min/session, 3 sessions/week, 16 weeks</td>
<td>Endurance training group: ↑ in the VO₂max (from 24.1 to 23.2 ml/kg/min), ↓ in the BMI (from 30.8 to 29.9 kg/m²), ↓ in the % of body fat (from 40.4 to 38.0%). Control group: ↔ at any parameters.</td>
</tr>
<tr>
<td>Tessier et al. 2000 (57)</td>
<td>39</td>
<td>69.3 ± 4.2</td>
<td>30.7 ± 5.4</td>
<td>Randomised controlled trial</td>
<td>Determine the impact of aerobic exercise programme in of older obese with T2D in relation to metabolic control, and body composition</td>
<td>Rapid walk 35–59% to 60–79% of HRmax, 20 min/session, 3 sessions/week, 16 weeks</td>
<td>Endurance training group: ↔ in body weight and BMI, ↔ in HbA1c, FPG and FPI, ↓ in total daily caloric intake (from 1746 ± 583 to 1544 ± 498 kcal). † in the attitudes towards diabetes (from 3.43 ± 0.44 to 3.55 ± 0.41). Control group: ↔ at any parameters.</td>
</tr>
<tr>
<td>Coker et al. 2006 (30)</td>
<td>21</td>
<td>73 ± 2</td>
<td>31 ± 1</td>
<td>Randomised controlled trial</td>
<td>Examined the influence of HI endurance training on ISGD in the elderly people</td>
<td>Exercise training on cycle ergometer 75% of VO₂max, 40 min/session, 4–5 sessions/week, 12 weeks</td>
<td>Endurance training group: ↑ in the VO₂max (from 1.4 ± 0.3 to 1.6 ± 0.1 l/min), ↑ in maximum power (from 111 ± 3 to 143 ± 11 W), ↑ in ISGD (5.0 ± 0.6 to 6.4 ± 0.5 mg/kg FFMin/min), ↑ in non-oxidative glucose disposal (4.6 ± 0.6 to 6.0 ± 0.8 mg/kg FFMin/min), ↔ in body weight, BMI and % of body fat. Control group: ↔ at any parameters.</td>
</tr>
<tr>
<td>Coker et al. 2009 (31)</td>
<td>6</td>
<td>73 ± 2</td>
<td>30 ± 1</td>
<td>Randomised controlled trial</td>
<td>Determine the efficacy of HI endurance training on the reduction in regional fat deposits and favourable changes in VO₂max in older, obese adults</td>
<td>Exercise training on cycle ergometer 75% of VO₂max, 40 min/session, 4–5 sessions/week, 12 weeks</td>
<td>Endurance training group: ↑ in the VO₂max (from 1.4 ± 0.1 to 1.7 ± 0.2 ml/kg/min). ↔ in body weight, BMI, and % of body fat. ↓ in visceral fat (−39 ± 11 cm², p &lt; 0.05), ↑ in thigh muscle attenuation (−18 ± 10 cm², p &lt; 0.05). ↔ in plasma adiponectin. Control group: ↔ at any parameters.</td>
</tr>
<tr>
<td>Snijders et al. 2010 (32)</td>
<td>15</td>
<td>61 ± 6</td>
<td>30.9 ± 0.8</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the impact of aerobic exercise programme in the treatment of older obese with T2D in relation to metabolic control, and body composition</td>
<td>Walking, cycling 75% of VO₂max, 40 min/session, 3 sessions/week, 24 weeks</td>
<td>Endurance training group: ↑ in the maximal workload capacity (from 168 ± 8 to 186 ± 9 W). ↑ in the VO₂max (from 21.7 ± 1.4 to 25.7 ± 1.5 ml/kg/min). ↓ in the body weight (from 92.8 ± 2.5 to 90.9 ± 2.5 kg). ↓ in the % body fat (from 33.9 ± 1.5 to 31.4 ± 1.1%). ↓ in the BMI (from 30.9 ± 0.8 to 30.2 ± 0.8 kg/m²). ↓ in HbA1c levels (from 7.0 ± 0.3 to 6.4 ± 0.2%). ↔ in FPG and FPI concentrations.</td>
</tr>
<tr>
<td>Author, year</td>
<td>Sample</td>
<td>Mean age (years)</td>
<td>Mean BMI (kg/m²)</td>
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<td>Outcomes</td>
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<td>Katzel et al. 1995 (27)</td>
<td>44</td>
<td>61.1 ± 1</td>
<td>30.4 ± 0.4</td>
<td>Randomised controlled trial</td>
<td>Compare the effects of dietary restraint vs. aerobic exercise training on coronary artery disease risk factors in obese older men</td>
<td>Exercise training on cycle ergometer 50–60% to 70–80% of HRR 30–45 min/session three session/week, 36 weeks</td>
<td>Endurance training group: ↑ in the VO₂max (+ 7.0 ± 0.8 ml/kg/min). ↓ in the % of body fat (from 30.0 to 29.2%). ↓ in the TG levels by 9% (p &lt; 0.01). ↑ in the HDL-C levels by 5% (p &lt; 0.05). ↔ in the TC and LDL-C levels. ↓ in the SBP by 3% (p &lt; 0.001). ↓ in the DBP by 8% (p &lt; 0.001). Dietary restraint group: ↔ in the VO₂max ↓ in the body weight (from 94.3 ± 1.3 to 84.8 ± 0.7). ↓ in the TG levels by 18% (p &lt; 0.001). ↓ in the LDL-C levels by 7% (p &lt; 0.05). ↑ in the HDL-C levels by 13% (p &lt; 0.001). ↔ in the TC levels. ↓ in the SBP by 2% (p &lt; 0.001). ↓ in the DBP by 8% (p &lt; 0.001). ↔ in VO₂max, BMI, and % of body fat. A decreasing trend in FPG concentration (117 ± 4 to 111 ± 3 mg/dl). ↓ in FPI concentration (12.9 ± 2.4 to 9.8 ± 1.8 µl/ml).</td>
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<tr>
<td>Kirwan et al. 2009 (33)</td>
<td>14</td>
<td>64 ± 2</td>
<td>31.9 ± 2.2</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the effect of exercise training on insulin action in obese older patients with T2D</td>
<td>Treadmill walking and stationary cycling 80–85% of HRmax, 50–60 min/session 1 session/day, 7 days</td>
<td>Endurance training group: ↑ in VO₂max (from 22.1 ± 5.3 to 26.9 ± 5.6 ml/kg/min). ↓ in the body weight (from 94.7 ± 10.5 to 90.1 ± 8.2 kg). ↓ in the BMI (from 31.0 ± 3.1 to 29.8 ± 2.7 kg/m²). ↓ in the % of body fat (from 30.0 ± 6.5 to 27.1 ± 6.7%). ↓ in the fat mass (from 27.0 ± 6.7 to 23.4 ± 6.0 kg). ↓ in the WC (from 109.2 ± 26.7 to 103.6 ± 6.4 cm). ↓ in the TG levels (from 232.7 ± 116.0 to 177.5 ± 56.2 mg/dl). ↓ in the TC/HDL-C (from 5.6 ± 0.9 to 4.8 ± 1.3 mg/dl). ↔ in TC, LDL-C, and HDL-C levels. ↓ in FPG concentration (from 13.0 ± 4.6 to 10.1 ± 4.6 µl/ml). ↔ in FPG concentrations.</td>
</tr>
<tr>
<td>Savage et al. 2003 (29)</td>
<td>15</td>
<td>62.5 ± 9.7</td>
<td>31.0 ± 3.1</td>
<td>Non-Randomised controlled trial</td>
<td>Evaluate the value of exercise training without dietary modification, on measures of body composition, and exercise capacity</td>
<td>Walking exercise 50–60% of VO₂max 60–90 min/session 5–7 sessions/week, 16 weeks</td>
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</table>
Table 1

