Exercise Training in Metabolic and Bariatric Surgery: An Overview of Systematic Reviews

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Abstract

Understanding how to incorporate exercise into metabolic and bariatric surgery programs to optimize treatment outcomes is of great interest, as evidenced by 11 reviews published on this topic in 2022 alone. This overview of reviews was conducted to create a single cohesive resource to aid clinicians and researchers by exploring the effects of pre- and postoperative exercise training on health outcomes. A literature search of seven electronic databases was performed (updated 09/2023) and 24 reviews met preset PICOS eligibility criteria and were included: 4 exploring preoperative exercise training, 13 postoperative, and 7 both. Comparing reviews, outcome results were organized as concordant, discordant, or inconclusive, and then categorized into "what we currently know", "what we think we know" and "what we still don't know". We do not currently know the effects of pre- or postoperative exercise training on any outcomes, but we think we know that preoperative exercise training has a positive effect on BMI and 6-minute walking test distance, and postoperative exercise training has a positive effect on body weight and BMI, waist circumference, bone mineral density, 6-minute walking test distance, muscle strength, and systolic blood pressure. Despite the abundance of research, much still needs to be done in terms of enhancing methodological rigor and reporting to achieve greater confidence in our conclusions; recommendations for next research steps are made

Keywords: Umbrella review; Physical activity; Obesity

Introduction

Metabolic and bariatric surgery (MBS) offers a multitude of health benefits beyond weight loss to the growing number of adults living with obesity.[1] Patients experience improved health related quality of life (QoL),[2] improved insulin sensitivity,[3] and reduced type 2 diabetes and other cardiometabolic risk factors (e.g., reduced triglycerides and total cholesterol).[3] However, like with all obesity treatments, MBS patients can experience recurrence of weight gain and related conditions[3,4] For example, a large cohort study (*N*=1406) found that 67% of participants who underwent Roux-en-Y gastric bypass regained ≥ 20% of their maximum weight loss five years after reaching nadir weight.[5] Consequently, adjunct interventions, including exercise training (ET), have been explored to mitigate these and other undesirable postoperative outcomes (e.g., decreased bone mineral density).[3]

The potential benefits of exercise and physical activity (PA) are well-documented in adults pre- and postMBS, and numerous systematic reviews have concluded that ET in this population (1) is feasible and acceptable,[6] (2) reduces cardiometabolic risk factors[7] and body weight,[8–11] (3) increases muscle strength[10,12] and cardiorespiratory fitness,[7,10,13,14] and (4) improves the maintenance of bone mineral density.[10,15] Notably, these types of reviews are on the rise. In 2022 alone, eight meta-analyses[6,8,12,13,15–18] and three systematic reviews[19–21] exploring exercise interventions (including ET and PA counselling) pre- and postMBS were published. Such amassed information can be incredibly difficult to navigate; thus, an overview of these reviews is necessary to provide a resource that summarizes evidence-based knowledge for researchers and clinicians to support adults undergoing MBS. This overview of systematic reviews focuses on ET (i.e., prescribed and often supervised exercise) rather than PA counselling (i.e., interventions to increase motivation to engage in PA through behavioural change techniques)[22] and addresses the following questions: (1) What are the anthropometric, body composition, functional capacity, PA, muscle strength, cardiometabolic, QoL, psychological, and surgical outcomes of ET pre- and postMBS? (2) Are there any ET characteristics (i.e., modality, duration, timing) associated with better health outcomes? (3) What is the feasibility and acceptability of ET in adults awaiting, or who have undergone MBS? Additionally, we aimed to: (1) synthetize available evidence on these questions, (2) identify concordance/discordance between the systematic reviews results, along with their strengths and limitations, and (3) explore potential explanations for discordant findings between systematic reviews, if present. Ultimately, this work will help to identify the gaps in the literature that can be addressed through future prospective clinical trials in order to establish exercise and PA guidelines for MBS patients.

Materials and Methods

This overview of reviews was registered in PROSPERO (CRD42022360120) in 2022 (minor amendments are addressed in Appendix A) and reported in accordance with the Preferred Reporting Items for Overviews of Reviews (PRIOR) reporting guidelines (see Appendix B for checklist).[23]

Eligibility Criteria

To guide the search process, key elements of the research question were identified *a priori* using the Population, Intervention, Comparison, Outcomes and Study Design (PICOS) framework (details provided in Table 1).[24,25] Publications that were not available in English or

French were excluded. Further, reviews including studies that combined ET with additional intervention strategies (e.g., dietary, therapeutic etc.) were only included if their control group was matched such that they received the same intervention without the ET component (e.g., exercise + protein vs only protein). Additionally, reviews that included only studies focusing on behavioral intervention to promote PA, without prescribed ET, were excluded. In addition, publications that reviewed ET delivered both pre- and postMBS were only included if the results were synthesized, or could be interpreted, separately for the two time points.

[insert Table 1 near here]

Information Sources and Search Strategy

A search strategy was created by a research librarian (VL) and conducted on November 21st, 2022, in MEDLINE (Ovid), Embase (Ovid), PsycInfo (Ovid), Cochrane Database of Systematic Reviews (Ovid), CINAHL (EBSCOhost), SPORTDiscus (EBSCOhost), and Scopus (see Appendix C for full search details). No limits to language or publication date were applied. The main search concepts comprised of terms related to MBS, exercise, and systematic reviews. An updated search was performed by VL using the same strategy on September 1st, 2023, for reviews published since the initial search. Reference lists from eligible systematic reviews were manually checked by two reviewers (MA and AB) to identify other potentially relevant systematic reviews.

Study Selection

Bibliographical records were extracted and imported into Covidence software (Veritas Health Innovation, Melbourne, Australia), and duplicates were eliminated using the Covidence platform’s duplicate identification feature. Next, two reviewers (MA and AD, then AB and JH for the update) independently screened all records against eligibility criteria (see Table 1) by titles and abstracts, and then screened the full texts. Disagreements were resolved by AB, and for the updated search two reviewers (AB and JH) met to discuss and reach a consensus on the included articles. Reviews were not excluded on the basis of overlapping PICOS criteria as the aim was to summarize the full body of available evidence.

