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

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

15

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42 **Potential conflict of interest**

43 Authors declare that they have no conflict of interest.

44 **Abstract**

45 We aimed to conduct a systematic review and meta-analysis of controlled trials assessing  
46 exercise training programs in patients with obesity undergoing bariatric surgery. We  
47 systematically searched exercise training studies performed after bariatric surgery published  
48 up to June 2017. Studies reporting changes in body composition, physical fitness, functional  
49 capacity, objectively-measured physical activity, quality of life or relevant health outcomes  
50 were included. The review protocol is available from PROSPERO (CRD42017069380).  
51 Meta-analyses were conducted using random-effects models when data were available from at  
52 least 5 articles. Twenty articles were included, describing 16 exercise training programs, of  
53 which 15 were included in the meta-analysis. Overall, exercise training was associated with  
54 higher weight loss (mean difference: -2.4 kg, 95% CI: -4.2;-0.6,  $I^2=49%$ , n=12), higher fat  
55 mass loss (-2.7 kg, 95% CI: -4.5;-1.0,  $I^2=50%$ , n=8), improved  $VO_2$ max and functional  
56 walking (standardized mean difference: 0.86, 95% CI: 0.29;1.44,  $I^2=57%$ , n=6; 1.45, 95% CI:  
57 0.32;2.58,  $I^2=89%$ , n=6, respectively). Exercise training was not associated with lean body  
58 mass changes. In conclusion, exercise training programs performed after bariatric surgery  
59 were found effective to optimize weight loss and fat mass loss and to improve physical  
60 fitness, although no additional effect on lean body mass loss were found.

61 **Introduction**

62

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

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

70

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

85

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

88

## 89 **Materials and Methods**

90

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

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

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

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

118

### 119 **Quality assessment**

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

131

### 132 **Reporting of findings**

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



136 cardiorespiratory fitness (assessed by a maximal exercise test) and maximal muscle strength.  
137 Functional capacity was assessed with field-based fitness assessments (e.g. 6-minute walk  
138 test, sit-to-stand test, half-squat test, arm curl test, chair sit-and-reach test, 8- foot up-and-go).  
139 Functional walking refers to the distance walked during walking tests. To facilitate the  
140 synthesis of results, we grouped related metabolic outcomes into broader categories, e.g.  
141 fasting or post-prandial glucose and insulin, HOMA-IR, insulin sensitivity, insulin  
142 responsiveness were grouped into a category named “glucose metabolism”; or total, LDL- or  
143 HDL-cholesterol and triglycerides into the “lipid profile” category.  
144 When several follow-up measurements were conducted, we reported results from the first  
145 assessment after the end of the exercise training. When results of a single trial were reported  
146 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>),  
147 we selected results from the parent trial or from the study with the largest sample size.

148

#### 149 **Data analysis**

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

159 Data from intention-to-treat analyses were included whenever available in included studies.

160 Pooled-effect estimates were expressed as the weighted mean difference between exercise and

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

173

## 174 **Results**

175

### 176 **Study characteristics and quality**

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

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

193

#### 194 **Study quality**

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

203

#### 204 **Description of interventions**

205 Interventions are described in detail in Table S2. Exercise started from 1 week after surgery<sup>20</sup>  
206 to 18 months after surgery<sup>29</sup>. Duration of exercise training ranged from 1 month<sup>20</sup> to 24  
207 months<sup>17</sup>, with a median duration of 3 months (Figure 2). Endurance training was performed  
208 in 5 studies<sup>15, 24, 29-31</sup>, resistance training in 2 studies<sup>14, 32</sup>, a combination of endurance and  
209 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  
210 exercise was usually defined in relative terms, according to maximal heart rate or maximal

