



# Effectiveness of exercise training after bariatric surgery-a systematic literature review and meta-analysis

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**Effectiveness of exercise training after bariatric surgery – A systematic literature review  
and meta-analysis**

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42 **Potential conflict of interest**

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## **Abstract**

We aimed to conduct a systematic review and meta-analysis of controlled trials assessing exercise training programs in patients with obesity undergoing bariatric surgery. We systematically searched exercise training studies performed after bariatric surgery published up to June 2017. Studies reporting changes in body composition, physical fitness, functional capacity, objectively-measured physical activity, quality of life or relevant health outcomes were included. The review protocol is available from PROSPERO (CRD42017069380). Meta-analyses were conducted using random-effects models when data were available from at least 5 articles. Twenty articles were included, describing 16 exercise training programs, of which 15 were included in the meta-analysis. Overall, exercise training was associated with higher weight loss (mean difference: -2.4 kg, 95% CI: -4.2;-0.6,  $I^2=49\%$ ,  $n=12$ ), higher fat mass loss (-2.7 kg, 95% CI: -4.5;-1.0,  $I^2=50\%$ ,  $n=8$ ), improved  $VO_{2max}$  and functional walking (standardized mean difference: 0.86, 95% CI: 0.29;1.44,  $I^2=57\%$ ,  $n=6$ ; 1.45, 95% CI: 0.32;2.58,  $I^2=89\%$ ,  $n=6$ , respectively). Exercise training was not associated with lean body mass changes. In conclusion, exercise training programs performed after bariatric surgery were found effective to optimize weight loss and fat mass loss and to improve physical fitness, although no additional effect on lean body mass loss were found.

## **Introduction**

Bariatric surgery is increasingly performed in patients with severe obesity worldwide and in Europe<sup>1</sup>. Bariatric surgery leads to marked weight loss, decreased morbidity and mortality, and improved quality of life and physical function<sup>2-4</sup>. Clinical guidelines emphasize the need for lifestyle changes, including regular physical activity, to enhance health benefits<sup>5</sup>.

Objectively-measured physical activity data indicate that most patients undergoing obesity surgery have insufficient levels of physical activity<sup>6</sup>, suggesting important potential benefits of physical activity interventions in these patients.

Emerging evidence suggests that physical activity might provide important health benefits after obesity surgery. A positive relationship between self-reported physical activity and the amount of weight loss has been described in a previous review published in 2011<sup>7</sup>. However, evidence came from observational studies only. Two recent reviews published in 2015, synthesizing findings from 5<sup>8</sup> and 8<sup>9</sup> intervention studies published at that time, suggested that exercise performed before or after surgery might improve physical fitness and metabolic health, without additional benefits on anthropometry and body composition<sup>8,9</sup>. However, both controlled and non-controlled studies were included, which represents a major bias given that bariatric surgery in itself is associated with decreased fat mass and lean body mass<sup>10</sup>, improved cardiorespiratory fitness<sup>4</sup> and decreased muscle strength<sup>4</sup>. In addition, the number of studies was insufficient to conduct a meta-analysis. Most recently, a number of controlled trials have described the effects of exercise training on various outcomes related to body composition, physical capacity or health status<sup>11-20</sup>. Therefore, a systematic updated overview of this topic, complemented by a meta-analysis, is relevant.

The aim of this review was to propose an updated overview and meta-analysis of the effectiveness of exercise training in patients with severe obesity undergoing bariatric surgery.

## **Materials and Methods**

### **Literature search, selection of studies and data extraction**

The systematic review protocol is available from PROSPERO (PROSPERO 2017: CRD42017069380). The literature search was performed in June 2017, using four electronic databases (PubMed, Web of Science, Cochrane Library and EMBASE). Combinations of terms related to bariatric surgery ("bariatric surgery", "obesity surgery", "metabolic surgery", "Roux-en-Y", "gastric bypass", "sleeve gastrectomy", "gastric banding", "duodenal switch") and to physical activity ("physical activity", "exercise", "sedentary", "endurance", "resistance training", "aerobic", "fitness", "muscle strength", "physical capacity") were used in the search. The reference lists of included articles and review articles were also scanned for further eligible studies. The initial inclusion criterion was the implementation of an exercise training program in adult patients with obesity undergoing bariatric surgery. Other inclusion criteria were: 1) articles written in English, 2) controlled trials comparing patients undergoing bariatric surgery receiving either usual care or usual care and exercise training 3) patients undergoing gastric bypass, sleeve gastrectomy, gastric banding, biliopancreatic diversion or duodenal switch 4) intervention conducted after bariatric surgery, 5) pre- to post-intervention changes reported for at least one of the following outcomes: anthropometry or body composition, objectively-measured physical activity or physical capacity, health-related quality of life, relevant other health outcomes.

The characteristics of included articles were extracted by one reviewer (AB) and checked by a second reviewer (JMO), and included: authors, journal, year of publication, study design,

sample size, surgical procedure, description of intervention, outcomes, assessment tools, times of measurement and main findings. Emphasis was placed on the description of intervention. The TIDierR checklist (including 12 items: brief name, why, what materials and procedures, who provided, how, where, when and how much, tailoring, modification of intervention throughout trial, strategies to improve or maintain intervention fidelity and extent of intervention fidelity) was used for description of interventions both in exercise and control groups<sup>21</sup>.

### **Quality assessment**

The methodological quality of included studies was scored using the Physiotherapy Evidence Database (PEDro) scale (<https://www.pedro.org.au/>)<sup>22</sup>. The PEDro scale has been used extensively to assess rehabilitation programs and exercise training interventions<sup>9, 23</sup>. The PEDro scale is an 11-item checklist (specification of eligibility criteria, random allocation, concealed allocation, baseline comparability, blind subjects, blind therapists, blind assessor, adequate follow up, intention-to-treat-analysis, between groups comparisons, point estimates and variability) receiving a “yes” or “no” rating. The total score ranges from 0 to 10 since the first item is not included in the calculation. Trials with a score < 4 were classified as poor-quality, 4-5 as fair-quality, 6-8 as good-quality, and  $\geq 9$  as excellent-quality<sup>9</sup>. Quality of each included study was assessed independently by two reviewers (AB, JMO). When opinions differed, consensus was reached through discussion.

### **Reporting of findings**

We reported changes in anthropometry, body composition, physical fitness, functional capacity, objectively-measured physical activity, quality of life and health outcomes after exercise training for each individual study (Table S1). Physical fitness included

cardiorespiratory fitness (assessed by a maximal exercise test) and maximal muscle strength. Functional capacity was assessed with field-based fitness assessments (e.g. 6-minute walk test, sit-to-stand test, half-squat test, arm curl test, chair sit-and-reach test, 8- foot up-and-go). Functional walking refers to the distance walked during walking tests. To facilitate the synthesis of results, we grouped related metabolic outcomes into broader categories, e.g. fasting or post-prandial glucose and insulin, HOMA-IR, insulin sensitivity, insulin responsiveness were grouped into a category named “glucose metabolism”; or total, LDL- or HDL-cholesterol and triglycerides into the “lipid profile” category. When several follow-up measurements were conducted, we reported results from the first assessment after the end of the exercise training. When results of a single trial were reported in several studies (e.g. the trial by Coen et al.<sup>24</sup> was followed by a series of studies<sup>12, 18, 25, 26</sup>), we selected results from the parent trial or from the study with the largest sample size.