<table>
<thead>
<tr>
<th>Author, year</th>
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<th>Mean age (years)</th>
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<tr>
<td>Martins et al. 2010</td>
<td>45</td>
<td>76.2 ± 7.4</td>
<td>30.1 ± 4.7</td>
<td>Randomised controlled trial</td>
<td>Investigate the effects of regular aerobic training vs. strength training in the lipid profile and body composition of an elderly obese population</td>
<td>Endurance training group: ↓ in the WC (from 93.3 ± 9.9 to 90.0 ± 8.6 cm). ↔ in BMI and in body weight. ↔ in TC, LDL-C and HDL-C levels. Strength training group: ↓ in the WC (94.6 ± 10.8 to 92.3 ± 10.9). ↔ in BMI and in body weight. ↑ in the HDL-C levels (from 52.6 ± 10.0 to 57.3 ± 14.0 mg/dl). ↔ in TC, LDL-C levels. ↑ in VO₂max (from 21.3 ± 0.8 to 24.3 ± 1.0 ml/kg/min). ↓ in the body weight (from 94.1 ± 4.3 to 90.9 ± 4.0). ↓ in the fat mass (from 38.8 ± 2.0 to 35.4 ± 2.2 kg). ↓ in the BMI (from 33.2 ± 1.4 to 32.1 ± 1.3 kg/m²). ↓ in the total abdominal fat (from 525.4 ± 40.3 to 442.5 ± 33.9 cm²). ↓ in the visceral fat (from 175.6 ± 20.2 to 136.2 ± 16.9 cm²). ↓ in the subcutaneous fat (from 351.4 ± 34.1 to 304.8 ± 27.7 cm²). ↔ in FFM. ↓ in the TC levels (from 202.9 ± 9 to 186 ± 8 mg/dl). ↓ in the TG levels (from 195 ± 26 to 164 ± 19 mg/dl). ↓ FPI concentrations (from 20.8 ± 2.7 to 16.7 ± 1.8 µU/ml). ↔ in FPG concentrations. ↔ in plasma adiponectin, leptin and in TNF-α.</td>
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<tr>
<td>O’Leary et al. 2005</td>
<td>16</td>
<td>63 ± 1</td>
<td>33.2 ± 1.4</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the effect of endurance training on glucose metabolism, abdominal adiposity and fitness in obese elderly people</td>
<td>Cycling or treadmill exercise 60–65% to 80–85% of HRmax, 50–60 min/session, 5 sessions/week, 12 weeks</td>
<td>VO₂max, maximum volume of oxygen; HRR, heart rate reserve; BMI, body mass index; HRmax, maximal heart rate; T2D, type 2 diabetes; FPG, fasting plasma glucose; FRI, fasting plasma insulin; HI, high intensity; ISGD, insulin-stimulated glucose disposal; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein; HDL-C, high-density lipoprotein; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference; FFM, free fat mass; TNF-α, tumour necrosis factor-α; †, significant improvement within group; ↓, significant decrease within group; ↔, no change within group.</td>
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</table>
ETD, older obese patients had a significantly higher VO$_{2\text{max}}$ compared to those with only dietary restrictions (DR) (25% vs. 15%). Yassine et al. (36), Amati et al. (37) and O’Leary et al. (38) reported 10%, 13% and 16% increases in VO$_{2\text{max}}$ respectively, after 12 weeks of ETD. Usually the type of diet used with exercise does not affect the improvement of cardio-respiratory performance. Indeed, three recent studies (38–40) reported that older obese subjects with a low-glycaemic index (LGI) diet combined with endurance training (LoGIX group) had approximately the same tendency of increase of the VO$_{2\text{max}}$ (from 1% to 25.5%), compared to those with a high-glycaemic index (HGI) diet combined with endurance training (the HiGIX group, from 5% to 24.1%). Recent research conducted by Ryan et al. (41–43) showed that 24 weeks of ETD improved cardio-respiratory fitness by increasing the VO$_{2\text{max}}$ from 7% to 14%. Using data from two non-randomised studies including older obese patients, Nicklas et al. (44) and Ryan et al. (45) observed a 9% and 11% increase in VO$_{2\text{max}}$ respectively, after ETD. Three other studies (46–48) reported a 6%, 11% and 12% increase in VO$_{2\text{max}}$ respectively, in older obese patients, following ETD programme.

Overall, therefore, ET or ETD does have a positive effect on cardio-respiratory performances in older obese patients.

**Effects on body mass loss and body composition**

Cross-sectional and longitudinal studies have shown that body composition changes with ageing, with an increase in fat mass and a decrease in muscle mass (49–51). Even without body weight changes, the amount of fat significantly increase with age (52). It has been shown that, in both men and women, both of normal weight and obese subjects, body weight tends to increase, peaking at about age 60 in men and later in women, and then decreasing with further ageing (53).

Several studies have shown that endurance training leads to a significant improvement in the body composition of older obese patients.

In particular, ET has been shown to reduce adipose tissue mass, which resulted in significant weight loss (54). Specifically, 16-week of ET at 50–60 of VO$_{2\text{max}}$ showed a significant reduction in multiple adiposity outcomes in older obese [i.e., total body mass (−4.9%), BMI (−3.5%), waist circumference (−5%), fat mass (−13.3%) and percentage of body fat (−9.7%), all p < 0.001] (29). Sniiders et al. (32) reported a significant decrease in total body mass, BMI and percentage of body fat (−2.5%, −2.3% and −7.4%, all p < 0.05) after 24 weeks of ET. O’Leary et al. (17) reported, in 16 older obese subjects, a significant reduction in body weight (−3.4%, p < 0.0001), in BMI (−3.3%, p < 0.0001) and in fat mass (−8.8%, p < 0.005), whereas they did not report any significant alteration in fat-free mass. In the same study a significant decrease in total abdominal fat (−15.8, p < 0.05), subcutaneous fat (−13.3%, p < 0.05) and visceral fat (−22.4%, p < 0.0001), were also found after 60 exercise sessions of ET programme at 60–85% of maximal heart rate (HR$_{\text{max}}$). However, evidence suggests that the aforementioned exercise-induced adaptations can also occur independently of weight loss (55). For example, 36 weeks of aerobic exercise in obese older men significantly reduced the percentage of body fat by 3% (p < 0.005) without an overall loss in body weight (27). A 16-week of ET in older obese women led to reductions in the percentage of body fat (−5.9%, p < 0.05) and in BMI (−2.5%, p < 0.01) in the intervention group, without a reduction in body weight (28). Martins et al. (56) reported a significant decrease in waist circumference (−3.54%, p < 0.05), without a reduction in body weight, after 16 weeks of ET. Conversely, only three randomised studies did not report any significant change in body composition after 12 weeks of ET through cycle ergometer (30,31) and after 16 weeks of ET through rapid walking (57). Likewise, one non-randomised study did not report any significant change in body composition after a short term of ET (33).