211 strength. The intervention included a behavioral component in 4 studies (physical activity  
212 and/or dietary counseling<sup>13, 29, 31, 33</sup> and a protein, calcium and vitamin D supplementation in 1  
213 study<sup>17</sup>). Exercise sessions were fully supervised (10 studies<sup>11, 13, 16, 19, 29-34</sup>), partially  
214 supervised (1 study<sup>24</sup>) or not supervised (2 studies<sup>15, 17</sup>). Supervision was not described in 1  
215 study<sup>20</sup>. Supervision was performed by physical activity specialists, physiotherapists, exercise  
216 physiologists or experts in physical medicine. Sessions were performed in a hospital or  
217 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  
218 study each. Only 1 study described that sessions were organized in groups<sup>32</sup>. One study  
219 sought to increase adherence by proposing a variety of exercise modalities<sup>13</sup>. Most studies  
220 provided no or very little information about the control group. The intervention received by  
221 control patients, described in 7 studies, included physical activity and/or dietary counseling  
222 sessions<sup>11, 13, 17, 19, 24, 31, 32</sup>, with multivitamin and mineral supplementation indicated in 3  
223 studies<sup>11, 17, 31</sup>.

224

## 225 **Compliance**

226 The percentage of included participants who completed the study ranged from 60%<sup>11</sup> to  
227 100%<sup>14, 19, 24</sup> (Table S3). Only 2 studies performed analysis for completers, defined as patients  
228 participating to either a minimum number of training sessions ( $\geq 80\%$ <sup>17</sup>) or a minimum  
229 duration of training ( $\geq 120$  min/week)<sup>24</sup>. In these studies, completers represented around 70%  
230 of all participants. Finally, 3 studies reported attendance to training sessions<sup>16, 32, 33</sup> that ranged  
231 from 75%<sup>33</sup> to 95%<sup>16</sup>.

232

## 233 **Effectiveness of interventions**

234

235 Overall, exercise training was associated with a higher loss in body mass (-2.4 kg, 95% CI: -  
236 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  
237 studies) compared to the control group but was not associated with changes in lean body mass  
238 (0.7 kg, 95% CI: -0.3, 1.7,  $I^2=50%$ , n=10 studies) (Figure 3). Exercise training was also  
239 associated with an improvement in  $VO_2$ max (standardized mean difference: 0.86, 95% CI:  
240 0.29, 1.44,  $I^2=57%$ , n=6 studies), and in functional walking (standardized mean difference:  
241 1.45, 95% CI: 0.32, 2.58,  $I^2=89%$ , n=6 studies) (Figure 4).

242 Sub-sample analyses were performed on  $VO_2$ max expressed relative to body mass, reported in  
243 5 studies<sup>19, 29, 31, 32, 34</sup>. A mean difference of 2.87 mL/kg/min (95% CI: 0.63, 5.12,  $I^2=83%$ )  
244 was found.

245

246 Changes in muscle strength, objectively-measured habitual physical activity, metabolic profile  
247 and health related-quality of life were not included in the meta-analysis. Muscle strength  
248 increased in most studies in the exercise group compared to the control group (Table 3).

249 Objectively-measured physical activity, metabolic profile (glucose metabolism, lipid profile,  
250 blood pressure) and health-related quality of life were found unchanged after exercise  
251 compared to control in most studies (Table 4).

252

## 253 **Discussion**

254

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

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

265

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

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

286

287 Another major finding of this meta-analysis was that exercise training further improved  
288 physical fitness and physical function as assessed by walking tests. Overall, VO<sub>2</sub>max was  
289 improved in the exercise training group, compared to the control group, by a mean 2.9  
290 mL/kg/min. Although not included in the meta-analysis, muscle strength also increased after  
291 exercise training in most studies, whether assessed as lower-limb<sup>11, 14, 34</sup> or upper-limb<sup>11, 15, 16,</sup>  
292 <sup>34</sup> maximal strength. Cardiorespiratory fitness and muscle strength are predictors of mortality  
293 risk both in healthy individuals and in patients with chronic diseases, including obesity<sup>37-40</sup>.  
294 According to a meta-analysis with a combined sample size of over 100,000 participants, each  
295 1-MET increase in cardiorespiratory fitness was associated with a 15% and 13% reduction in  
296 all-cause and cardiovascular mortality, respectively<sup>41</sup>. The improvement in cardiorespiratory  
297 fitness with exercise training observed in the present meta-analysis is therefore likely to be  
298 associated with improved health status after bariatric surgery. Interestingly, additive effects  
299 between low cardiorespiratory fitness and muscle strength have been reported<sup>42</sup>, which  
300 emphasizes the need to promote both dimensions of physical fitness in patients with obesity  
301 undergoing bariatric surgery.