## **Data analysis**

We performed meta-analyses using Review Manager version 5.3 when data were available from at least 5 studies. We reported the mean and standard deviation (SD) of absolute changes in body mass, fat mass, lean body mass, VO<sub>2</sub>max and functional walking (results of walking tests). Absolute changes were calculated as differences between arithmetic means before and after intervention. Transformation methods were used for studies that did not provide the SD of absolute change but provided the exact p-value for intra-group or inter-group analyses, as suggested by the Cochrane Handbook for systematic reviews of interventions<sup>27</sup>. One study was not included in the meta-analysis due to insufficient data despite attempts to contact the study authors. Data from intention-to-treat analyses were included whenever available in included studies. Pooled-effect estimates were expressed as the weighted mean difference between exercise and

control groups for changes in body mass, fat mass and lean body mass. For changes in VO<sub>2</sub>max and functional walking, because different walking tests were performed and VO<sub>2</sub>max was expressed in values either relative to body mass or to lean body mass, estimates were expressed as the standardized mean difference. Calculations were performed using a random-effects model because of the small number of studies available and their methodological diversity. A p-value < 0.05 was considered statistically significant. Heterogeneity was measured using the I<sup>2</sup> test<sup>27</sup>. When the number of studies was insufficient to perform a meta-analysis, we synthesized study findings by presenting the number of studies reporting (1) an improvement (i.e. if a significant positive effect of exercise was found for at least one outcome, and no deterioration was found) or (2) no change (i.e. if no significant difference in any direction was found between exercise and control groups).

## **Results**

### **Study characteristics and quality**

Among the 3,504 articles initially identified, 20 were included in our review (Figure 1). The main characteristics of the 20 articles are presented in Table 1. Five articles reported results of the same intervention study<sup>12, 18, 25, 26, 28</sup> and one study compared two interventions<sup>15</sup>. Sixteen distinct intervention studies were therefore included. Studies were published between 2011 and 2017. Five studies were conducted in the USA, 3 in Brazil, 2 in Iran and UK and 1 in Austria, Belgium and Italy. Studies were randomized (9 studies) or non-randomized (6 studies) controlled trials. Most studies had limited sample sizes, except for four studies that included more than 50 participants<sup>13, 15, 17, 24</sup>. Ten studies included both men and women, the remaining studies included women only. Patients underwent Roux-en-Y gastric bypass

(RYGB) in 6 studies, sleeve gastrectomy in one study and either RYGB, gastric banding or sleeve gastrectomy in the remaining studies. The most frequently reported outcomes were anthropometry (15 studies), body composition (11 studies), physical function, VO<sub>2</sub>max and muscle strength (7, 6 and 6 studies, respectively) and health-related quality of life (6 studies). Objectively-measured physical activity was reported in only 4 studies, blood pressure, glucose metabolism and lipid profile in 4, 3 and 3 studies, respectively. Preoperative data were collected in 6 studies.

### **Study quality**

Study quality was rated as poor, fair and good in 2, 9 and 4 studies, respectively (Table 2). No study was rated as excellent-quality. Most studies reported a measure of variability (15/15) and conducted between-group comparison (14/15). About two-third to three-quarters of studies were randomized, achieved similarity of groups at baseline and specified eligibility criteria. About half of studies performed intention-to-treat analysis and concealed allocation to experimental groups. Only one third of studies reported changes in one key outcome for at least 85% of study participants. Blinding of participants, therapists or assessors could not be achieved in any study, except for one that mentioned the blinding of all assessors<sup>24</sup>.

### **Description of interventions**

Interventions are described in detail in Table S2. Exercise started from 1 week after surgery<sup>20</sup> to 18 months after surgery<sup>29</sup>. Duration of exercise training ranged from 1 month<sup>20</sup> to 24 months<sup>17</sup>, with a median duration of 3 months (Figure 2). Endurance training was performed in 5 studies<sup>15, 24, 29-31</sup>, resistance training in 2 studies<sup>14, 32</sup>, a combination of endurance and resistance training in 8 studies<sup>11, 13, 15-17, 19, 33, 34</sup> and balance training in 1 study<sup>20</sup>. Intensity of exercise was usually defined in relative terms, according to maximal heart rate or maximal

strength. The intervention included a behavioral component in 4 studies (physical activity and/or dietary counseling<sup>13, 29, 31, 33</sup> and a protein, calcium and vitamin D supplementation in 1 study<sup>17</sup>). Exercise sessions were fully supervised (10 studies<sup>11, 13, 16, 19, 29-34</sup>), partially supervised (1 study<sup>24</sup>) or not supervised (2 studies<sup>15, 17</sup>). Supervision was not described in 1 study<sup>20</sup>. Supervision was performed by physical activity specialists, physiotherapists, exercise physiologists or experts in physical medicine. Sessions were performed in a hospital or research center in 5 studies<sup>16, 19, 30, 31, 33</sup>, and outdoor<sup>29</sup> or in a private training facility<sup>32</sup> in one study each. Only 1 study described that sessions were organized in groups<sup>32</sup>. One study sought to increase adherence by proposing a variety of exercise modalities<sup>13</sup>. Most studies provided no or very little information about the control group. The intervention received by control patients, described in 7 studies, included physical activity and/or dietary counseling sessions<sup>11, 13, 17, 19, 24, 31, 32</sup>, with multivitamin and mineral supplementation indicated in 3 studies<sup>11, 17, 31</sup>.

## **Compliance**

The percentage of included participants who completed the study ranged from 60%<sup>11</sup> to 100%<sup>14, 19, 24</sup> (Table S3). Only 2 studies performed analysis for completers, defined as patients participating to either a minimum number of training sessions ( $\geq 80\%$ <sup>17</sup>) or a minimum duration of training ( $\geq 120$  min/week)<sup>24</sup>. In these studies, completers represented around 70% of all participants. Finally, 3 studies reported attendance to training sessions<sup>16, 32, 33</sup> that ranged from 75%<sup>33</sup> to 95%<sup>16</sup>.

## **Effectiveness of interventions**

Overall, exercise training was associated with a higher loss in body mass (-2.4 kg, 95% CI: -4.2, -0.6,  $I^2=49\%$ ,  $n=12$  studies) and in fat mass (-2.7 kg, 95% CI: -4.5, -1.0,  $I^2=50\%$ ,  $n=8$  studies) compared to the control group but was not associated with changes in lean body mass (0.7 kg, 95% CI: -0.3, 1.7,  $I^2=50\%$ ,  $n=10$  studies) (Figure 3). Exercise training was also associated with an improvement in  $VO_{2max}$  (standardized mean difference: 0.86, 95% CI: 0.29, 1.44,  $I^2=57\%$ ,  $n=6$  studies), and in functional walking (standardized mean difference: 1.45, 95% CI: 0.32, 2.58,  $I^2=89\%$ ,  $n=6$  studies) (Figure 4). Sub-sample analyses were performed on  $VO_{2max}$  expressed relative to body mass, reported in 5 studies<sup>19, 29, 31, 32, 34</sup>. A mean difference of 2.87 mL/kg/min (95% CI: 0.63, 5.12,  $I^2=83\%$ ) was found.