Although exercise alone plays a critical role in weight maintenance (58), when exercise is combined with appropriate dietary restrictions, a larger weight loss is reported (59). Indeed, it has been suggested that the most effective weight-loss programmes should include a combination of diet, exercise and behavioural modifications (60–62). A recent study conducted by Nicklas et al. (44) reported that 24 weeks of ETD in obese older women led to a significant decrease in body weight (−8.2%, p < 0.001), and in percentage of body fat (−9.2%, p < 0.01) with no significant change in the fat-free mass (FFM). These authors also observed a significant decrease in the intra-abdominal area (−13.9%, p < 0.05) and in the subcutaneous fat area (−17%, p < 0.01). In four recent research projects, Ryan et al. (41–43,45) studied the relationship between ETD and body composition in older obese subjects. In the first three studies (41–43) 24 weeks of ETD, resulted in 7–9% decrease in body weight accompanied by a 3–9% reduction in BMI, a 4–12% reduction in the percentage of body fat and a 4–18% reduction in fat mass. In the remaining study (45), 12 weeks of ETD resulted in an 8% decrease in body weight accompanied by a 9% reduction in BMI and a 15% reduction in fat mass (all,
Health benefits of endurance training for obese patients over 60

ETD leads to a greater decrease in body composition than ET [(body weight: -7.4% vs. -3.8%, p = 0.02), (BMI: -7.1% vs. -3.7%, p = 0.01), (fat mass: -16% vs. -10.8%, p < 0.001), (waist circumference: -4.7% vs. -5.7%, p < 0.001), (visceral fat: -17.6% vs. -16.8%, p < 0.001) and (subcutaneous fat: -9.2% vs. -15.5%, p < 0.001)]. On the other hand, Solomon et al. (46) reported that ETD programme in older obese adults leads to a greater improvement in body composition than the DR programme (body weight: -7.7% vs. -3.3%, p < 0.01), BMI (-7.9% vs. -3.7%, p < 0.01) and (fat mass: -14.9% vs. -4.6%, p < 0.01). Similarly, Chomentowski et al. (63) reported that ETD programme in older adults, resulted in a greater reduction in fat mass (-19.6% vs. -16%, p < 0.001) and in percentage of body fat (-13% vs. -8%, p < 0.001) than DR programme. The same study also found that older obese adults with ETD had a significantly lower FFM than those with only DR (-4.3%, p < 0.007, vs. -1.1%, p = 0.075). Finally, Hays et al. (34) reported the same tendency in older obese adults with greater improvement in body composition in EDT group than in DR group (body weight: -5% vs. 3%, p < 0.001), in BMI (-2% vs. -1.1%, p < 0.001), in % of body fat (-4%, p < 0.001 vs. -2.5%, p < 0.01) and in tissue area of thigh fat (-15% vs. -10%, p < 0.001).

Overall, these data suggest that ET and ETD are important when designing weight management strategies in obese adults over 60.