302

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

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

329

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



334 frequent limitation of non-pharmacological interventions<sup>45</sup>. Better describing the intervention  
335 delivered to both the intervention and control groups would help interpret study results and  
336 replicate studies in real-life settings<sup>21</sup>. Included studies were also characterized by important  
337 variations in terms of intervention (type, duration and timing) and evaluation (timing of  
338 assessment, assessment tools, data analysis and reporting). To date, data are insufficient to  
339 answer important research questions, such as the effect by type of exercise, relevant  
340 intervention duration or intervention timing, the additional effect of supervising exercise  
341 sessions and the long term effect of exercise training. Two thirds of exercise programs lasted  
342 3 months or less, which might be too short to observe a significant impact on health  
343 outcomes. Interestingly, Muschitz et al.<sup>17</sup> observed that the preservation of lean body mass  
344 became significant only after 18 months of intervention, during the weight stabilization phase.  
345 Long-term trials are needed to determine the most effective duration and timing of exercise  
346 training programs in patients with obesity undergoing bariatric surgery.

347

## 348 **Conclusion**

349 Exercise training programs performed after bariatric surgery were found effective to increase  
350 weight loss and fat mass loss and to improve physical fitness, although no additional effect on  
351 lean body mass or health outcomes were found compared to usual care follow-up. This meta-  
352 analysis provides evidence that exercise training is an effective strategy to optimize follow-up  
353 care after bariatric surgery. Both health professionals and patients should be aware of the type  
354 of benefits they should expect from an exercise program in this context, especially given the  
355 fact that additional weight and fat loss with exercise was of relatively small magnitude.  
356 Included studies were characterized by important heterogeneity, precluding an analysis by  
357 type and amount of exercise. More studies are needed to identify the most effective and  
358 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.

362

363 **Conflict of Interest Disclosure Statement**

364 Authors declare that they have no conflict of interest.

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500

501 **Tables titles and legends**

502

503 **Table 1**

504 Title: Characteristics of included studies (N=20)

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

507 Abbreviations, RCT, randomized controlled trial; NRCT, non-randomized controlled trial;

508 RYGB, Roux-en-Y gastric bypass; SG, sleeve gastrectomy; GB, gastric banding; END,

509 endurance training; RES, resistance training, BALANCE, balance training; 6MWT, 6-minute

510 walk test; WC, waist circumference; TC, total cholesterol; TG, triglycerides; NA, not

511 available.

512

513 **Table 2**

514 Title: Results on study quality

515 Legend: PEDro criteria: (1) specification of eligibility criteria, (2) random allocation, (3)

516 concealed allocation, (4) baseline comparability, (5) blind subjects, (6) blind therapists, (7)

517 blind assessor, (8) adequate follow up, (9) intention-to-treat-analysis, (10) between groups

518 comparisons, (11) point estimates and variability.