Changes in muscle strength, objectively-measured habitual physical activity, metabolic profile and health related-quality of life were not included in the meta-analysis. Muscle strength increased in most studies in the exercise group compared to the control group (Table 3). Objectively-measured physical activity, metabolic profile (glucose metabolism, lipid profile, blood pressure) and health-related quality of life were found unchanged after exercise compared to control in most studies (Table 4).

## **Discussion**

In this systematic review, we provided an updated overview of the effectiveness of exercise training on physical fitness, body composition, objectively-measured habitual physical activity, health-related quality of life and health outcomes in patients undergoing bariatric surgery. The review identified 20 articles assessing the effect of 16 distinct exercise training programs performed after surgery. Compared with the previous reviews by Coen et al. (2015)<sup>8</sup>

and Pouwels et al. (2015)<sup>9</sup>, this review added a number of recent articles published in 2016 and 2017 assessing a combination of endurance and resistance exercise training which, until recently, had received little attention in the context of bariatric surgery. Our main finding was that exercise training performed after bariatric surgery was effective to optimize weight loss and fat mass loss and to improve physical fitness.

This meta-analysis provides evidence of additional benefits of exercise training on body mass and body fat loss after bariatric surgery although no preservation of lean body mass was found. This adds to the body of knowledge previously reviewed by Coen et al.<sup>8</sup> and Pouwels et al.<sup>9</sup> who concluded that there was insufficient evidence for an additional effect of exercise training on body composition. The amount of additional weight loss observed in our meta-analysis, of approximately 2.5 kg, seems however to represent a relatively modest benefit as compared to the amount of weight lost after bariatric surgery itself (i.e. around 30 to 35% loss of initial weight during the first post-operative year<sup>2</sup>). The relatively small added energy deficit induced by exercise may not be sufficient to substantially influence energy balance<sup>12</sup>, especially taking into account that the post-bariatric setting is characterized by a major energy deficit<sup>35</sup>. Interestingly, the major part of weight loss seems to be related to loss in body fat, which can be considered as a favorable effect. However, based on results of our meta-analysis, exercise training was not significantly associated with changes in lean body mass, compared to usual care without training. Preserving lean body mass in this context appears to be particularly challenging, which might be explained, at least in part, by the dramatic decrease in protein intake observed in the first months following bariatric surgery<sup>35</sup>. When associated with resistance training, protein supplementation is recognized as an important means for preserving lean body mass during dietary-induced weight loss<sup>36</sup>. The effects of

protein supplementation, with or without resistance training after bariatric surgery warrant further investigation.

Another major finding of this meta-analysis was that exercise training further improved physical fitness and physical function as assessed by walking tests. Overall,  $\text{VO}_{2\text{max}}$  was improved in the exercise training group, compared to the control group, by a mean 2.9 mL/kg/min. Although not included in the meta-analysis, muscle strength also increased after exercise training in most studies, whether assessed as lower-limb<sup>11, 14, 34</sup> or upper-limb<sup>11, 15, 16, 34</sup> maximal strength. Cardiorespiratory fitness and muscle strength are predictors of mortality risk both in healthy individuals and in patients with chronic diseases, including obesity<sup>37-40</sup>. According to a meta-analysis with a combined sample size of over 100,000 participants, each 1-MET increase in cardiorespiratory fitness was associated with a 15% and 13% reduction in all-cause and cardiovascular mortality, respectively<sup>41</sup>. The improvement in cardiorespiratory fitness with exercise training observed in the present meta-analysis is therefore likely to be associated with improved health status after bariatric surgery. Interestingly, additive effects between low cardiorespiratory fitness and muscle strength have been reported<sup>42</sup>, which emphasizes the need to promote both dimensions of physical fitness in patients with obesity undergoing bariatric surgery.

Because of a limited number of studies and important methodological heterogeneity, we were not able to compare the effects of different types of exercise training. Given the known principle of specificity of exercise training, stating that the physiological adaptations to exercise are specific to the type of exercise performed<sup>43</sup>, we would expect that endurance training would preferentially improve cardiorespiratory fitness, and that resistance training would improve muscle strength. This hypothesis would, however, need to be confirmed in

patients undergoing bariatric surgery. Data were also insufficient to determine the minimum amount of exercise needed to optimize weight loss. In secondary analyses of data from the trial by Coen et al.<sup>24</sup>, which investigated the effect of a semi-supervised endurance training program, authors reported a significant weight and fat loss only in patients who exercised most, i.e. those who exercised on average 286 minutes per week<sup>25</sup>. The need to increase exercise duration to promote weight loss would be in agreement with the role of physical activity in general in the prevention of weight regain<sup>44</sup>. Further analysis of the trial by Coen et al<sup>24</sup> revealed that irrespective of exercise training, patients with the highest level of habitual physical activity based on daily steps experienced higher body weight and body fat loss<sup>12</sup>. These findings suggest that increasing total physical activity (i.e. both exercise and incidental physical activity) might be necessary to optimize weight loss and body composition changes after bariatric surgery. However, direction and magnitude of change in habitual physical activity after bariatric surgery is still a matter of discussion. According to recent reviews, data generated from self-reported questionnaires consistently indicated an increase in physical activity whereas data from objective measures indicated no change or only modest increases<sup>4, 7, 8</sup>. Of note is the fact that very few studies included in the present review assessed habitual physical activity using objective methods such as accelerometry<sup>12, 16, 31</sup>. Overall, these findings emphasize the need for a more systematic and detailed assessment of physical fitness and habitual physical activity to gain better understanding of the role of exercise training and daily activities in the follow-up of bariatric surgery.

Although the overall study quality was rated as fair to good in most studies, a number of studies under-reported important aspects of interventions such as the mode of delivery (individual or group sessions), the potential modifications of the intervention during the course of the study, or the use of strategies to improve or maintain adherence, which is a

frequent limitation of non-pharmacological interventions<sup>45</sup>. Better describing the intervention delivered to both the intervention and control groups would help interpret study results and replicate studies in real-life settings<sup>21</sup>. Included studies were also characterized by important variations in terms of intervention (type, duration and timing) and evaluation (timing of assessment, assessment tools, data analysis and reporting). To date, data are insufficient to answer important research questions, such as the effect by type of exercise, relevant intervention duration or intervention timing, the additional effect of supervising exercise sessions and the long term effect of exercise training. Two thirds of exercise programs lasted 3 months or less, which might be too short to observe a significant impact on health outcomes. Interestingly, Muschitz et al.<sup>17</sup> observed that the preservation of lean body mass became significant only after 18 months of intervention, during the weight stabilization phase. Long-term trials are needed to determine the most effective duration and timing of exercise training programs in patients with obesity undergoing bariatric surgery.