Data Extraction

The data extraction was completed using Microsoft Excel by a single reviewer (IZS) and verified by a second reviewer (MA). Another reviewer (AB) synthesized the data into tables which were verified by a fourth reviewer (JH). Relevant details were extracted from the article text and supplementary files; the list of extracted variables is summarized in accordance with their subject (i.e., the review or the primary articles) in Table 2. Data were also extracted from available tables in the case where (1) results text included a synthesis of combined pre- and postoperative ET details or combined intervention types (e.g., exercise and diet interventions) and/or (2) outcomes that were discussed in the text required further elaboration (e.g., if the review text discusses a single primary article where weight loss significantly improved after ET, the article tables could then be explored to determine the additional number of studies that show no significant difference on weight loss). Similarly, sub analysis results were extracted from meta-analyses when available. Data was extracted from articles and reported *as is,* i.e., additional efforts were not made to locate missing/discrepant data or, when not reported, to assess the risk of bias (ROB) for included primary articles or the level of confidence of conducted analyses.

[insert Table 2 near here]

Risk of Bias of Included Systematic Reviews

The methodological quality of each review was assessed independently by two reviewers (AB and MA) using the AMSTAR 2 rating scale,[26] and disagreements were resolved by a third reviewer (YW). The authors critical item list was followed, however, item 7 was removed in agreement with Ferguson et al[27] because providing a list of excluded original articles with reasons for exclusion is not required by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines.[28] Additionally, as done in Chaput et al,[29] item 16 was modified such that conflict of interest was only required to be reported for the review, and not the review plus all included articles. As per AMSTAR 2 criteria, the present review rated the methodological quality as high, moderate, low or critically low.[26]

Certainty of Evidence of Randomized Controlled Trial-Only Meta-Analyzed Outcomes

The GRADE approach for overviews of reviews developed by Pollock and colleagues was used to assess certainty of evidence (COE)[30]. Following Pollock et al's[30] recommendation to focus on randomized controlled trials (RCT), two authors (JH, YW) independently calculated the COE for RCT-only meta-analyzed comparisons (n_{total}=61; n_{preMBS}= 10, $n_{postMBS}$= 40, $n_{postMBS\ sub}$=11). Downgrades were assigned based on (1) sample size ($n \geq 200$ no downgrade, n=100-199 one downgrade, and n=1-99 two downgrades), (2) trial quality (≥75% of participants have low/good ROB no downgrade and <75% have low/good ROB one downgrade), (3) heterogeneity ($I^2 \leq 75\%$ no downgrade and $I^2 > 75\%$ one downgrade), and (4) review quality based on AMSTAR2 evaluation (zero critical absence no downgrade, one critical absence one downgrade, and two or more critical absences two downgrades). COE was scored based on the total number of downgrades where high=0, moderate=1-2, low=3-4, and very low=5-6.

Data Synthesis

Synthesis of Review Data: Individual Review Findings

Outcome data were summarized as they were presented in the reviews and no further statistical analyses on the data were performed. All results were organized based on pre- or postoperative delivery of ET. A summary of (1) review characteristics, (2) details on the primary studies' population and intervention and (3) concordant and discordant findings as a function of the outcome (for the most recent reviews published in the last 5 years, i.e., in or after 2018), are presented narratively. Further, tables were synthesized to detail individual review characteristics and findings, as well as methodological details. Further, results for each outcome were synthesized into tables and conclusions were drawn for each review where (1) "+"/"-"=100% concordance (within a systematic review) or a meta-analysis revealing a significant positive or negative effect, (2) "(+)"/"(-)" =≥67% (i.e., 2/3) concordance within a systematic review for a significant positive or negative effect, (3) "?"=discordant findings within a systematic review, (4) "(NS)"=≥67% concordance within a systematic review for a non significant effect and (5) "NS"=100% concordance (within a systematic review) or a meta-analysis revealing a non significant effect; conclusions for individual reviews were identified as inconclusive if (1) there was only one primary article included, (2) there were multiple primary articles included but they derived from the same original study (i.e. same cohort) or (3) results combined pre- and postMBS results. In addition, results from subanalyses were organized into a table by characteristic (i.e., ET type, starting time, duration and prescribed exercise/week) and subcategories (e.g. endurance [E] vs resistance [R] vs combined endurance/resistance[E/R]), then significant positive effects were identified.

Comparison of Data Between Reviews

To account for many primary articles being present in multiple systematic reviews and meta-analyses, [31,32] several steps outlined by Hennessey and Johnson[32] were followed to assess the degree of overlap: (1) Microsoft excel was used to produce citation matrices in accordance with instructions detailed by Pieper et al.[31], and (2) the corrected cover area (CCA) was calculated across two primary matrices as a function of the ET timing (i.e., pre- or postoperative) and across various secondary matrices as a function of outcome (not including subanalyses). The overlap of studies was interpreted as slight when the CCA was 0-5%, moderate when 6-10%, high when 11-15% and very high when >15%.[31] However, based on the inclusion of systematic reviews addressing the same outcome, high to very high level of overlap was expected.

Next, one of the authors (JH) created a flow diagram (which evolved through discussion with another author [AB]; see Appendix P) in order to determine whether the findings were (a) concordant, (b) discordant with potential explanations, (c) discordant without a known reason or (d) inconclusive, between multiple reviews (1st conclusion). Prior to categorizing a conclusion for each outcome, individual review conclusions were removed from the outcome table if they were a meta-analysis that included multiple primary articles from the same original study and/or the results were combined for ET delivered pre- and postoperatively. Additionally, conclusions for outcomes at one-year postMBS follow up were removed as they all only considered one study.[33] Using the flow diagram, two of the authors (AB and JH) independently categorized the results and then met to reach a consensus. Next, for outcomes with discordant conclusions between multiple reviews, (1) study aims, search strategies and PICOS selection criteria were explored to determine potential reasons for discordance and (2) priority was given to more comprehensive and recent reviews for interpretation of discordant findings.[32].