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

520

521 **Table 3**

522 Title: Changes in muscle strength, physical activity, quality of life and metabolic profile in

523 exercise group compared to control group

524 Legend:

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

528

## 529 **Figures titles and legends**

530

### 531 **Figure 1:**

532 Title: Flow chart of the literature search

533

### 534 **Figure 2:**

535 Title: Timing of intervention and assessment

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

540

### 541 **Figure 3**

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

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

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

549

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**

<b>Authors</b>	<b>Country</b>	<b>Study design</b> <b>Sample size</b> <b>Surgery type</b>	<b>Intervention</b> <b>(in addition to usual care)</b>	<b>Outcomes</b>	<b>Measures for corresponding outcomes</b>
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 - Skinfolds - 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. (2015) <sup>25</sup>	USA	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	- Intramyocellular lipids - Mitochondrial respiration - Lipid profile: TC, LDL-c, HDL-c, TG - Blood pressure - Anthropometry: body weight - Body composition - VO <sub>2</sub> peak - Resting metabolic rate - Glucose metabolism: insulin sensitivity - Mitochondrial respiration - Lipid oxidation - Anthropometry: body weight - Body composition - Skeletal muscle mass - Physical activity and sedentary behavior - VO <sub>2</sub> peak - Resting metabolic rate - Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> peak: maximal exercise test - Glucose metabolism: insulin sensitivity - MicroRNAs profiling - Lipid profile: TC, LDL-c, HDL-c, TG - Blood pressure	- Muscle biopsy - Muscle biopsy - Blood analyses - Clinical examination - Clinical examination - DEXA - Maximal exercise test - Indirect calorimetry - Intravenous glucose tolerance test - Muscle biopsy - Muscle biopsy - Clinical examination - DEXA - Computed tomography - Accelerometer - Maximal exercise test - Indirect calorimetry - Clinical examination - DEXA - Maximal exercise test - Intravenous glucose tolerance test - Arterialized blood analyses - Blood analyses - Clinical examination
Carnero et al. (2017) <sup>12</sup>	USA	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	- Anthropometry: body weight - Body composition - Skeletal muscle mass - Physical activity and sedentary behavior - VO <sub>2</sub> peak - Resting metabolic rate - Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> peak: maximal exercise test - Glucose metabolism: insulin sensitivity - MicroRNAs profiling - Lipid profile: TC, LDL-c, HDL-c, TG - Blood pressure	- Clinical examination - DEXA - Computed tomography - Accelerometer - Maximal exercise test - Indirect calorimetry - Clinical examination - DEXA - Maximal exercise test - Intravenous glucose tolerance test - Arterialized blood analyses - Blood analyses - Clinical examination
Nunez Lopez et al. (2017) <sup>18</sup>	USA	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	- Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> peak: maximal exercise test - Glucose metabolism: insulin sensitivity - MicroRNAs profiling - Lipid profile: TC, LDL-c, HDL-c, TG - Blood pressure	- Clinical examination - DEXA - Maximal exercise test - Intravenous glucose tolerance test - Arterialized blood analyses - Blood analyses - Clinical examination
Huck et al. (2015) <sup>32</sup>	USA	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	- Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> max - Muscle strength - Physical function	- Clinical examination - Impedance - Maximal exercise test - Weight machines, handgrip dynamometer - Sit-to-stand test, chair sit-and-reach test
Jassil et al. (2015) <sup>33</sup>	UK	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	- Anthropometry: body weight - Physical function - Quality of life	- Clinical examination - 6MWT - Dartmouth COOP
Marchesi et al. (2015) <sup>29</sup>	Italy	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	- Anthropometry: body weight, WC - Body composition - VO <sub>2</sub> max - Quality of life - Lipid profile: TC, HDL-c, TG - Glucose metabolism: glucose	- Clinical examination - DEXA - Maximal exercise test - SF-36 - Blood analyses - Blood analyses