## **Conclusion**

Exercise training programs performed after bariatric surgery were found effective to increase weight loss and fat mass loss and to improve physical fitness, although no additional effect on lean body mass or health outcomes were found compared to usual care follow-up. This meta-analysis provides evidence that exercise training is an effective strategy to optimize follow-up care after bariatric surgery. Both health professionals and patients should be aware of the type of benefits they should expect from an exercise program in this context, especially given the fact that additional weight and fat loss with exercise was of relatively small magnitude. Included studies were characterized by important heterogeneity, precluding an analysis by type and amount of exercise. More studies are needed to identify the most effective and feasible strategies and to better understand the role of daily physical activity in the follow-up

359 of bariatric surgery. Also, important aspects of interventions should be described in more  
360 detail to facilitate implementation and maintenance of exercise training programs in post-  
361 bariatric patients in routine clinical care.

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363 **Conflict of Interest Disclosure Statement**

364 Authors declare that they have no conflict of interest.

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## **Tables titles and legends**

### **Table 1**

Title: Characteristics of included studies (N=20)

Legend: Articles are presented in chronological order and articles reporting results from the same trial are presented together.

Abbreviations, RCT, randomized controlled trial; NRCT, non-randomized controlled trial; RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; GB, gastric banding; END, endurance training; RES, resistance training, BALANCE, balance training; 6MWT, 6-minute walk test; WC, waist circumference; TC, total cholesterol; TG, triglycerides; NA, not available.

### **Table 2**

Title: Results on study quality

Legend: PEDro criteria: (1) specification of eligibility criteria, (2) random allocation, (3) concealed allocation, (4) baseline comparability, (5) blind subjects, (6) blind therapists, (7) blind assessor, (8) adequate follow up, (9) intention-to-treat-analysis, (10) between groups comparisons, (11) point estimates and variability.

The first criterion was not included in the calculation of the total score.

### **Table 3**

Title: Changes in muscle strength, physical activity, quality of life and metabolic profile in exercise group compared to control group

Legend:

Abbreviations, 1-RM, 1 repetition maximum or repetition-maximum or maximum weight that can be used to complete 1 repetition; MVPA, moderate-to-vigorous physical activity; EE, energy expenditure.

## **Figures titles and legends**

### **Figure 1:**

Title: Flow chart of the literature search

### **Figure 2:**

Title: Timing of intervention and assessment

Legend: The letter “S” represents the time of surgery, the circles represent the time of assessment and the lines represent the duration of the exercise training program. Some trials have been reported in different articles. This figure includes only articles that present results of the parent trial.

### **Figure 3**

Title: Changes in body mass and body composition after bariatric surgery in exercise group compared to control group

Legend: Presents the difference in change in body mass and body composition after bariatric surgery between the participants in the exercise and control groups. The sample size represents the number of participants who completed the trials.

Hassannejad 2017a: endurance training. Hassannejad 2017b: endurance and resistance training

550

551 **Figure 4:**

552 Title: Changes in physical fitness after bariatric surgery in exercise group compared to control  
553 group

554 Legend: Presents the difference in change in VO<sub>2</sub>max and functional walking after bariatric  
555 surgery between the participants in the exercise and control groups. The sample size  
556 represents the number of participants who completed the trials.

557 Hassannejad 2017a: endurance training. Hassannejad 2017b: endurance and resistance  
558 training

559

560 **Supporting information**

561 **Table S1:** Changes in anthropometry, body composition, objectively-measured physical  
562 activity, physical fitness, quality of life and health outcomes in exercise and control groups

563 **Table S2:** Intervention description (using the TIDieR checklist)

564 **Table S3:** Compliance to exercise training program

**Table 1**

Authors	Country	Study design Sample size Surgery type	Intervention (in addition to usual care)	Outcomes	Measures for corresponding outcomes
Castello et al. (2011) <sup>30</sup>	Brazil	RCT n=21 W RYGB	<u>Type</u> : END, 3 sessions/week <u>Supervision</u> : total <u>Timing</u> : 3 months, starting 1 month after surgery	- Anthropometry: body weight, WC - Body composition - Physical function	- Clinical examination - Skinfolde - 6MWT
Castello-Simoes et al. (2013) <sup>28</sup>	Brazil	RCT n=19 W RYGB	<u>Type</u> : END, 3 sessions/week <u>Supervision</u> : total <u>Timing</u> : 3 months, starting 1 month after surgery	- Anthropometry: body weight - Physical function	- Clinical examination - 6MWT
Shah et al. (2011) <sup>31</sup>	USA	RCT n=33 W+M RYGB, GB	<u>Type</u> : END, 5 sessions/week <u>Supervision</u> : total <u>Timing</u> : 3 months, starting 3-42 months after surgery + Behavioral intervention	- Anthropometry: body weight, WC - Body composition - Physical activity - VO <sub>2</sub> max - Resting energy expenditure - Glucose metabolism: glucose, insulin - Lipid profile: TC, LDL-c, HDL-c, TG - Quality of life	- Clinical examination - DEXA - Pedometer - Maximal exercise test - Indirect calorimetry - Blood analyses, oral glucose tolerance test - Blood analyses - SF-36, IWQOL-L
Stegen et al. (2011) <sup>34</sup>	Belgium	NRCT n=15 W+M RYGB	<u>Type</u> : END + RES, 3 sessions/week <u>Supervision</u> : total <u>Timing</u> : 3 months, starting 1 month after surgery	- Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> peak: maximal exercise test - Muscle strength - Muscle fatigue - Physical function	- Clinical examination - Impedance - Maximal exercise test - Weight machines, handgrip dynamometer - Handgrip dynamometer - 6MWT, sit-to-stand test
Coen et al. (2015) <sup>24</sup>	USA	RCT n=128 W+M RYGB	<u>Type</u> : END 3-5 sessions/week <u>Supervision</u> : partial <u>Timing</u> : 6 months, starting 1-3 months after surgery	- Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> peak - Glucose metabolism: insulin sensitivity - Lipid profile: TC, LDL-c, HDL-c, TG - Blood pressure	- Clinical examination - DEXA - Maximal exercise test - Intravenous glucose tolerance test - Blood analyses - Clinical examination
Coen et al. (2015) <sup>26</sup>	USA	RCT n=101 W+M RYGB	<u>Type</u> : END 3-5 sessions/week <u>Supervision</u> : partial <u>Timing</u> : 6 months, starting 1-3 months after surgery	- Anthropometry: body weight WC - Body composition - VO <sub>2</sub> peak: maximal exercise test - Glucose metabolism: insulin sensitivity	- Clinical examination - DEXA - Maximal exercise test - Intravenous glucose tolerance test