Categorization of Outcome Findings

Finally, the same flow diagram was followed by two researchers (JH and AB) who independently categorized the findings as “what we currently know”, “what we think we know’ or “what we still don’t know” and met to reach a consensus (2nd conclusion). The “what we currently know” and “what we think we know” categories represent findings where (a) there was concordance between multiple reviews, (b) there was a single review with conclusive findings (i.e., + or NS), (c) there was discordance between reviews with a potential reason and concordance between reviews for a subgroup, or (d) there was discordance between reviews but a review(s), with concordant/conclusive findings, was prioritized due to being more recent and comprehensive; what differentiates them is that “what we currently know” means one or more meta-analyses were conducted with 3+ studies and “what we think we know” means no meta-analysis was conducted or included meta-analyses had less than three studies. The remaining findings fell into the “what we still don’t know” category. Finally, four of the authors (JH, AB, YW, DB) met to reach consensus about the final categorization of each outcome finding based on established “downgrade rules” (see Appendix Q) considering: (1) the reported and calculated COE, (2) RCT-only versus mixed (RCT+non randomized controlled trials [NRCT]) results, (3) whether included data represented final trial data (e.g., inclusion of conference abstract data), (4) the number of included studies (systematic reviews) and sample size, (5) the inclusion of multiple publications from a single original study, (6) variability in outcome measurements or domains, and (7) the author conclusions of the included systematic reviews; importantly, although multiple reasons for downgrade may exist for one outcome, a maximum of one downgrade was applied. Final categorization of outcomes was disseminated to all authors to gain their perspective and feedback on the interpretation of results.

Results

The PRISMA flow diagram is presented in Figure 1. A total of 1803 records were identified through database searches and 950 remained after removal of duplicates. Following screening of titles and abstracts, 53 articles were retrieved for full-text review and 25 were eligible for inclusion (see Appendix D for excluded articles and the reason for exclusion based on PICOS eligibility criteria). Notably, one article[10] was found to be an updated version of another article by the same primary author and principle investigator[34]; thus, as per Hennessey and Johnson,[32] only the most recent was considered in the interpretation of outcome conclusions. Consequently, 24 articles were included in results interpretation for the current overview of which four focused on preoperative ET,[13,16,20,21] 13 focused on postoperative ET,[7–9,11,12,14,15,17,18,35–38] and seven focused on pre- and postoperative ET[6,10,19,39–42].

[insert Figure 1 around here]

For the included reviews, (a) methodological details, (b) a breakdown of the AMSTAR2 ratings, (c) a summary of the CCA calculations, and (d) author conclusions on potential reporting or publication bias per outcome (including GRADE COE when reported) are available in Appendix E, F, G, and N respectively.

Certainty of Evidence of RCT-Only Meta-Analyzed Outcomes

A summary of the COE calculations is presented in Table S22 and missing data impacting COE calculations is presented in Table S23 (see Appendix O). Imprecision (i.e., sample size) and ROB (both trial quality and review quality) negatively impacted COE the most and a majority of the calculated COEs were very low (80.00% preMBS, 12.50% postMBS, and 8.33% postMBS subanalyses) or low (20.00% preMBS, 77.50% postMBS, and 83.30% postMBS subanalyses), and a small proportion were scored as moderate (0.00% preMBS, 10.00% postMBS, and 8.33% postMBS subanalyses).

Overarching Results

The final categorizations of outcome findings into "what we currently know", "what we think we know" and "what we still don't know" in accordance with the flow diagram (see Appendix P) are summarized in Figure 2. The process of categorizing the findings was elaborate and so, details are provided in a simplified visual summary in Appendix R.

Preoperative Exercise Training

Four meta-analyses[6,13,16,40] and seven systematic reviews[10,19–21,39,41,42] explored the impact of preoperative ET (characteristics summarized in Appendix I). Five of the reviews were classified as low quality[6,19,21,39,40] whereas the remainder were critically low quality[10,13,16,20,41,42]; note, for both preoperative and postoperative ET reviews, the factors contributing to such low assessed quality were a lack of reporting of a comprehensive literature search strategy and inappropriate use of statistics to combine results for meta-metanalyses (i.e., the combined analysis of RCTs with NRCTs without providing rationale or conducting sensitivity analyses). There was a high (18%) overlap of primary articles between the reviews and three primary articles that appeared in more than half of the reviews (i.e., 6/11[43,44] or 7/11[33]). The reviews reflected a total of 21 primary articles (see Appendix J for references and their inclusion in the reviews) with a range of one to 13 original studies (i.e., unique cohorts) per review.

All reviews focused on adults awaiting MBS, however, one review specified it had to be patients' first MBS[16] and another that the MBS care had to be delivered by a team with member representation from three or more disciplines (e.g., surgeon, nurse, nutritionist, physical therapist etc.)[40]. Six of the reviews included only ET [6,10,16,39,41,42] whereas five also considered PA counselling[13,19–21,40]. Of the 11 reviews, eight listed the requirement for a control group, one stated that the included primary articles could have a control group or not, and two did not identify comparator requirements. Additionally, except one review that looked solely at feasibility and acceptability outcomes,[6] all the reviews included a combination of anthropometric, body composition, functional capacity, PA, muscle strength, cardiometabolic, QoL, psychological, and surgical outcome measures. Four reviews only included RCTs[13,16,19,40], six reviews included a combination of RCTs and NRCTs, uncontrolled clinical trials or intervention trials[6,10,20,21,39,41], and one did report the design of its included studies[42].

The reviews had sample sizes ranging from 46-305 and their primary articles ranged from 0-100% women, aged 28-54 years with a BMI of 41.5-51.4 kg/m^2. The ET included E, R, combined E/R, high intensity interval training (HIIT) and aquatic exercises, of light-to-vigorous intensity, that lasted 2-52 weeks. Exercise sessions occurred 1-7 times per week, lasted 25-219 minutes per session, and ranged from un- to fully supervised (not reported in N=1)[21] with mainly usual care control groups (not reported in N=3)[39,41,42].