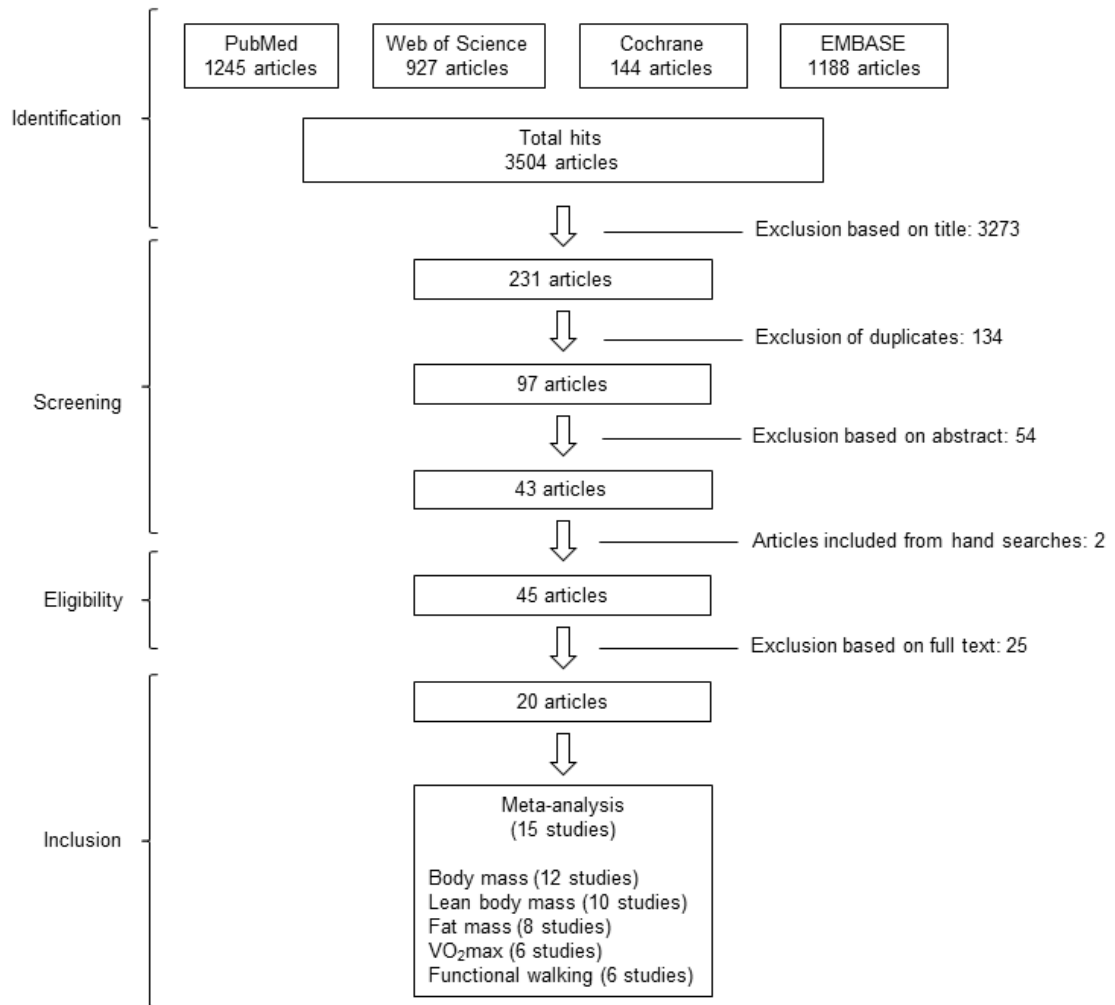
Muschitz et al. (2016) <sup>17</sup>	Austria	RCT n=220 W+M RYGB, SG	<u>Type:</u> END + RES, 3 and 2 sessions/week + protein, calcium, vit. D supplementation <u>Supervision:</u> none <u>Timing:</u> 24 months, starting 2 week after surgery	- Anthropometry: body weight) - Body composition - Bone mineral 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**