Woodlief et al. USA (2015) <sup>25</sup>	RCT n=98 W+M RYGB	<u>Type:</u> END 3-5 sessions/week <u>Supervision:</u> partial <u>Timing:</u> 6 months, starting 1-3 months after surgery	<ul style="list-style-type: none"> <li>- Intramyocellular lipids</li> <li>- Mitochondrial respiration</li> <li>- Lipid profile: TC, LDL-c, HDL-c, TG</li> <li>- Blood pressure</li> <li>- Anthropometry: body weight</li> <li>- Body composition</li> <li>- VO<sub>2</sub>peak</li> <li>- Resting metabolic rate</li> <li>- Glucose metabolism: insulin sensitivity</li> <li>- Mitochondrial respiration</li> <li>- Lipid oxidation</li> </ul>	<ul style="list-style-type: none"> <li>- Muscle biopsy</li> <li>- Muscle biopsy</li> <li>- Blood analyses</li> <li>- Clinical examination</li> <li>- Clinical examination</li> <li>- DEXA</li> <li>- Maximal exercise test</li> <li>- Indirect calorimetry</li> <li>- Intravenous glucose tolerance test</li> <li>- Muscle biopsy</li> <li>- Muscle biopsy</li> </ul>
Carnero et al. USA (2017) <sup>12</sup>	RCT n=96 W+M RYGB	<u>Type:</u> END 3-5 sessions/week <u>Supervision:</u> partial <u>Timing:</u> 6 months, starting 1-3 months after surgery	<ul style="list-style-type: none"> <li>- Anthropometry: body weight</li> <li>- Body composition</li> <li>- Skeletal muscle mass</li> <li>- Physical activity and sedentary behavior</li> <li>- VO<sub>2</sub>peak</li> <li>- Resting metabolic rate</li> </ul>	<ul style="list-style-type: none"> <li>- Clinical examination</li> <li>- DEXA</li> <li>- Computed tomography</li> <li>- Accelerometer</li> <li>- Maximal exercise test</li> <li>- Indirect calorimetry</li> </ul>
Nunez Lopez et al. USA (2017) <sup>18</sup>	RCT n=22 W+M RYGB	<u>Type:</u> END 3-5 sessions/week <u>Supervision:</u> partial <u>Timing:</u> 6 months, starting 1-3 months after surgery	<ul style="list-style-type: none"> <li>- Anthropometry: body weight, WC</li> <li>- Body composition</li> <li>- VO<sub>2</sub>peak: maximal exercise test</li> <li>- Glucose metabolism: insulin sensitivity</li> <li>- MicroRNAs profiling</li> <li>- Lipid profile: TC, LDL-c, HDL-c, TG</li> <li>- Blood pressure</li> </ul>	<ul style="list-style-type: none"> <li>- Clinical examination</li> <li>- DEXA</li> <li>- Maximal exercise test</li> <li>- Intravenous glucose tolerance test</li> <li>- Arterialized blood analyses</li> <li>- Blood analyses</li> <li>- Clinical examination</li> </ul>
Huck et al. USA (2015) <sup>32</sup>	NRCT n=15 W+M RYGB, GB	<u>Type:</u> RES 2-3 sessions/week <u>Supervision:</u> total <u>Timing:</u> 3 months, starting 4 months after surgery	<ul style="list-style-type: none"> <li>- Anthropometry: body weight, WC</li> <li>- Body composition</li> <li>- VO<sub>2</sub>max</li> <li>- Muscle strength</li> <li>- Physical function</li> </ul>	<ul style="list-style-type: none"> <li>- Clinical examination</li> <li>- Impedance</li> <li>- Maximal exercise test</li> <li>- Weight machines, handgrip dynamometer</li> <li>- Sit-to-stand test, chair sit-and-reach test</li> </ul>
Jassil et al. UK (2015) <sup>33</sup>	NRCT n=24 W RYGB, SG	<u>Type:</u> END + RES 1 session/week <u>Supervision:</u> total <u>Timing:</u> 2 months, starting 3-6 months after surgery + behavioral intervention	<ul style="list-style-type: none"> <li>- Anthropometry: body weight</li> <li>- Physical function</li> <li>- Quality of life</li> </ul>	<ul style="list-style-type: none"> <li>- Clinical examination</li> <li>- 6MWT</li> <li>- Dartmouth COOP</li> </ul>
Marchesi et al. Italy (2015) <sup>29</sup>	NRCT n=20 W RYGB	<u>Type:</u> END, 3 sessions/week <u>Supervision:</u> total <u>Timing:</u> 10 months, starting 1-3 year after surgery + behavioral intervention	<ul style="list-style-type: none"> <li>- Anthropometry: body weight, WC</li> <li>- Body composition</li> <li>- VO<sub>2</sub>max</li> <li>- Quality of life</li> <li>- Lipid profile: TC, HDL-c, TG</li> <li>- Glucose metabolism: glucose</li> </ul>	<ul style="list-style-type: none"> <li>- Clinical examination</li> <li>- DEXA</li> <li>- Maximal exercise test</li> <li>- SF-36</li> <li>- Blood analyses</li> <li>- Blood analyses</li> </ul>