Outcomes

Table 3 summarizes results for preoperative ET as a function of outcome. Next, results are organized as concordant, discordant or inconclusive based on comparisons between multiple reviews. Concordance for a significant positive effect was found for 6-minute walking test distance. Concordance for a non significant effect was found for blood pressure. Discordance was found for VO_2max and maximal aerobic capacity, muscle strength and functional capacity, body weight/body mass index/weight loss and QoL. Conclusive results could not be determined for length of hospital stay and fat-mass, as there was only one primary article included in each review. Comparisons could not be made for fat-free mass, lean body-mass, resting heart rate, glucose and lipid metabolism, PA or adverse surgical events, as there were not multiple reviews with conclusive findings for the same outcome/ outcome measure.

[insert Table 3 near here]

Of the 14 outcomes, seven were categorized into "what we still don't know" (i.e., fat-mass, lean body mass, muscle strength, resting heart rate, glucose/lipid metabolism, surgical adverse events, and length of hospital stay), two were categorized and remained as "what we think we know" (i.e., BMI, 6-minute walking test distance), two were downgraded from "what we currently know" to "what we think we know" (i.e., VO_2max and QoL), and three were downgraded from "what we think we know" to "what we still don't know (i.e., fat-free mass, blood pressure, and PA). A low sample size or small number of studies with no sample size reported contributed to 60% of downgrades, and a low/very low COE, a lack of confirmed final data, variability of outcome domains, and inability to isolate effect of ET from PA counselling each contributed to 20%. See Appendix R for individual outcome categorization details.

Postoperative Exercise Training

Fourteen meta-analyses[6–12,14,15,17,18,35,36,40] and six systematic reviews[19,37–39,41,42] explored the impact of postoperative ET (characteristics summarized in Appendix K) with two classified as moderate quality,[15,17] nine low quality,[6,11,12,19,35–37,39,40] and nine critically low quality[7–10,14,18,38,41,42]. Between the reviews, there was a high (19%) overlap of primary articles with seven primary articles[45–51] appearing in ≥50% of the reviews (10/20,[46,47] 11/20,[49,51] 12/20,[48] 13/20,[45] and 14/20[50]). A total of 42 primary articles were captured in the reviews (see Appendix L for references and their inclusion in the reviews), with a range of 3 to 21 original studies per review.

All reviews considered adults who have undergone MBS. Further, one review specified that the MBS had to be delivered by a multidisciplinary (3+ disciplines) team[40]. ET was the only intervention in all but two reviews[8,36] which also considered PA counselling, whole-body electrical myostimulation (in association with dynamic exercise), physiotherapy and respiratory training interventions. Three reviews required the ET to have a duration of ≥1-month,[9,18,38] and another ≥3-months[15]; further, one review required the ET to have a resistance exercise component,[37] and another allowed for interventions that combined exercise with diet supplementation[27]. Of the 20 reviews, 12 listed the requirement for a control group, one had control participants receive a placebo supplementation, one stated the articles could utilize a control group or not, and six did not specify any comparator requirements. Moreover, a majority of the reviews included a combination of body composition, anthropometric, muscle strength, functional capacity, PA, QoL, cardiometabolic, psychological, and surgical outcome measures; by contrast, some reviews chose to focus on one outcome category including weight loss[36] and specifically weight loss >12 months[35], feasibility and acceptability,[6] muscle strength,[12] bone mineral density,[15] cardiorespiratory fitness[14] and cardiometabolic risk factors[7,18]. A majority of the reviews explored a combination of RCTs and NRCTs or prospective trials (*N*=12[6,7,10,12,14,15,19,36,37,39–41])[a] whereas only seven explored only RCTs[8,9,11,17,18,35,38] and one did report the design of its included studies[42].

The sample sizes of the reviews ranged from 64-638 and their primary articles ranged from 55-100% women, aged 18-65 years with a BMI of 29.6-49.8 kg/m^2. The ET included endurance, resistance, combined endurance/resistance, HIIT, respiratory and balance training, of light-to-vigorous intensity. The ET began immediately-7 years postMBS and lasted 4-104 weeks. Exercise sessions occurred 1-5 times per week and lasted 5-110 minutes per session. Supervision was reported in 13 reviews[6,7,9,10,12,15,19,35–37,39–41] and ranged from unsupervised to fully supervised. Six reviews did not report details on the control groups,[14,37–39,41,42] however the remainder reported mainly usual care.

Outcomes

Table 4 summarizes results for postoperative ET as a function of outcome. Next, comparisons were made between multiple reviews and results are organized as concordant, discordant, or inconclusive. Concordance for a significant positive effect was found for bone mineral density, muscle strength, and waist circumference. Concordance for a non significant

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[a] da Silva et al[14] incorrectly claimed to only explore RCTs when 4/7 included primary articles were in fact NRCTs.

effect was found for lean body mass, diastolic blood pressure, QoL, variables related to glucose (fasting insulin and glucose, and homeostatic model assessment for insulin resistance [HOMA-IR]) and lipid metabolism (total cholesterol, triglycerides, and low-density lipoprotein cholesterol). Discordance was found for body weight/body mass index, fat-free mass, VO_2max, 6-minute walking test distance, fat mass, resting heart rate, systolic blood pressure, and high-density lipoprotein cholesterol. Comparisons could not be made for weight loss ≥12 months postMBS, or the remaining glucose metabolism outcome measures (hemoglobin A1C [HbA1c], insulin sensitivity, acute insulin response to glucose [AIRg], disposition index [Di], single-point insulin sensitivity estimator [SPISE], and glucose effectiveness), as there was only a single systematic review exploring each.

[insert Table 4 near here]

Of the 28 outcomes, five were categorized into "what we still don't know" (i.e., insulin sensitivity, AIRg, Di, SPISE, and glucose effectiveness), 20 were downgraded from "what we currently know" to "what we think we know" (i.e., body weight, BMI, weight loss ≥12 months postMBS, waist circumference, fat/fat-free/lean body mass, bone mineral density, VO_2max, 6-minute walking test distance, muscle strength, resting heart rate, systolic and diastolic blood pressure, fasting insulin and glucose, triglycerides, low and high-density lipoprotein, and total cholesterol), and three were downgraded from "what we think we know" to "what we still don't know" (i.e., QoL, HOMA-IR, and HbA1c). A low/very low COE contributed to 71% of downgrades, differing results when NRCTs were included contributed to 16%, a small number of studies with no reported sample size contributed to 6%, and author conclusions and variability of outcome domains each contributed 3%. See Appendix R for individual outcome categorization details.