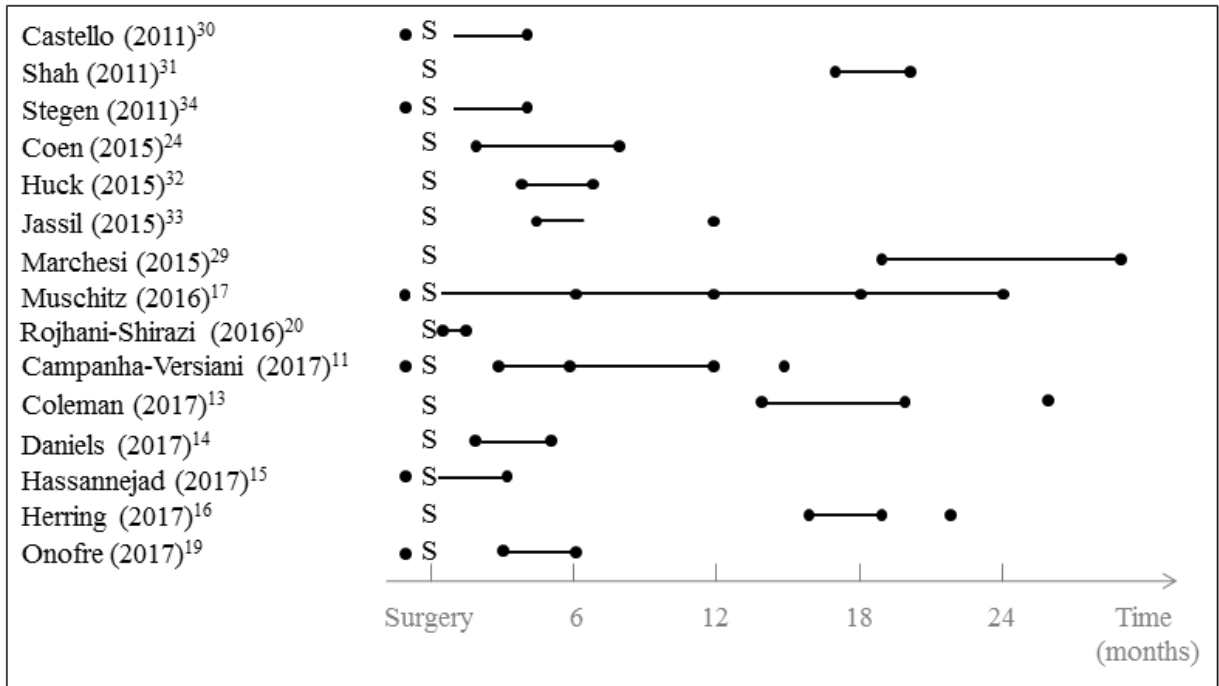
	<b>Criteria</b>											<b>Total score</b>	<b>Coding</b>
	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>		
Castello et al. (2011) <sup>30</sup>	1	1	1	1	0	0	0	0	0	1	1	<b>5</b>	<b>Fair</b>
Shah et al. (2011) <sup>31</sup>	1	1	0	1	0	0	0	0	1	1	1	<b>5</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
<b>Muscle strength</b>			
Lower-limb 1-RM	3	0	3
Upper-limb 1-RM	4	1	3
Handgrip strength	3	1	2
<b>Physical activity and energy metabolism</b>			
MVPA	2	1	1
Daily steps	3	2	1
Mitochondrial respiration	1	0	1
Resting EE	2	2	0
<b>Quality of life</b>	4	4	0
<b>Metabolic profile</b>			
Glucose metabolism	3	2	1
Lipid profile	3	3	0
Blood pressure	4	3	1