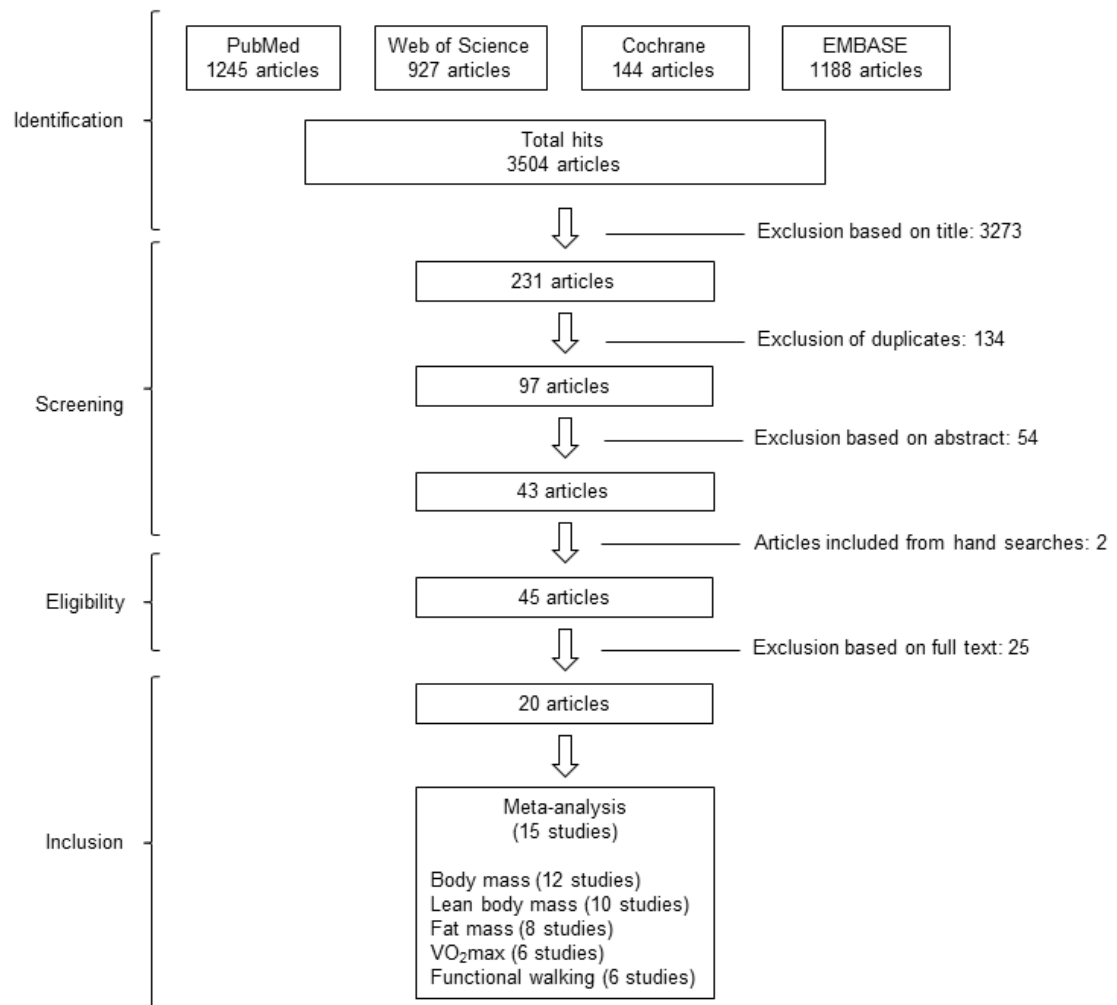
Muschitz et al. (2016) <sup>17</sup>	Austria	RCT n=220 W+M RYGB, SG	<u>Type:</u> END + RES, 3 and 2 sessions/week + protein, calcium, vit. D supplementation <u>Supervision:</u> none <u>Timing:</u> 24 months, starting 2 week after surgery	- Anthropometry: body weight) - Body composition - Bone mineral density - Bone metabolism markers - Quality of life	- Clinical examination - DEXA - DEXA - Blood analyses - SF-36
Rojhani-Shirazi et al. (2016) <sup>20</sup>	Iran	RCT n=32 W SG	<u>Type:</u> BALANCE 4 sessions/week <u>Supervision:</u> not described <u>Timing:</u> 1 months, starting 5 days after surgery	- Anthropometry: body weight, WC - Balance control	- Clinical examination - Single leg stance, star excursion balance test, get up and go test
Campanha-Versiani et al. (2017) <sup>11</sup>	Brazil	NRCT n=37 W+M RYGB	<u>Type:</u> END + RES 2 sessions/week <u>Supervision:</u> total <u>Duration:</u> 9 months, starting 3 months after surgery	- Anthropometry: body weight - Body composition - Muscle strength - Bone mineral density - Bone turnover markers	- Clinical examination - DEXA - Weight machines - DEXA - Blood analyses
Coleman et al. (2017) <sup>13</sup>	USA	RCT n=51 W+M RYGB, SG, lap band	<u>Type:</u> END + RES 2 sessions/week <u>Supervision:</u> total <u>Timing:</u> 6 months, starting 6-24 months after surgery + behavioral intervention	- Anthropometry: body weight - Physical activity - Physical function	- Clinical examination - Pedometer - 6MWT, 8-foot up-and-go, 30-s chair rise, arm curl test, chair sit-and-reach test
Daniels et al. (2017) <sup>14</sup>	USA	RCT n=16 W RYGB	<u>Type:</u> RES 3 sessions/week <u>Supervision:</u> not described <u>Timing:</u> 3 months, starting 2 months after surgery	- Anthropometry: body weight - Body composition - Skeletal muscle mass - Muscle strength	- Clinical examination - Displacement plethysmography - MRI - Weight machines
Hassannejad et al. (2017) <sup>15</sup>	Iran	RCT n=60 W+M RYGB, SG	<u>Type:</u> END 3-5 sessions/week or END 3-5 sessions/week + RES 3 sessions/week <u>Supervision:</u> none <u>Timing:</u> 3 months, starting 0 (END) to 5 (RES) week after surgery	- Anthropometry: body weight - Body composition - Muscle strength - Physical function	- Clinical examination - Impedance - Weight machines - Sit-to-stand test, 12-min walk-run test
Herring et al. (2017) <sup>16</sup>	UK	RCT n=24 W+M RYGB, SG, GB	<u>Type:</u> END + RES 3 sessions/week <u>Supervision:</u> total <u>Timing:</u> 3 months, starting 12-24 months after surgery	- Anthropometry: body weight, WC - Body composition - Physical activity and sedentary behavior - Muscle strength - Physical function - Blood pressure	- Clinical examination - Impedance - Accelerometer - Handgrip dynamometer - Incremental shuttle walk test, sit-to-stand test - Clinical examination
Onofre et al. (2017) <sup>19</sup>	Brazil	NRCT n=12 W RYGB, SG	<u>Type:</u> END + RES 3 sessions/week <u>Supervision:</u> total <u>Timing:</u> 3 months, starting 3 months after surgery	- Anthropometry: body weight, WC - VO <sub>2</sub> peak	- Clinical examination - Maximal exercise test