Effects on blood pressure values

Inactivity is associated with an increased risk (30–50%) of developing high blood pressure in older obese patients. There is robust evidence for the benefits of aerobic activity alone or combined with diet on blood pressure values (26,64). In a recent study involving 44 obese subjects, Katzel et al. (27) reported that aerobic exercise is associated with a lowering of both systolic blood pressure (SBP) by 3% and diastolic blood pressure (DBP) by 2%. However, evidence shows that the benefits of ET or ETD on blood pressure in older subjects are less consistent. In a small randomised trial on healthy normotensive older obese, Yassin et al. (35) reported a significant decrease in both SBP and DBP by 11% after ETD and by 11% and 12%, respectively after ET. Solomon et al. (40) observed, that the LoGIX group had a significantly lower decrease in SBP (-8.4% vs. -1.4%) than the HiGIX group. However, no significant effects were found on resting DBP in either group. Finally, in another study including older obese subjects, Solomon et al. (38) observed a significant reduction in resting SBP in both LoGIX and HiGIX groups in older obese adults following ETD, compared with older obese adults who did ET. Twelve weeks of ETD in older obese subjects led to a greater decrease in body weight (8.1% vs. 3.4%, p < 0.0001), in BMI (-7.9% vs. -3.5%, p < 0.0001) as well as in fat mass (FM; -16%, p < 0.001 vs. -3.3%, p < 0.05), compared with ET (37). However, the FFM decreased significantly only in the ET group (-2.9%, p < 0.03) (37). Similarly, in 64 older obese individuals, Amati et al. (36) observed a greater significant decrease in ETD group than in ET group, in BMI (-26% vs. -4.3%; p < 0.05, respectively), and in FM (-48% vs. -11.5%; p < 0.05, respectively), however, the FFM decreased only in the ET group (-3%, p < 0.05). Solomon et al. (48) showed that body composition was significantly improved in older obese patients following ETD, as compared with those who did ET [(body weight: -8.3%; p < 0.001 vs. -3.7%; p < 0.01), (BMI: -8.3%; p < 0.001 vs. -3.6%; p < 0.01), (fat mass: -16%; p < 0.01 vs. -5.2%; p < 0.05) and (waist circumference: -5.3%; p < 0.01 vs. -3.4%; p < 0.05)]. Yassin et al. (35) confirmed the same tendency, and concluded that...
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<th>Author, year</th>
<th>Sample</th>
<th>Mean age (years)</th>
<th>Mean BMI (kg/m²)</th>
<th>Study design</th>
<th>Purpose</th>
<th>Protocol type</th>
<th>Outcomes</th>
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<tbody>
<tr>
<td>Solomon et al. 2009 (46)</td>
<td>16</td>
<td>66 ± 1</td>
<td>34.0 ± 1.4</td>
<td>Randomised controlled trial</td>
<td>Investigate the effect of 12 weeks of exercise training with and without caloric restriction on body composition, metabolic parameters and lipid profile</td>
<td>Aerobic exercise training 65% of VO&lt;sub&gt;2max&lt;/sub&gt; 60 min/session, 5 sessions/week, 12 weeks, Hypocaloric Diet: reduction of 500 kcal/day</td>
<td>Endurance training + diet group: ↑ in the VO&lt;sub&gt;2max&lt;/sub&gt; (from 1.80 ± 0.16 to 1.90 ± 0.11 l/min). ↓ in the body weight (from 88.4 ± 4.6 to 81.7 ± 4.4 kg). ↓ in the fat mass (from 36.0 ± 3.7 30.9 ± 3.7 kg). ↓ in the BMI (from 32.8 ± 1.8 to 30.2 ± 1.7 kg/m²). ↓ in the TG levels (from 209.3 ± 25.4 to 170.7 ± 27.5 mg/dl). ↓ in the TC (from 222.9 ± 12.3 to 194.7 ± 10.6 mg/dl). ↓ in FPI concentration (from 16.3 ± 1.3 to 12.9 ± 1.3 lU/ml). ↔ in FPG concentration. ↓ in plasma leptin (18.5 ± 4.8 to 13.6 ± 3.0 ng/ml). Endurance training group: ↑ in the VO&lt;sub&gt;2max&lt;/sub&gt; (from 1.83 ± 0.12 to 1.99 ± 0.13 l/min). ↓ in the body weight (from 96.0 ± 6.1 to 92.8 ± 6.0 kg). ↓ in the fat mass (from 42.2 ± 3.3 40.3 ± 3.5 kg). ↓ in the BMI (from 35.3 ± 2.1 to 34.0 ± 1.9 kg/m²). ↓ in the TG levels (from 196.8 ± 44.7 to 167.9 ± 25.4 mg/dl). ↓ in the TC (from 209.4 ± 9.5 to 203.0 ± 10.4 mg/dl). ↓ in FPI concentration (from 24.9 ± 6.2 to 18.3 ± 3.9 lU/ml). ↔ in FPG concentration. ↓ in plasma leptin (25.8 ± 5.6 to 23.3 ± 5.0 mg/ml).</td>
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<tr>
<td>Solomon et al. 2010 (38)</td>
<td>22</td>
<td>66 ± 1</td>
<td>34.4 ± 0.8</td>
<td>Randomised controlled trial</td>
<td>Examine the effect of a LoGIX vs. HiGIX on glucose metabolism and insulin secretion in obese, pre-diabetic individuals</td>
<td>Exercise training on treadmill walking and cycle ergometry, 85% of HR&lt;sub&gt;max&lt;/sub&gt; 60 min/session, 5 sessions/week, 12-week Diet: low-GI diet or high-GI diet</td>
<td>LoGIX group: ↑ in the VO&lt;sub&gt;2max&lt;/sub&gt; (20.4 ± 1.1 to 25.6 ± 2.1 ml/kg/min). ↓ in the body weight (from 97.4 ± 3.8 to 92.8 ± 3.4 kg). ↓ in the fat mass (from 46.8 ± 2.0 to 40.0 ± 2.2 kg). ↓ in the BMI (from 34.9 ± 1.1 to 32.1 ± 1.3 kg/m²). ↓ in the FFM (from 49.9 ± 2.9 to 49.7 ± 2.8 kg). ↓ in the SBP (from 127 ± 3 118 ± 2 mmHg). ↓ in the DBP (from 76 ± 3 73 ± 2 mmHg). ↓ in the TG levels (from 164.2 ± 26.1 to 110.9 ± 12.2 mg/dl). ↓ in the TC (from 214.6 ± 11.3 to 183.5 ± 9.6 mg/dl). ↓ in the LDL-C levels (from 128.5 ± 9.1 to 111.1 ± 9.7 mg/dl). ↔ HDL-C levels. ↓ in the VLDL-C levels (from 32.8 ± 5.3 to 22.1 ± 2.4 mg/dl). ↓ in FPI concentration (from 24.6 ± 4.8 to 14.2 ± 2.4 IU/ml). ↓ in FPG concentration (from 101.1 ± 2.3 to 97.6 ± 1.5 mg/dl). HiGIX group: ↑ in the VO&lt;sub&gt;2max&lt;/sub&gt; (from 23.2 ± 1.9 28.8 ± 1.8 ml/kg/min). ↓ in the body weight (from 94.7 ± 4.4 to 85.7 ± 4.1 kg). ↓ in the fat mass (from 42.0 ± 2.2 to 36.1 ± 2.9 kg). ↓ in the BMI (from 33.2 ± 1.4 to 32.1 ± 1.3 kg/m²). ↓ in the FFM (from 55.2 ± 3.6 to 53.9 ± 3.5 kg). ↓ in the SBP (from 133 ± 5 119 ± 4 mmHg).</td>
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<td>Author, year</td>
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<td>Ryan et al. 2014 (45)</td>
<td>65</td>
<td>63.0</td>
<td>33 ± 1</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the effects of aerobic exercise combined with diet on body composition in obese older women</td>
<td>Exercise training on treadmill, 50–60% to 85% of HRR, 45 min/session, 3 sessions/week, 12-week Diet: reduction of 350–500 kcal/day</td>