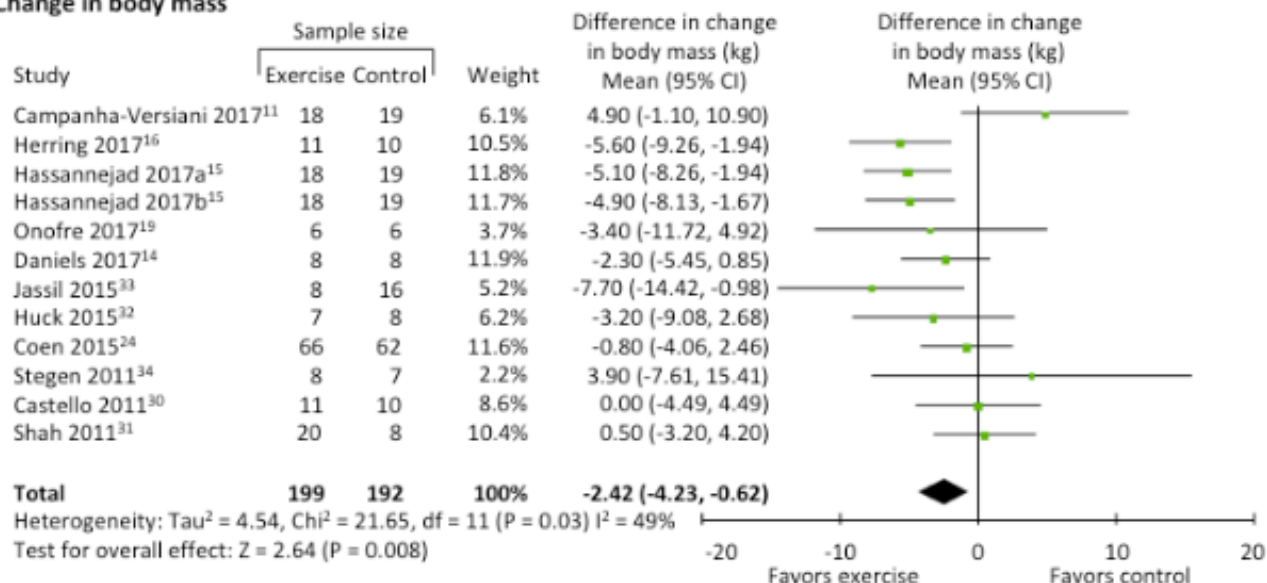


**Figure 1**

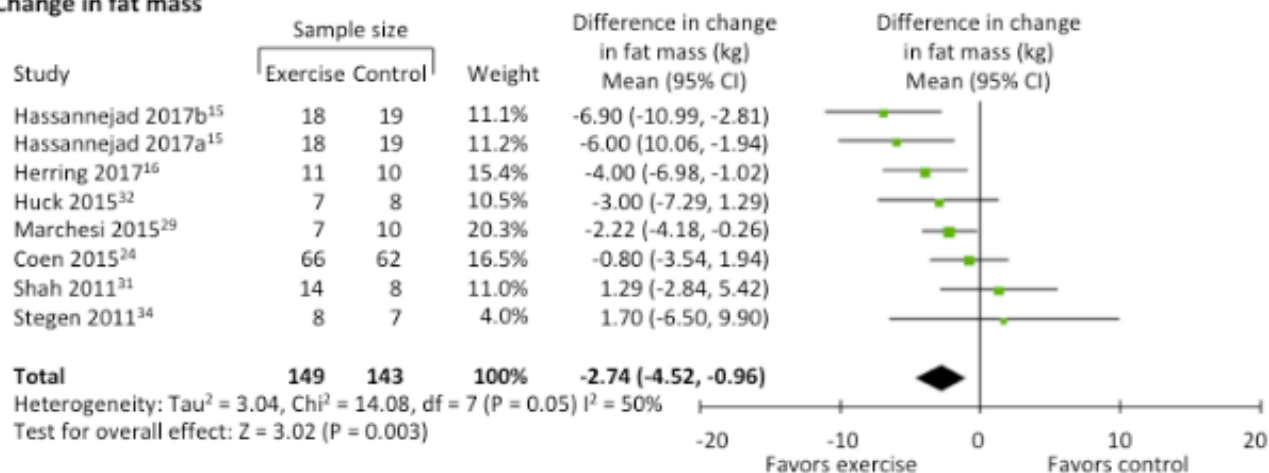


**Figure 2**

### Change in body mass



### Change in fat mass



### Change in lean body mass

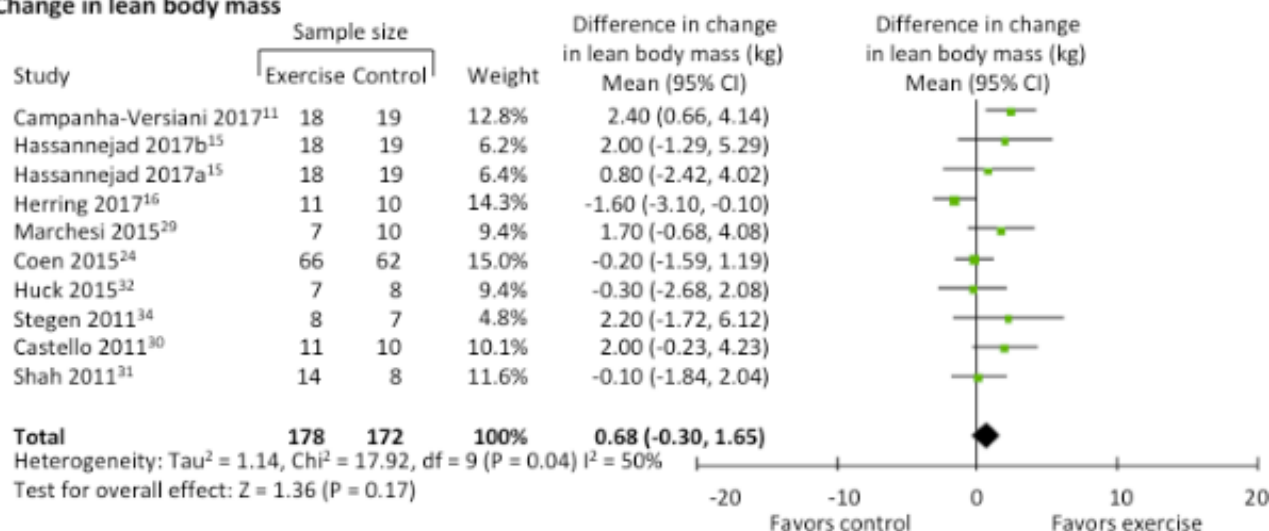


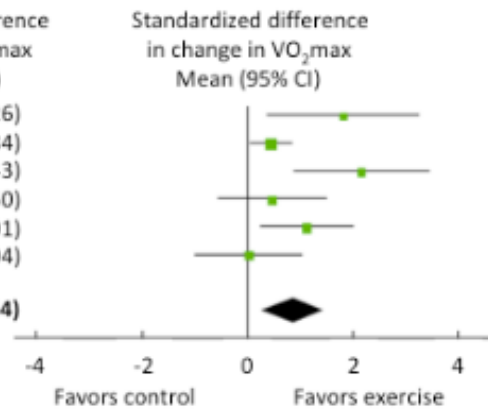
Figure 3



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

Study	Sample size		Weight	Standardized difference in change in VO <sub>2</sub> max Mean (95% CI)
	Exercise	Control		
Onofre 2017 <sup>19</sup>	6	6	10.6%	1.82 (0.38, 3.26)
Coen 2015 <sup>26</sup>	50	51	27.5%	0.44(0.05, 0.84)
Marchesi 2015 <sup>29</sup>	7	10	12.3%	2.16 (0.89, 3.43)
Huck 2015 <sup>32</sup>	7	8	15.6%	0.47 (-0.56, 1.50)
Shah 2011 <sup>31</sup>	20	8	18.1%	1.13 (0.25, 2.01)
Stegen 2011 <sup>34</sup>	8	7	15.9%	0.02 (-0.99, 1.04)
<b>Total</b>	<b>98</b>	<b>90</b>	<b>100%</b>	<b>0.86 (0.29, 1.44)</b>