**Table 2**

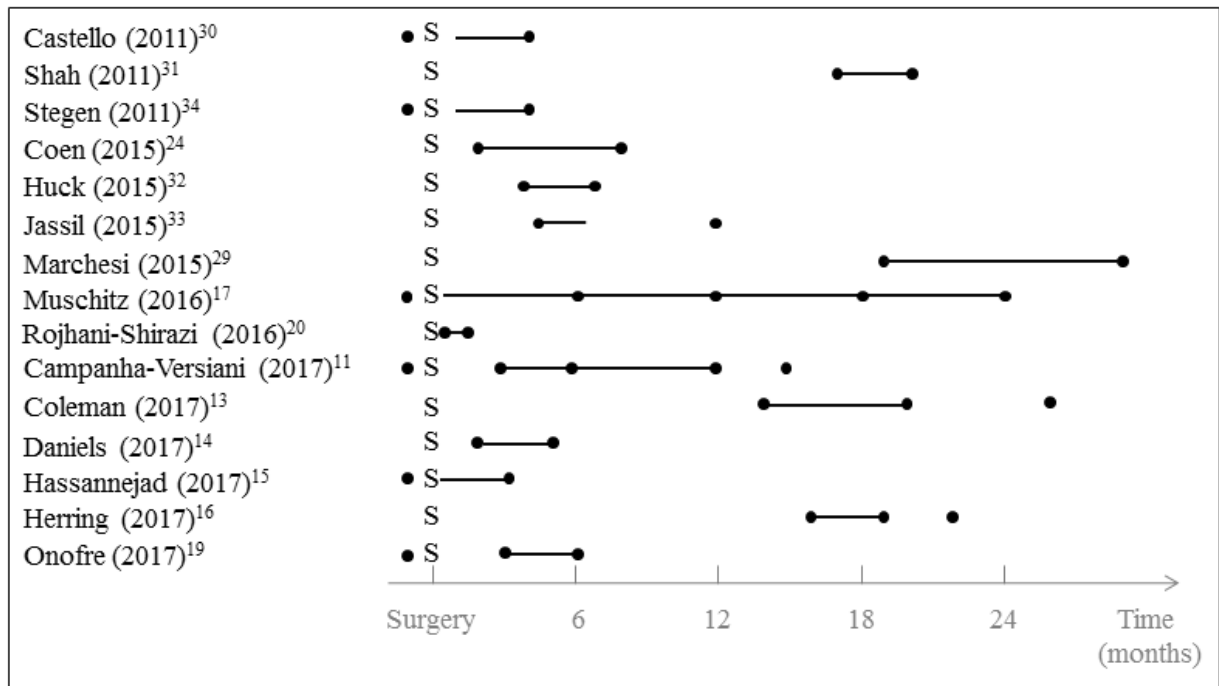
	<b>Criteria</b>											<b>Total score</b>	<b>Coding</b>
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>		
Castello et al. (2011) <sup>30</sup>	1	1	1	1	0	0	0	0	0	1	1	<b>5</b>	<b>Fair</b>
Shah et al. (2011) <sup>31</sup>	1	1	0	1	0	0	0	0	1	1	1	<b>5</b>	<b>Fair</b>
Stegen et al. (2011) <sup>34</sup>	0	0	0	0	0	0	0	0	0	1	1	<b>5</b>	<b>Fair</b>
Coen et al. (2015) <sup>24</sup>	1	1	1	1	0	0	1	1	1	1	1	<b>8</b>	<b>Good</b>
Huck et al. (2015) <sup>32</sup>	0	0	0	1	0	0	0	0	1	1	1	<b>4</b>	<b>Fair</b>
Jassil et al. (2015) <sup>33</sup>	1	0	0	1	0	0	0	0	0	1	1	<b>3</b>	<b>Poor</b>
Muschitz et al. (2015) <sup>17</sup>	1	1	1	1	0	0	0	0	1	1	1	<b>6</b>	<b>Good</b>
Marchesi et al. (2015) <sup>29</sup>	1	0	0	1	0	0	0	0	0	1	1	<b>3</b>	<b>Poor</b>
Rojhani-Shirazi et al. (2016) <sup>20</sup>	0	1	0	1	0	0	0	0	0	1	1	<b>4</b>	<b>Fair</b>
Campanha-Versiani et al. (2017) <sup>11</sup>	1	0	1	1	0	0	0	0	0	1	1	<b>4</b>	<b>Fair</b>
Coleman et al. (2017) <sup>13</sup>	1	1	1	1	0	0	0	0	1	0	1	<b>5</b>	<b>Fair</b>
Daniels et al. (2017) <sup>14</sup>	0	1	0	0	0	0	0	1	1	1	1	<b>5</b>	<b>Fair</b>
Hassannejad et al. (2017) <sup>15</sup>	1	1	1	1	0	0	0	1	0	1	1	<b>6</b>	<b>Good</b>
Herring et al. (2017) <sup>16</sup>	1	1	1	0	0	0	0	1	1	1	1	<b>6</b>	<b>Good</b>
Onofre et al. (2017) <sup>19</sup>	1	0	0	1	0	0	0	1	1	1	1	<b>5</b>	<b>Fair</b>

**Table 3**

	Number of studies		
	Measuring the outcome	Reporting no difference between exercise and control groups	Reporting an improvement in exercise group vs. control group
Muscle strength			
Lower-limb 1-RM	3	0	3
Upper-limb 1-RM	4	1	3
Handgrip strength	3	1	2
Physical activity and energy metabolism			
MVPA	2	1	1
Daily steps	3	2	1
Mitochondrial respiration	1	0	1
Resting EE	2	2	0
Quality of life	4	4	0
Metabolic profile			
Glucose metabolism	3	2	1
Lipid profile	3	3	0
Blood pressure	4	3	1