<td>↓ in the DBP (from 79 ± 3 to 71 ± 3 mmHg). ↓ in the TG levels (from 129.8 ± 18.9 to 89.0 ± 14.2 mg/dl). ↓ in the TC (from 207.3 ± 8.3 to 181.2 ± 9.2 mg/dl). ↔ in TC, LDL-C, and HDL-C levels. ↓ in the LDI-L levels (from 131.6 ± 6.7 to 116.4 ± 7.8 mg/dl). ↓ in the VLDL-L levels (from 25.9 ± 3.8 to 17.8 ± 2.8 mg/dl). ↓ in FPI concentration (from 20.9 ± 6.4 to 9.2 ± 1.2 lU/ml). ↓ in FPG concentration (from 96.7 ± 2.0 to 90.8 ± 1.7 mg/dl). ↑ in the VO₂max. ↑ in the VO₂max (from 1.77 ± 0.07 to 1.97 ± 0.08 l/min). ↑ in the body weight (from 84 ± 2 to 77 ± 2 kg). ↓ in the BMI (from 32 ± 1 to 29 ± 1 kg/m²). ↓ in the fat mass (from 39.9 ± 1.6 to 33.8 ± 1.6 kg). ↓ in the WC (from 95 ± 2 to 90 ± 2 cm). ↓ in the FFM (from 45.0 ± 1.0 to 44.1 ± 0.8 kg). ↑ in the % of body fat. ↓ in the TC (from 193.4 ± 10.4 to 177.4 ± 9.3 mg/dl). ↓ in FPI concentration (from 21.9 ± 3.5 to 16.0 ± 2.0 μU/ml). ↔ in FPG concentration. ↑ in insulin sensitivity (from 2.37 ± 0.37 to 3.28 ± 0.52 mg/kg/min). ↔ in TNF-α.</td>
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<tr>
<td>Kirwan et al. 2009 (47)</td>
<td>11</td>
<td>62 ± 2</td>
<td>33.2 ± 2.0</td>
<td>Non-Randomised controlled trial</td>
<td>Assess the combined effects of exercise and dietary glycaemic load on insulin resistance in older obese adults</td>
<td>Exercise training on a treadmill and stationary cycling 55–60% of HRmax 50–60 min/session 5 sessions/week, 12 weeks Diet: dietary glycaemic load</td>
<td>↓ in the TC (from 207.3 ± 8.3 to 181.2 ± 9.2 mg/dl). ↓ in the FPG concentration. ↓ in FPG concentration (from 96.7 ± 2.0 to 90.8 ± 1.7 mg/dl). ↑ in the VO₂max. ↑ in the VO₂max (from 1.77 ± 0.07 to 1.97 ± 0.08 l/min). ↑ in the body weight (from 84 ± 2 to 77 ± 2 kg). ↓ in the BMI (from 32 ± 1 to 29 ± 1 kg/m²). ↓ in the fat mass (from 39.9 ± 1.6 to 33.8 ± 1.6 kg). ↓ in the WC (from 95 ± 2 to 90 ± 2 cm). ↓ in the FFM (from 45.0 ± 1.0 to 44.1 ± 0.8 kg). ↑ in the % of body fat. ↓ in the TC (from 193.4 ± 10.4 to 177.4 ± 9.3 mg/dl). ↓ in FPI concentration (from 21.9 ± 3.5 to 16.0 ± 2.0 μU/ml). ↔ in FPG concentration. ↑ in insulin sensitivity (from 2.37 ± 0.37 to 3.28 ± 0.52 mg/kg/min). ↔ in TNF-α.</td>
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<td>Hays et al. 2004 (34)</td>
<td>34</td>
<td>66 ± 1</td>
<td>30.8 ± 1.1</td>
<td>Randomised controlled trial</td>
<td>Examine the effect of a HI-CHO diet alone and in combination with aerobic exercise training on body weight composition in older obese with impaired glucose tolerance</td>
<td>Exercise training on cycle ergometer 80–85% of HRmax 45 min/session, 4 sessions/week, 14 weeks HI-CHO Diet: an isoenergetic mixed diet</td>
<td>↓ in the body weight (−5%, p &lt; 0.001). ↓ in the fat mass (−4%, p &lt; 0.001). ↓ in the BMI (−2%, p &lt; 0.001). HI-CHO diet group: ↓ in the body weight (−5%, p &lt; 0.001). ↓ in the fat mass (−4%, p &lt; 0.001). ↓ in the BMI (−2%, p &lt; 0.001).</td>
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<td>O’Leary et al. 2007 (37)</td>
<td>21</td>
<td>67.4 ± 1.3</td>
<td>34.0 ± 1.4</td>
<td>Randomised controlled trial</td>
<td>Determine the effect of exercise + diet intervention on body composition in elderly obese people</td>
<td>Aerobic exercise training 80–85% of HRmax 60 min/session, 5 sessions/week, 12 weeks Hypocaloric Diet: reduction of 500 kcal/day</td>
<td>↑ in the VO₂max. ↑ in the VO₂max (from 20.9 ± 1.0 to 24.7 ± 0.9 ml/kg/min). ↓ in the body weight (from 97.1 ± 4.7 to 89.3 ± 4.1 kg). ↓ in the fat mass (from 38.7 ± 2.8 to 32.6 ± 2.6 kg). ↓ in the FFM (from 58.4 ± 3.6 to 56.7 ± 3.4 kg). ↓ in the BMI (from 34.0 ± 1.4 to 31.3 ± 1.3 kg/m²).</td>
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<td>Author, year</td>
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<td>Outcomes</td>
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<td>Nicklas et al. 1997 (44)</td>
<td>20</td>
<td>61 ± 2</td>
<td>31</td>
<td>Non-Randomised controlled trial</td>
<td>Examine the effect of low-intensity endurance training combined with diet in body composition in postmenopausal obese women</td>
<td>Exercise training on treadmill walking 50–50 to 65–70% of HRR 20 to 45–60 min/session 3 sessions/week, 24 weeks, Hypocaloric Diet: reduction of 250–350 kcal/day</td>
<td>↑ in the VO₂max (from 20.6 ± 0.8 to 22.9 ± 0.8 ml/kg/min). ↓ in the body weight (from 97.1 ± 4.7 to 89.3 ± 4.1 kg). ↓ in the fat mass (from 42.0 ± 3.3 to 40.6 ± 3.5 kg). ↓ in the BMI (from 34.6 ± 1.9 to 33.4 ± 1.7 kg/m²). ↔ in the FFM. ↔ in plasma adiponectin.</td>
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<tr>
<td>Chomentowski et al. 2009 (63)</td>
<td>29</td>
<td>67.2 ± 4.2</td>
<td>31.8 ± 3.3</td>
<td>Randomised controlled trial</td>
<td>Examine the effects of dietary restraint alone and in combination with moderate aerobic exercise, on skeletal muscle mass in older adults</td>
<td>Exercise training: treadmill or walking or cycling 65–75% of HRmax 45 min/session 5 session/week, 16 weeks Diet: a caloric restriction of 500–1000 kcal/day</td>
<td>Endurance training + diet group: ↑ in the VO₂max (from 1.63 ± 0.06 to 1.78 ± 0.06 l/min). ↓ in the body weight (from 80.6 ± 3.0 to 74.0 ± 3.1 kg). ↓ in the % of body fat (from 47.9 ± 1.5 to 43.5 ± 1.9%). ↔ in the FFM. ↓ in the intra-abdominal area (from 151 ± 10 to 130 ± 9 cm²). ↓ in the subcutaneous fat area (from 451 ± 36 to 374 ± 28 cm²).</td>
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<td>Amati et al. 2008 (36)</td>
<td>64</td>
<td>67 ± 0.5</td>
<td>30.7 ± 0.4</td>
<td>Randomised controlled trial</td>
<td>Determine the effect of exercise training alone or combined with diet on body composition for elderly obese patients</td>
<td>Aerobic exercise training 75% of VO₂max 45 min/session 3–5 session/week, 16 weeks Diet: a caloric restriction of 500–1000 kcal/day</td>
<td>Endurance training group: ↑ in the VO₂max (+4.3 ± 3.2 ml/kg/min). ↓ in the body weight (+10.4 ± 2.1 kg). ↓ in the FFM (+1.5 ± 0.5 kg). ↓ in the BMI (−8.6 ± 0.8 kg/m²). Endurance training group: ↑ in the VO₂max (+10.4 ± 2.1 ml/kg/min). ↓ in the body weight (−3.6 ± 1.1 kg). ↓ in the FFM (−1.3 ± 0.4 kg/m²). ↔ in the FFM.</td>
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<td>Ryan et al. 1998 (41)</td>
<td>30</td>
<td>63 ± 6</td>
<td>30.5 ± 2.8</td>
<td>Non-Randomised controlled trial</td>
<td>Examine the effects of aerobic training and diet on body composition in older obese women</td>