Sub-Analyses. All sub-analysis outcomes are summarized in Appendix M. Here we focus solely on outcomes with a significant positive effect found by one or more meta-analysis.

ET Type. Four meta-analyses compared ET that included (1) E, and combined E/R exercises,[18] (2) E, combined E/R and R,[9,11] (3) E, R, combined E/R and alternative exercises,[36] and (4) programmed, supervised and combined programmed and supervised ET.[36] Discordance was found for the effect of combined E/R on weight related variables (body weight/body mass index/weight loss).[9,11,36] Significant benefits were found for the effect of combined E/R ET on systolic blood pressure and triglycerides in one meta-analysis.[18]

ET Start Time. Four meta-analyses compared ET beginning (1) <6 months to >6 months postMBS,[9,18] (2) <3 months to >3 months postMBS,[36] and (3) <6 months to >12 months postMBS to varying start times[11]. Discordance was found for the effect of ET starting <6 months postMBS on weight related variables.[9,11] Additional sets of multiple reviews using the same time frame and outcome variables were not found, however, within the meta-analyses significant positive effects were found for (1) ET starting >6 months postMBS on systolic blood pressure,[18] and (2) ET starting >6 months and >12 months postMBS on body weight[9,11] and BMI[9].

ET Duration. Three meta-analyses compared ET lasting ≤12 weeks to >12 weeks,[9,18] or ≤16 weeks to >16 weeks[36]. The only significant finding was that one meta-analysis determined that ET lasting >12 weeks significantly improved systolic blood pressure.[18]

ET Time/Week. One meta-analysis compared ET with ≤150 mins/week of prescribed exercise to those with >150 min/week and found no significant differences on weight loss.[36]

Of the 11 training characteristic outcomes with sub analysis data, two were categorized and remained at "what we currently know" (i.e., positive effects of combined E/R ET and intervention duration >12 weeks on systolic blood pressure), seven were downgraded from "what we currently know" to "what we think we know" (i.e., positive effects of combined e/R ET on body weight, BMI, and triglycerides, positive effect of ET start time >6 months postMBS on body weight and BMI, non significant effects of ET start time < 6 months postMBS on body weight and BMI), and two were downgraded from "what we think we know" to "what we still don't know" (i.e., impact of ET start time > 6 months postMBS on systolic blood pressure and >12 months postMBS on body weight). A low/very low COE contributed to 66% of downgrades, and differing results when NRCTs are included and a small number of studies with a small/no reported sample size each contributed to 18%. See Appendix R for individual outcome categorization details.

Feasibility and Acceptability

Only one meta-analysis[6] reported on feasibility and acceptability data. The main feasibility and acceptability outcomes presented by Baillot and colleagues[6] are summarized in Table 5 and an expanded summary (including pre- and postMBS analyses and control group analyses is presented in Appendix N. As well, of the 16 studies that reported on adverse events from exercise: (a) nine reported none, (b) four reported occasional pain, fatigue, or dyspnea, (c) two reported hypoglycemia or hypotension, and (d) one reported a back bruise after a fall. Further, subanalyses revealed no significant differences for feasibility and acceptability measures based on ET timing (i.e., pre- or postMBS) or duration (i.e., ≤ 12 weeks or > 12 weeks).

[insert Table 5 around here]

Baillot and colleagues[9] concluded that caution should be taken when interpreting their results due to a lack of reporting of these outcomes within the primary articles. As such, the findings that ET likely has high attendance and retention rates, and low drop out rates, were downgraded from "what we currently know" to "what we think we know". As well, Baillot and colleagues[9] emphasized that little is known about adherence rates and that although no significant differences in feasibility or acceptability outcomes were found based on ET timing and duration, this absence could be explained by the lack of statistical power; thus, these outcomes were categorized into "what we still don't know".

[insert Figure 2 around here]

Discussion

The current overview of reviews aimed to employ a strict and stepwise methodology to summarize the evidence-based knowledge on the benefits of ET delivered pre- and postMBS into a single cohesive resource to aid clinicians and researchers. Exploring reviews focused on postoperative ET revealed a greater number of reviews (20 vs 11), total number of primary articles (42 vs 21), range of original studies per review (3 to 21 vs 1 to 13), and concordance between reviews (10 variables vs 2), compared to those focused on preoperative ET. Across pre- and postMBS, Exercise training/intervention had a positive effect on 10 outcomes (24%; n_{preMBS}=3, $n_{postMBS}$=7), a non significant effect on 14 outcomes (33%; n_{preMBS}=1, $n_{postMBS}$=13), and the effect could not be determined for the remaining 18 outcomes (43%, n_{preMBS}=10, $n_{postMBS}$=8). Our categorization process for these 42 outcomes (n_{preMBS}=14, $n_{postMBS}$=28) led to zero outcomes in "what we currently know", 25 in "what we think we know" (n_{preMBS}=4, $n_{postMBS}$=20), and 18 in "what we still don't know" (n_{preMBS}=10, $n_{postMBS}$=8).