Heterogeneity: Tau<sup>2</sup> = 0.27, Chi<sup>2</sup> = 11.71, df = 5 (P = 0.04) I<sup>2</sup> = 57%  
 Test for overall effect: Z = 2.95 (P = 0.003)



### Change in functional walking

Study	Sample size		Weight	Standardized difference in change in walking distance Mean (95% CI)
	Exercise	Control		
Coleman 2017 <sup>13</sup>	21	23	15.6%	4.79 (3.58, 5.99)
Herring 2017 <sup>16</sup>	11	10	16.0%	2.07 (0.96, 3.17)
Hassannejad 2017b <sup>15</sup>	16	15	17.5%	0.61 (-0.11, 1.34)
Hassannejad 2017a <sup>15</sup>	18	15	17.6%	0.44 (-0.26, 1.13)
Castello 2011 <sup>30</sup>	11	10	16.9%	0.72 (-0.17, 1.62)
Stegen 2011 <sup>34</sup>	8	7	16.3%	0.40 (-0.62, 1.43)
<b>Total</b>	<b>85</b>	<b>80</b>	<b>100%</b>	<b>1.45 (0.32, 2.58)</b>

Heterogeneity: Tau<sup>2</sup> = 1.75, Chi<sup>2</sup> = 46.64, df = 5 (P < 0.001) I<sup>2</sup> = 89%  
 Test for overall effect: Z = 2.52 (P = 0.01)

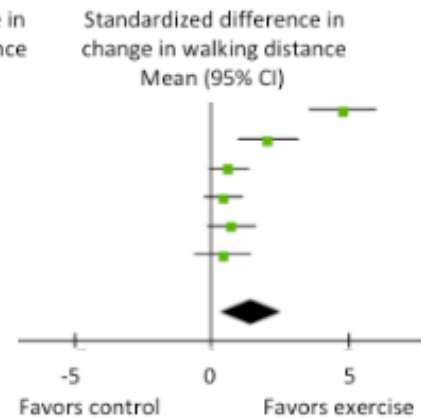


Figure 4