<td>Exercise training in jogging or walking on treadmill 50–60% of HRR to 70% of VO₂max, 35 min/session, 3 sessions/week, 24-week Diet: restrict caloric intake by 250–350 kcal/day</td>
<td>↑ in the VO₂max (+0.13 ± 0.06 l/min), ↓ in the body weight (−6.6 ± 2.2 kg), ↓ in the BMI (−2.6 ± 0.9 kg/m²), ↓ in the fat mass (−4.0 ± 2.5 kg).</td>
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<td>Haus et al. 2011 (39)</td>
<td>15</td>
<td>66 ± 1</td>
<td>33 ± 1</td>
<td>Randomised controlled trial</td>
<td>Assess the effects of exercise and diet intervention on insulin sensitivity in older obese adults</td>
<td>Exercise training: treadmill walking and cycle ergometry 80–85% of HR max 60 min/session 1 session/day, 1-week Diet: low-GI diet or high-GI diet</td>
<td>↑ in the VO₂max (+1.2 ± 0.7 ml/kg/min, p &lt; 0.004), ↓ in the body weight (−1.7 ± 0.6 kg, p &lt; 0.0005), ↓ in the BMI (−0.6 ± 0.2 kg/m², p &lt; 0.0004), ↓ in the FPI (−3.8 ± 1.6 U/ml, p &lt; 0.02).</td>
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<td>Ryan et al. 2014 (42)</td>
<td>14</td>
<td>63 ± 2</td>
<td>32.0</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the effects of aerobic exercise training + diet on body composition and insulin sensitivity in older, obese insulin-resistant men</td>
<td>Exercise training on treadmills, 50–70% of VO₂max 20–30 to 45–50 min/session, 3 sessions/week, 24-week Hypocaloric diet: restrict caloric intake by 500 kcal/day</td>
<td>↑ in the VO₂max (from 1.97 ± 0.09 to 2.19 ± 0.13 l/min), ↓ in the body weight (from 97.8 ± 3.7 to 89.2 ± 3.7 kg), ↓ in the BMI (from 31.7 ± 1.0 to 29.0 ± 1.1 kg/m²), ↓ in the % of body fat (from 34.1 ± 2.0 to 29.9 ± 2.3%), ↓ in the WC (from 106.7 ± 3.0 to 98.8 ± 3.2 cm), ↓ in the FFM (from 63.7 ± 1.4 to 62.6 ± 1.7 kg).</td>
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<tr>
<td>Ryan et al. 2013 (43)</td>
<td>33</td>
<td>61 ± 1</td>
<td>31 ± 1</td>
<td>Non-Randomised controlled trial</td>
<td>Determine the effect of aerobic exercise training and dietary restriction on the metabolic profile and insulin sensitivity in older, obese adults</td>
<td>Exercise training on treadmills, 60% of HRR to 80% of VO₂max 20–30 to 50 min/session, 3 sessions/week, 24-week Diet: restrict caloric intake by 500 kcal/day</td>
<td>↑ in insulin sensitivity (from 0.039 ± 0.004 to 0.049 ± 0.004 μmol/kg/min/pmol/L), ↓ in FPG concentration (from 5.46 ± 0.12 to 5.23 ± 0.13 mmol/L), ↔ in FPI concentration.</td>
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<td>Author, year</td>
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<td>Mean age (years)</td>
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<td>Yassine et al. 2009 (35)</td>
<td>24</td>
<td>65.5 ± 5.0</td>
<td>34.3 ± 5.2</td>
<td>Randomised controlled trial</td>
<td>Examine the effect of exercise alone or combined with diet on major cardiovascular disease risk factors, in older obese men and women</td>
<td>Exercise training walking on a treadmill and/or pedalling a cycle ergometer 60–70%–80–85% of HR_{max} 50–60 min/session 5 session/week, 12-week</td>
<td>Diet: reduce the energy intake by 500 kcal/day</td>
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<td>Endurance training + diet group:</td>
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<td>↑ in the VO_{2max} (from 2.0 ± 0.5 to 2.2 ± 0.5 l/min).</td>
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<td>↓ in the body weight (from 94.9 ± 16.5 to 88.0 ± 14.5 kg).</td>
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<td>↓ in the BMI (from 33.7 ± 4.7 to 31.3 ± 4.3 kg/m²).</td>
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<td>↓ in the fat mass (from 37.6 ± 9.8 to 31.6 ± 8.7 kg). ↔ in the FFM.</td>
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<td>↓ in the WC (from 113.6 ± 12.7 to 107.1 ± 11.7 cm).</td>
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<td>↓ in the visceral fat (from 236.8 ± 71.6 to 197.0 ± 73.6 cm³).</td>
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<td>↓ in the subcutaneous fat (426.7 ± 121.7 to 360.4 ± 130.3 cm³).</td>
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<td>↓ in the TG levels (from 171.1 ± 52.6 to 117.0 ± 48.2 mg/dl).</td>
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<td>↓ in the TC (from 181.2 ± 24.0 to 157.1 ± 27.6 mg/dl).</td>
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<td>↓ in the LDL-C levels (from 118.2 ± 17.3 to 104.2 ± 19.0 mg/dl). ↔ in the HDL-C levels.</td>
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<td>↓ in FPG concentration (from 107.1 ± 6.6 to 103.5 ± 6.6 mg/dl).</td>
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<td>Solomon et al. 2009 (40)</td>
<td>32</td>
<td>66 ± 1</td>
<td>33.8 ± 0.7</td>
<td>Randomised controlled trial</td>
<td>Examine the effects of a combined low-GI diet and exercise training vs. a high-GI diet and exercise training on insulin sensitivity in older obese humans</td>
<td>Exercise training: treadmill walking and cycle ergometry 80–85% HR_{max} 60 min/session 1 session/day, 1-week</td>
<td>Diet: low-GI diet or high-GI diet</td>
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<td>LoGIX group:</td>
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<td>↑ in the VO_{2max} (from 2.14 ± 0.14 to 2.25 ± 0.16 U/min).</td>
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<td>↓ in the body weight (from 93.6 ± 4.0 to 91.8 ± 3.8 kg).</td>
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<td></td>
<td>↓ in the BMI (from 32.8 ± 1.0 to 32.2 ± 1.0 kg/m²).</td>
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<td>↓ in the % of body fat (from 41.7 ± 2.2 to 41.4 ± 2.1%).</td>
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<td>↓ in the SBP (130.9 ± 2.8 to 119.9 ± 2.8 mmHg). ↔ in the DBP.</td>
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<td>↓ in the TG (165.5 ± 19.3 to 113.5 ± 15.0 mg/dl).</td>
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<td>↓ in the TC (203.7 ± 9.1 to 188.1 ± 9.2 mg/dl).</td>
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<td>↓ in the HDL-C (49.7 ± 4.3 to 48.9 ± 4.6 mg/dl). ↔ in the LDL-C and VLDL-C.</td>
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<td>↓ in FPG concentration (from 103.2 ± 2.8 to 99.5 ± 2.4 mg/dl).</td>
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Table 2 Continued