Certainty of Evidence and Study Design Considerations

Our assessment of COE of RCT-only meta-analyzed outcomes revealed a major barrier to developing confidence in our findings, as a low/very low COE contributed to 75% of the 40 total downgraded outcomes (including beneficial exercise characteristics and feasibility and acceptability outcomes). Concerns with imprecision (i.e., sample size) and ROB (both of the reviews and primary articles) indicate a clear need for more original research, ideally well-powered RCTs, and systematic reviews, both performed with a higher level of methodological rigor. It is important to note that the ROB of the reviews could be impacted by a lack of reporting, rather than only a lack of methodological rigor; in considering page restrictions imposed by most journals, authors are encouraged to utilize supplementary files and open science practices to promote transparency in their reporting of both their methods and results in accordance with PRISMA reporting guidelines.[52] In addition, differing results between RCT-only and mixed (RCT + NRCTs) reviews contributed to 18% of downgraded outcomes. Although RCTs provide the most reliable evidence, conducting them can be impractical and their findings may be unrepresentative of real-world settings[53]; resultingly, NRCTs are commonly used to fill the gap, but their findings need to be interpreted with caution since they are more prone to bias and overestimation of effects.[53] Within the reviews incorporated into the outcome tables, about 41% of the meta-analyses and 50% of the systematic reviews included both RCTs and NRCTs. In a framework presented by Sarri and colleagues[53], steps were shared to synthesize data from both NRCTs and RCTs together, however, the included mixed meta-analyses did not statistically or narratively explore any differences between the impact of RCTs and NRCTs on the reported outcomes. Thus, the findings originating from RCT-only reviews were prioritized when applicable.

Effects of Exercise Training: What We Think We Know

Preoperative Exercise Training

Positive Effects of Exercise Training. For BMI, the magnitude of the effect could not be determined as the meta-analyses were removed from the comparison; one because of the inclusion of multiple publications from the same study and the other to exclude analyses that included PA counselling to resolve discordance between reviews. Notably, in PA counselling, compared to prescribed ET, the amount of exercise performed is likely lower, may not include as much vigorous exercise, and is often unsupervised, which may explain why the inclusion of PA counselling interventions above does not lead to a significant effect on BMI. It is important that authors explicitly mention the type of exercise intervention (i.e., ET, PA counselling, etc.) in their conclusions to avoid misinterpretation. The finding that preoperative ET has a positive effect on BMI aligns with the literature on adults living with obesity which demonstrates that endurance (MD: −0.94 kg/m^2; 95% CI: −1.29, −0.60, low COE) and combined E/R ET (MD: −0.51 kg/m^2; 95% CI: −0.94, −0.08, low COE) leads to a greater decrease in BMI than control conditions,[54] however, these results are unlikely to be clinically important for patients undergoing MBS as this weight loss is very small relative to the 20-40% of total body weight loss resulting from the MBS procedure.[55] These findings suggest that weight loss should not be the primary aim/motivation for engaging in preMBS ET.

For physical fitness, preoperative ET likely has a large effect size (SMD: 2.59; 95% CI: 1.89, 3.30, high COE reported, very low COE calculated in the current overview)[16] on 6-minute walking test distance which is in accordance with the literature exploring ET in adults living with obesity.[56] Exploring the primary articles[43,44,57–59] included in the meta analysis[16] and additional systematic reviews,[10,20] improvements in 6-minute walking test distance of 7.5-146m were reported from pre- to postET, which supports the clinical significance of this finding when compared to the minimal clinically importance difference of 14.0-30.5m for adults with pathology (although not specific to obesity or MBS).[60] Moreover, our findings agree with the literature in adults with overweight and obesity showing that ET can lead to improvements in VO_2max.[61,62] The effect size for preMBS VO_2max change at maximal follow up (MD: 0.98 mL/kg/min, 95% CI: 0.05, 1.90, very low calculated COE) does not meet the standard clinically important difference of 3.5 mL/kg/min[63]; that said, for patients with cardiovascular disease, an improvement of just 1 mL/kg/min has been found to be associated with a 10% reduction in all-cause mortality.[64]

Non Significant Effects of Exercise Training. The finding that ET has a non significant effect on QoL was impacted by substantial variability in the domains and measures used to assess QoL. Future research should seek to make consistent use of validated measures (e.g., SF-36)[65] and standardize how results are reported to improve comparisons across studies. Moreover, in a recent meta-analysis, it was found that ET improves QoL in adults with overweight or obesity[66]; thus, it is possible that ET could positively impact QoL in adults awaiting MBS but that the prioritized meta-analysis[16] was not adequately powered to detect the effect (k=3, n=53). Consequently, future studies should explore the impact of preMBS ET on QoL as a primary study aim.

Postoperative Exercise Training

Positive Effects of Exercise Training. Similarly to preMBS ET, the most comprehensive review exploring postMBS ET on body weight and BMI[9] revealed small positive effects (body weight MD: -2.51 kg, 95% CI: -4.74, - 0.27, low calculated COE; BMI MD: -0.84 kg/m^2, 95% CI: -1.60, -0.08, low calculated COE) which while aligning with the literature on adults with obesity,[54] does not represent a meaningful change above and beyond the weight lost as a result of undergoing MBS. Furthermore, for waist circumference the more recent postMBS meta-analysis[9] revealed a mean difference of -4.14 cm (95% CI: -8.16, -0.12, low calculated COE) from pre- to postET; exceeding the -3.2 cm (95% CI: -3.86, -2.51, low reported COE) observed following aerobic exercise in adults living with obesity.[67] Data showed that a 1 cm and 5 cm increase in waist circumference is associated with a 2% increase in cardiovascular disease[68] and a 7% in men/9% in women increase in mortality risk[69] respectively, the reverse can be inferred[67] and thus, the 4.14 cm decrease in waist circumference may represent a clinically significant improvement. Due to the high variability and low COE, these results should be interpreted with caution.

For 6-minute walking test distance, postMBS results mirror preMBS ET in that a weighted mean difference of 29.67 m (95% CI: 25.97, 33.37, low calculated and reported COE) aligns with literature on adults living with obesity[56] and meets the 14.0-30.5 m minimal clinically importance difference for adults with pathology.[60] For systolic blood pressure, the results of the most recent comprehensive review in postMBS [18] (MD: -5.33 mmHg, 95% CI: -8.99, -1.66, moderate reported COE and low calculated COE) align with the reported benefits of ET in adults with overweight and obesity,[70] and reach the minimal clinically important difference of 2 mmHg for adults living with obesity[71] or hypertension.[72]

For muscle strength, postMBS results demonstrate the beneficial impact of ET for a variety of measurements – i.e., 1-repetition maximum for upper and lower muscle, sit to stand test, and dynamometer test – while other results present potential limitations to its benefits, i.e., non significant effect on handgrip test. Future research should aim to collect a variety of previously used outcome measures that are consistent with the exercise performed in the training. Although there is no RCT-only meta-analysis for bone mineral density, supporting mixed (RCTs + NRCTs) reviews lend support to the positive effect of postMBS ET on bone mineral density. This finding is more impressive in light of the fact that postMBS patients can experience a loss of bone mass[73]; thus, ET may have an additional protective benefit on bone mineral density.