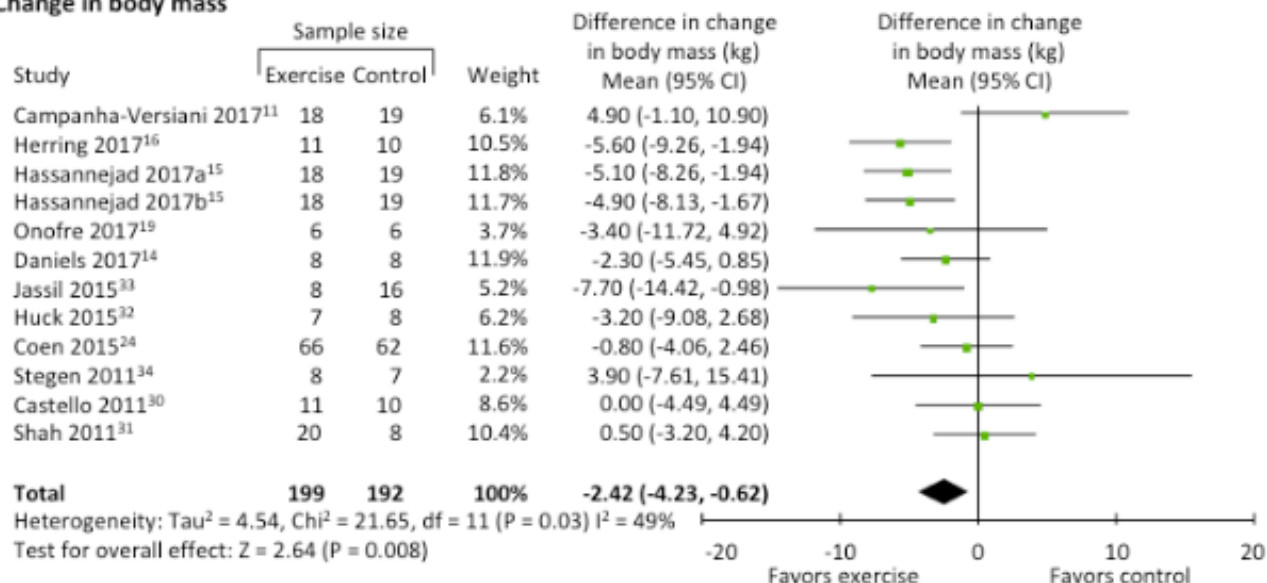


**Figure 1**

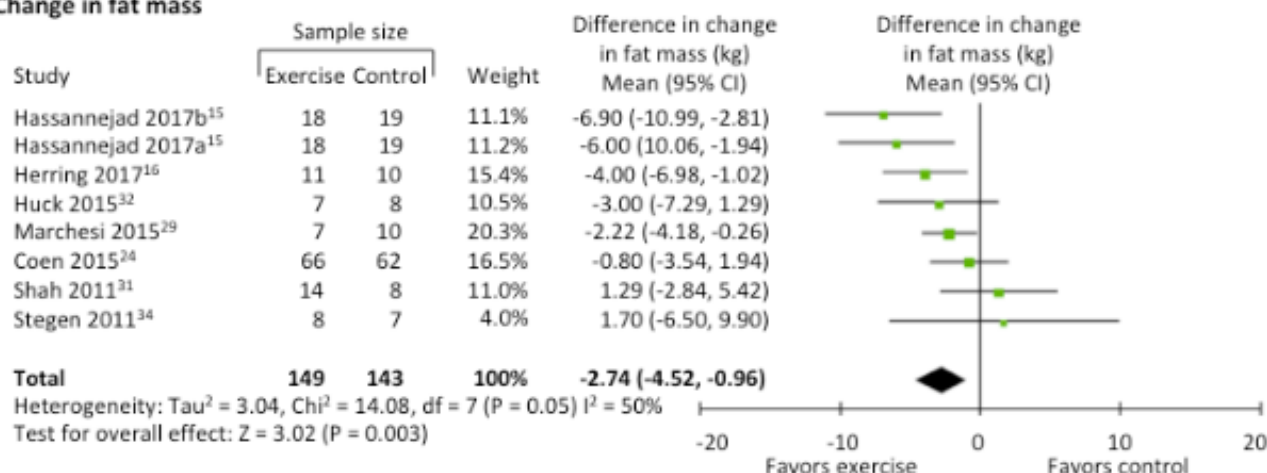


**Figure 2**

### Change in body mass



### Change in fat mass



### Change in lean body mass

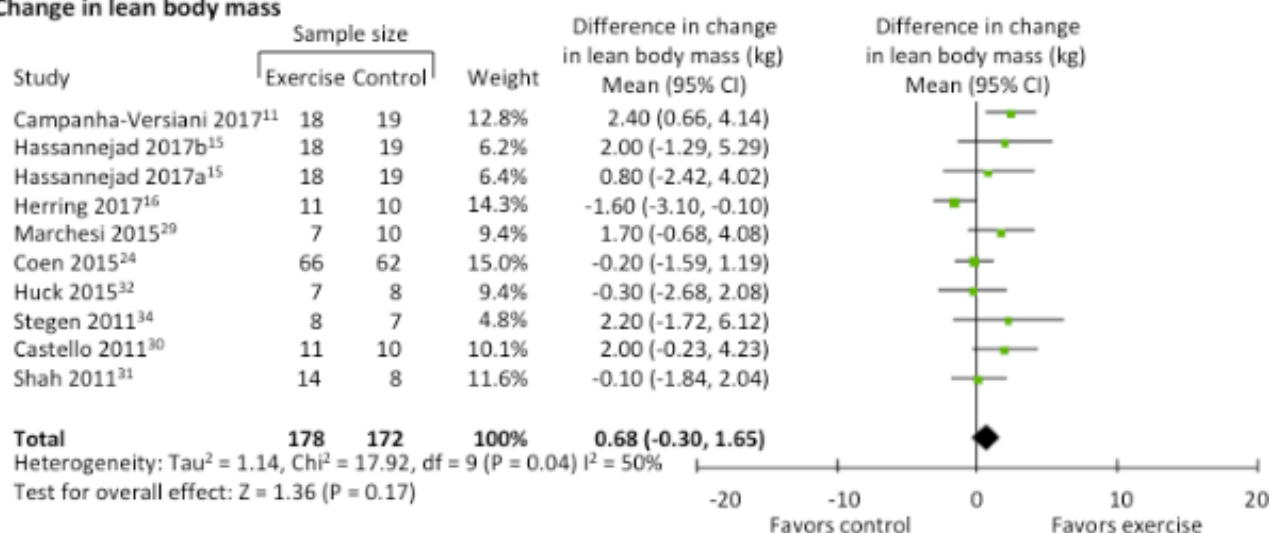
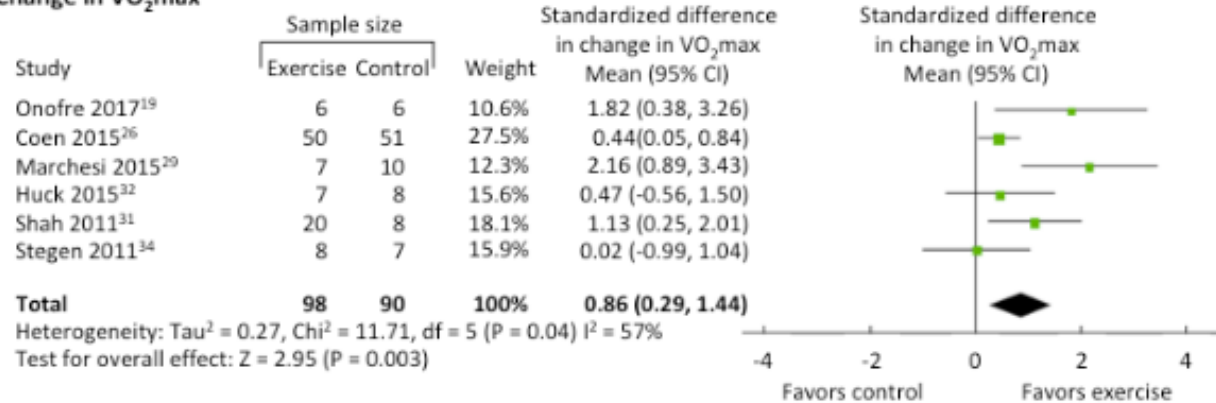


Figure 3

### Change in VO<sub>2</sub>max



### Change in functional walking

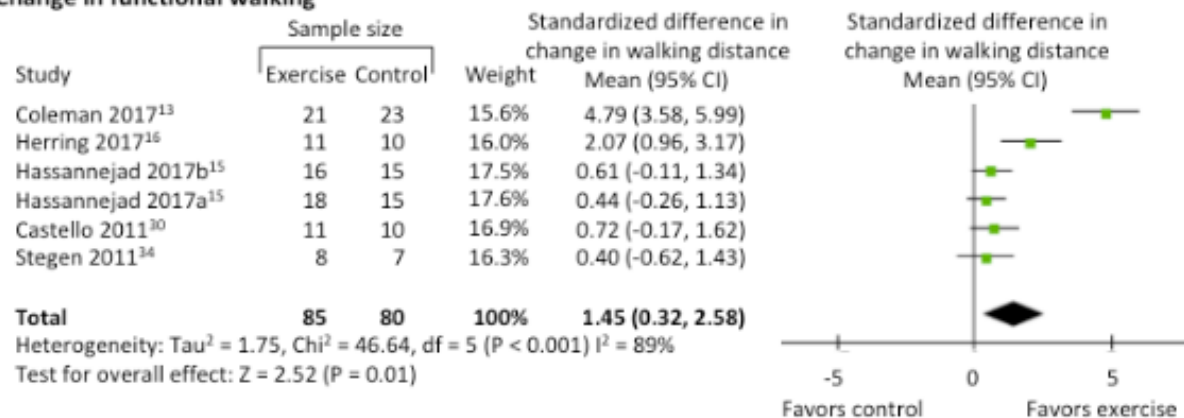


Figure 4