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Sample</th>
<th>Mean age (years)</th>
<th>Mean BMI (kg/m²)</th>
<th>Study design</th>
<th>Purpose</th>
<th>Protocol type</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solomon et al. 2008 (48)</td>
<td>23</td>
<td>66 ± 1</td>
<td>33.2 ± 1.4</td>
<td>Non- Randomised controlled trial</td>
<td>Compare the effect of exercise and diet vs. exercise alone on insulin sensitivity and substrate metabolism in older adults</td>
<td>Exercise training on treadmill walking and cycle ergometry, 75% of VO_{2\text{max}} 60 min/session, 5 sessions/week, 12 weeks</td>
<td>Hypocaloric Diet: reduction of 500 kcal/day</td>
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</tbody>
</table>

- ↓ in FPI concentration (from 16.8 ± 1.5 to 13.0 ± 1.4 μU/ml).
- ↑ in VO_{2\text{max}} (2.13 ± 0.11 to 2.15 ± 0.12 l/min).
- ↓ in the VO_{2\text{max}} (34.6 ± 1.0 to 34.1 ± 1.0 kg/m²).
- ↓ in the % of body fat (from 43.6 ± 1.6 to 43.0 ± 1.6%).
- ↓ in the SBP (133.6 ± 3.9 to 132.2 ± 4.2 mmHg).
- ↔ in the body weight (from 97.8 ± 4.1 to 96.4 ± 4.1 kg).
- ↑ in the DBP.
- ↓ in the BMI (34.6 ± 1.0 to 34.1 ± 1.0 kg/m²).
- ↓ in the % of body fat (from 43.6 ± 1.6 to 43.0 ± 1.6%).
- ↓ in the SBP (133.6 ± 3.9 to 132.2 ± 4.2 mmHg).
- ↔ in the DBP.
- ↓ in the body weight (from 97.8 ± 4.1 to 96.4 ± 4.1 kg).
- ↓ in the BMI (34.6 ± 1.0 to 34.1 ± 1.0 kg/m²).
- ↓ in the % of body fat (from 43.6 ± 1.6 to 43.0 ± 1.6%).
- ↓ in the SBP (133.6 ± 3.9 to 132.2 ± 4.2 mmHg).
- ↔ in the DBP.

VO_{2\text{max}} maximum volume of oxygen; BMI, body mass index; TG, triglyceride; TC, total cholesterol; LDL-C, low-density lipoprotein; HDL-C, high-density lipoprotein; FPG, fasting plasma glucose; FPI, fasting plasma insulin; FFM, free fat mass; SBP, systolic blood pressure; DBP, diastolic blood pressure; HRR, heart rate reserve; HR_{\text{max}}, maximal heart rate; LoGIX, low-glycaemic index diet and exercise; HiGIX, high-glycaemic index diet and exercise; GI, glycaemic index; VLDL-C, very low-density lipoprotein; WC, waist circumference; HI-CHO, low fat, high-complex carbohydrate diet; TNF-α, tumour necrosis factor-α; kcal, kilocalories; ↑, significant improvement within group; ↓, significant decrease within group; ↔, no change within group.

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and HiGIX groups (−7.1% and −10.5%, respectively) as well as in resting DBP (−4% and −10%, respectively).

Although these blood pressure reductions may appear modest, a significant blood pressure reduction of 3 mmHg is associated by 5–9% reduction in cardiac morbidity, 8–14% reduction in stroke, and by 4% reduction in all-cause mortality (65).

**Effects on lipid profile**

Obesity is positively correlated with lipid levels in circulation indicating a higher risk of cardiovascular disease. Indeed, increased levels of triglycerides, cholesterol, low-density lipoproteins (LDL-C) and decreased levels of high-density lipoproteins (HDL-C) indicate a problematic lipid profile that results in an increased risk of heart disease (66). Thus, ageing is associated with changes in plasma lipids that expose older adults to a host of metabolic complications (67). Specific effects of ET or ETD on lipid parameters in older obese people have been evaluated in a few studies. O’Leary et al. (17) found that 12 weeks of ET led to a significant decrease in total cholesterol (TC) by 8% and in triglyceride (TG) by 16% (all, p < 0.005). Similarly, 16 weeks of walking ET led to a significant improvement in TG by 23.7% as well as in the atherogenic ratio of TC/HDL-C by 14.3%, with no significant change in TC, LDL-C and HDL-C (29). In another study, lipid profile was examined in obese older men after 36 weeks of ET on a cycle ergometer. The results showed a 9% decrease in TG and a 5% increase in HDL-C, however, there was no significant change in TC and in the LDL-C (27). Conversely, 16 weeks of ET did not lead to a significant change in lipid profile (56).

The addition of energy restriction to endurance training plays an important role in determining lipid profile improvements in older obese individuals. Yasine et al. (35) reported that older obese subjects with ETD had a higher improvement in lipid profile compared to those with ET (TG: 31.6% vs. 20.7%, TC: 13.3% vs. 10.5%, and LDL-C: 11.8% vs. 7.3%), with no significant change in HDL-C in either group. Solomon et al. (46) confirmed the same tendency in older obese people after 12 weeks of ETD vs. ET (i.e. TG: 18.4% vs. 14.7%, and TC: 31.4% vs. 3%, respectively). Moreover, Solomon et al. (40) observed a significant decrease in TG (−31.4% and −36.2%), in TC (−7.7%, in both groups) in both LoGIX and HiGIX groups, respectively. In the same study, a slight but significant decrease in HDL-C (−1.6% and −3.5%, respectively) was also recorded in both groups, with no change in LDL-C in either group. Similarly, Solomon et al. (38) confirmed the same tendency through an improvement in lipid profile in both LoGIX and HiGIX groups, respectively (TG: −32.5% and −31.4%, TC: −14.5% and −12.6%, LDL-C: −13.5% and −11.5%, and in very low-density lipoprotein (VLDL): −32.5%, respectively), with no significant change in HDL-C in either group.

As a result of the high incidence of cardiovascular events in older obese people, even a small reduction in lipid profile (e.g. small reductions in LDL-C through ET or ETD) should be taken into account in terms of absolute risk reduction.