Non Significant Effects of Exercise Training. Exploring the impact of ET on weight loss ≥12 months postMBS reveals an important gap in the research on the topic of weight loss maintenance. To fill this gap, additional high-quality RCTs should be performed with (1) weight loss maintenance as a primary outcome, (2) thorough reporting of PA compliance and adherence, and (3) longer term follow-up postMBS. Although the few experimental studies available didn't report a significant effect of PA on weight loss maintenance,[35] observational studies found that highest levels of moderate-to-vigorous intensity PA postMBS are associated with the lowest weight recurrence.[74] Additional evidence is required but weight loss maintenance seems to be a better motivator for engaging in PA than weight loss.

Non significant effects on fat, fat-free, and lean body mass are supported by two recent overviews of reviews revealing similar findings for the effect of ET on adults with overweight or obesity. [62,75] Specifically, ET was found to have a (1) significant positive effect on weight loss and muscle strength, and (2) a non significant effect on lean-body mass. Importantly, within the overview of reviews[75] for lean-body mass, two meta-analyses comparing exercise to control groups revealed significantly more weight loss in the exercise group but no significant differences in lean-body mass change between groups; thus, it is possible that the significant positive effect of postMBS ET on body weight and the non significant effect on lean-body mass actually reflects a preservation of that would otherwise be lost to factors such as protein deficiency postMBS. Further studies are required to determine the impact of protein supplementation on lean-body mass preservation postMBS.[76]

At first glance, some of our findings may appear to be counterintuitive. For example, it appears odd that ET postoperatively would have positive effects on BMI and body weight, while having non significant effects on fat-mass and fat-free mass. As well, the absence of a significant effect on VO_2max is surprising since ET is well know to improved VO_2max in adults with obesity.[62] It is important to consider that the assessment of body composition and certain fitness measures (e.g., VO_2max) are not as reliable, have not been validated, and/or involve barriers related to their use (e.g., weight limit of equipment, high cost for gold-standard methods, and difficulty reaching peak exertion) in populations with obesity. [77,78] For other outcomes (i.e., resting heart rate, diastolic blood pressure, fasting insulin and glucose, total cholesterol, triglycerides, low density and high density lipoprotein), it is possible that minor changes resulting from ET are simply overshadowed by the drastic improvement in these outcomes as a result of MBS.[79]

Beneficial Characteristics of Exercise Training Programs

The second aim for the current overview was to determine whether better health outcomes could be attributed to any characteristic(s) of the ET. Only data originating from postoperative ET studies were found, and while 14 meta-analyses were conducted on this subject, only four[9,11,18,36] conducted subgroup analyses, and only two[9,18] explored variables outside of body weight/BMI/weight loss.

What We Currently Know

Similarly to research on adults living with obesity, evidence demonstrates that ET that combines E/R[70] and ET that lasts >12 weeks[80] both improve systolic blood pressure in adults postMBS. While ET has the potential to support patients in MBS programs, it is also important to note that maintaining the benefits of MBS requires sustained lifestyle changes and a single short duration ET intervention alone is unlikely to create lasting effects. Therefore, longer duration ET may be most beneficial.

What We Think We Know

For body weight and BMI, ET starting <6 months postMBS had a non significant effect, whereas ET ≥ 6 months postMBS had a positive effect. Importantly, in the short term after MBS (up to ~ 1 year), weight loss is often rapid and requires minimal effort[81]; consequently, to further improve weight loss and to prevent weight recurrence, ET is likely most beneficial after the metabolic and surgical effects of MBS have stabilized. Further, the positive impact of combined E/R ET on body weight, BMI, and triglycerides arises from the consecutive or concurrent leveraging of the cardiovascular and musculoskeletal systems to promote widespread physiological adaptations.[70]

Feasibility and Acceptability

Although findings by Baillot and colleagues[6] suggest that ET seems feasible and acceptable in adults awaiting-or who have undergone MBS, they must be interpreted with caution due to the lack of reporting of these outcome variables in primary articles; adherence data is rarely reported (~11%) and attendance to sessions and drop out rates were often not reported (39% and 64% respectively). Adherence is important because while an individual may attend a session, their completion of the prescribed exercise will provide crucial information when interpreting the success of the training. Further, studies with lower attendance and higher dropout rates may represent those that did not report this data, thereby biasing the results. As well, while no significant differences reported in any of the feasibility or acceptability measures based on ET timing (pre- or postMBS) or duration (≤ 12 weeks, or > 12 weeks) were found, these subanalyses were underpowered and so researchers should make explicit efforts to collect and report on feasibility and acceptability data to aid in transparency and potential explanations for the impacts, or lack thereof, of ET.

What We Still Don't Know Overall– Implications for Research

Regarding preMBS ET, before additional systematic reviews are conducted, more high-quality original research is needed to explore the impact on fat/fat-free/lean body mass, muscle strength, resting heart rate, blood pressure (systolic and diastolic blood pressure separately), glucose and lipid metabolism, habitual PA, adverse surgical-related events, and length of hospital stay. For muscle strength and glucose/lipid metabolism, clear and consistent outcomes should be used to allow for comparisons between reviews. For PA, addressing habitual practice in both the short and long-term postMBS may provide insight into successful intervention methods, and strategies to extend the benefits of MBS and ET beyond the short term. For postMBS ET, QoL domains should be used clearly and consistently, and more original research is required to explore both QoL and glucose metabolism outcomes (i.e., HOMA-IR, HbA1c, insulin sensitivity, AIRg, Di, SPISE, and glucose effectiveness). Although the effects of ET in pre- and postMBS adults seems mostly like those found in adults living with obesity, certain characteristics could impact the effects of ET or require different prescriptions to obtain the same effect (e.g. higher body dissatisfaction, mental health concerns, preoperative weight, rapid weight loss, metabolic and surgical changes due to surgery, vitamins/minerals deficiencies, reduced food intake). For these reasons, additional research is required in this population, and results found in non surgical populations of adults with obesity should be generalized with caution.