**Effects on insulin sensitivity**

It is well known that insulin resistance is a major risk for obese people (68). Exercise increases energy expenditure, which has been shown to improve insulin sensitivity, the major concern of older obese individuals suffering from type 2 diabetes (69,70). Indeed, several studies have shown that ET leads to enhanced insulin sensitivity in obese individuals. For example, three non-randomised studies carried out by O’Leary et al. (17); Kirwan et al. (33) and Savage et al. (29) reported a significant decrease in fasting plasma insulin (FPI) by 19.7%, 24% and 28.7%, respectively; but they observed no significant change in fasting plasma glucose (FPG) after ET programme. Other studies produced conflicting results regarding the impact of ET on insulin sensitivity. For example, a recent study by Snijders et al. (32) showed an 8.6% decrease in HbA1c with no significant difference in FPG and FPI. Coker et al. (30) revealed that 12-week of high intensity ET, led to a 28% increase (p < 0.05) in insulin-stimulated glucose disposal (ISGD), and a 30% increase (p < 0.05) in non-oxidative glucose disposal. Conversely, no significant changes in insulin sensitivity were observed in obese older people after a short-term ET programme (no significant change in HbA1c, FPG and FPI), except for a significant improvement in attitudes towards diabetes by 3.5% (57).

It is also suggested that ETD is an effective non-pharmaceutical treatment for improving insulin sensitivity in older, obese individuals (35). Two recent studies conducted by Ryan et al. (43) and Kirwan et al. (47) reported a significant decrease (21% and 38%; respectively) in FPI in older obese patients, while no significant change in FPG was found in the same studies.

Evidence has shown that insulin sensitivity was significantly improved by 35% (42) and 47% (47), in older obese individuals following ETD programme. A recent study revealed a significant improvement in FPG and FPI after ETD (3.4% and 21.6%; respectively), and after ET (3.3% and 27%; respectively) (40). However, Solomon et al. (46) confirmed the same tendency with a significant improvement only
in FPI, by 26.5% after ETD programme, and by 20.8% after ET programme.

Three other articles (38–40) compared the insulin sensitivity of older obese subjects between a LoGIX group and a HiGIX group. Two of the studies (38,40) which were randomised, reported a 3.5% and 3.6% improvement in FPG, and a 42.3% and 22.6% improvement in FPI, respectively, in the LoGIX group. In the same two studies, a 6.1% and 3.7% improvement in FPG, and a 56% and 11.1% improvement in FPI, respectively, were also found in the HiGIX group. However, Haus et al. (39) reported a significant improvement only in FPI, by 3.8% and 0.3% respectively, in both the LoGIX and the HiGIX groups.

Overall, the effects of ET or ETD on insulin sensitivity are still under investigation, yet insulin sensitivity may be acutely enhanced after certain exercise programmes.

Effects on inflammatory status

Obesity is positively correlated with chronic inflammation (71). Adipose tissue is responsible for the secretion of adipokines such as adiponectin and leptin, as well as immune factors such as tumour necrosis factor-α (TNF-α) (71,72). These substances play a crucial role in the pathogenesis of obesity (72,73). Specific effects of ET or ETD on inflammatory status among older obese patients are less documented and were found only in a few studies.

Twelve weeks of ET led to a slight non-significant increase in plasma adiponectin (31). Similarly, O’Leary et al. (17) reported no significant change in plasma adiponectin, leptin and in TNF-α after 12 weeks of ET. Solomon et al. (48) reported no significant change in plasma adiponectin with a significant decrease in circulating leptin (31.6%, p < 0.01) following ETD programme. Moreover, a significant decrease in circulating leptin by 26.5% (p < 0.01) was observed in obese adults after 12-week programme of ETD (46). Furthermore, O’Leary et al. (37), demonstrated no significant change in plasma adiponectin after 12-week of ETD. Finally, Kirwan et al. (47) reported no significant change in TNF-α in obese adults after 3 months of ETD.

With increasing age, it appears more difficult to obtain positive results with ET or ETD on inflammatory status. Thus, further works are needed to examine the relationship between long-term ET or ETD, and inflammatory status among older obese patients.

Discussion

To our knowledge, this is the first systematic review targeting the beneficial effects of endurance training alone or combined with diet on the health of obese patients over 60.

This systematic review included 26 published studies: 10 studies on endurance training (ET) and 16 studies on endurance training combined with diet (ETD). The majority of studies reported an improvement in cardio-respiratory fitness, good maintenance of blood pressure, regulation of the lipid profile as well as of insulin sensitivity and a significant improvement in the body composition, with no significant changes in inflammatory status among obese patients aged over 60.

Comparison with other reviews

Although several systematic reviews have already been published on the benefits of ET or ETD for the general population, to our knowledge, very few studies have focused on health benefits for obese patients aged over 60.

Concerning the effect of intervention trials on weight loss, our findings are in agreement with the systematic review by Witham et al. (23). These authors analysed the effect of diet, physical activity and mixed approaches on health outcomes in obese adults over 60. Their findings indicated a modest but significant reduction in weight. However, their findings are in disagreement with ours, regarding the lipid profile, which in their study showed no clinically significant improvement. In addition, the data published in their review make it difficult to draw clear conclusions regarding the effect of weight loss interventions on other cardiovascular risk factors. On the other hand, our findings are in accordance with the review by Miller et al. (21), who demonstrated the beneficial effects of exercise training combined with diet on cardiovascular fitness and body composition in middle-aged and older obese adults.

With increasing age, there is a well-described decline in voluntary physical activity, leading to an increased risk of frailty. In the present systematic review, we restricted our inclusion criteria to obese individuals aged over 60, whereas Moredich et al. (20) examined the effect of physical activity and diet in obese women over 48. Despite the difference in the age of the subjects and the type of training programme, our review agrees with the review by Moredich et al. regarding changes in body composition caused by significant weight loss. Finally, regarding weight loss, metabolic outcomes and cardiovascular parameters, our systematic review agrees with the review by Waters et al. (7), in which these authors demonstrate the beneficial effects of exercise training combined with caloric restriction in obese adults over 65.
Conclusion

Overall, this systematic review of studies on the effect of endurance training alone or combined with diet on the health of obese patients over 60 revealed six different types of outcomes.

Alone or combined with energy restriction, endurance training improves cardio-respiratory fitness, metabolic outcomes, blood pressure and the lipid profile, as well as body composition, with significant improvement in inflammatory status among older obese patients.

Clinicians can now use this evidence to formulate actions to enable the older obese to profit from the health benefits of endurance training and diet. This will not only help reduce the number of older obese people, which continues to increase dramatically but also help prevent sarcopenic obesity, which is a complex challenge for healthcare professionals.

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Author contribution

All the authors mentioned meet the criteria for authorship and give final approval of this manuscript to be published. Furthermore, they have been involved in: The conception of the study, Internet search and the acquisition of data: Walid Bouaziz, Thomas Vogel and Elise Schmitt. The conduct of the analysis: Walid Bouaziz, Bernard Geny and Georges Kaltenbach. The writing and the reviewing of the manuscript: Walid Bouaziz, Elise Schmitt and Thomas Vogel.

References

Health benefits of endurance training for obese patients over 60


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