Also, no conclusions could be made on the long-term impacts of ET (pre- or postMBS) on any variable as only one primary article[33] included an extended follow-up (1 year). Distinctly, "extended" is referring to the time since ET, rather than since MBS, as some ET interventions did not even begin until 7 years postMBS. Thus, there is still a need to determine whether ET has direct long-term benefits or leads to prolonged and impactful changes in PA patterns.

For beneficial characteristics of ET, as the subanalyses were only performed on postMBS ET interventions, currently we still don't know of any training characteristics of preMBS ET interventions that lead to improved health outcomes. To determine the most effective ET interventions to support adults awaiting, or who have undergone MBS, there is a need to explore the training characteristics that most benefit health outcomes through comprehensive meta-analyses. Thus, future researchers should make explicit efforts to collect, report, and analyse subgroup data. A recent overview of reviews exploring the effect of ET on adults with overweight and obesity gives insight into the potential impacts of ET modality; specifically, certain modalities had a greater positive impact than others on lean body mass loss (i.e., R > other types), VO_2max (i.e. HIIT > E = combined E/R > R) and muscle strength (i.e., R = combined E/R > E).[62] As a result, future research should explore the ET modality relative to the goal of the training (e.g., improving cardiorespiratory fitness versus increasing muscular strength).

Future research should also specifically explore ET timing, duration, and sustained effects on various outcomes; for example, how soon should an ET intervention be delivered postMBS to achieve long-term weight loss maintenance. Similarly, future research should seek to determine the impact of ET characteristics on feasibility and acceptability outcomes (e.g., does exercise intensity impact attendance and retention rates?).

Strengths and Limitations

The key strengths of this overview lay in the rigor and transparency of the methodology employed following the established PRIOR guidelines to ensure complete and accurate reporting. However, there are also limitations of the current overview, related primarily to either the methodology or limitations of the included research, that impact the generalizability of the findings. Throughout this overview, emphasis has been placed on the conducted meta-analyses and several suggestions for future meta-analyses have been made. One limitation of the current overview is that, as done in previous reviews, the intervention timing is divided into pre-and postMBS, however, this fails to capture an important distinction in the time frame postMBS; for example, defining the impact of ET 6-12 months postoperatively versus ≤12 months postoperatively may be just as important considering the potential for weight recurrence and the resulting changes to adults cardiometabolic risk factors. Despite this knowledge, observing the wide range of intervention start times postMBS (see Appendix J) makes conducting this comparison impractical at this time.

Further, specific to the methodology, the current overview did not (a) include a search of grey literature, (b) include articles that were not available in French of English, and (c) explore original/primary articles that were published recently and thus, not captured within the identified reviews. In addition, as emphasized above in the details regarding COE, a large limitation exists in the quality of both the primary articles and the included reviews. Finally, for many of the outcomes, the review authors could not statistically assess risk of publication bias due to the inclusion of less than 10 studies in the analysis (see Appendix O), and so the risk of publication bias and the “file drawer effect” affecting the current findings cannot be ruled out entirely.[53]

Conclusion

The current overview assumed the challenge of collecting, condensing, interpreting, and reporting on a large body of literature pertaining to the impacts of pre- and postMBS exercise training on various health outcomes. Despite the published research available, what we still don’t know far outweighs what we currently know. High quality original research and reviews performed with methodological rigor are required to fill this gap in our knowledge to provide evidence-based recommendations for the integration of ET before and after MBS.

Disclosures

Author Contributions

The authors confirm the following contributions to the manuscript. Study design and conception by AB, MA, DB, DC, PP, and BG. Data collection by JH, MA, VL, and AB. Data analysis by JH, MA, YW, and AB. Draft manuscript preparation by JH. All authors were involved in the interpretation of results, provision of manuscript feedback, and approval of the final version of the manuscript.

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Supplementary Material

The supplementary materials are available as a single file uploaded alongside this manuscript.

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Table 1: Eligibility Criteria in Accordance with PICOS framework

Category	Eligibility Criteria
Population	Adults (> 18 years old) who were awaiting, or had already undergone, MBS
Intervention	Exercise training pre- and/or post-MBS of any duration, frequency, supervision (fully, partially, or non supervised), type (i.e., endurance, resistance, HIIT etc., or any combination thereof), delivery modalities (i.e., individual or group-based), or setting (home-based, center/hospital-based etc.).
Comparator	No control group required unless study combined exercise training with an additional intervention [e.g., diet]; in this case, control group would have to be matched such that they received the same intervention without the exercise training component (e.g., exercise + diet vs only diet).
Outcomes	*Critical Outcomes* [a]*:* (1) changes in lean body mass, muscle mass and/ or bone mineral density, (2) changes in physical fitness including cardiorespiratory fitness and muscle strength, (3) changes in physical activity and/ or sedentary behaviors measured objectively or subjectively, (4) peri-operative outcomes (e.g., length of hospital stay, complications rate), and (5) feasibility and acceptability outcomes (e.g., adherence rates, adverse events) *Other Important Outcomes:* (1) weight loss and weight recurrence, (2) changes in fat mass, (3) changes in physical functioning including balance and coordination, (4) changes in cardio-metabolic markers including triglycerides, total cholesterol, high and low density lipoprotein cholesterol (HDL-C and LDL-C), haemoglobinA1c (HbA1c), glucose and insulin, blood pressure, (5) changes in health or weight- related quality of life and psychosocial outcomes including depression and anxiety, and (6) changes in obesity comorbidities including type 2 diabetes and hypertension.
Study Design	All self-identified meta-analyses and systematic reviews (including those only looking at RCTs and those with various primary article study designs)

Note. PICOS=Population, Intervention, Comparator, Outcomes and Study Design; MBS=Metabolic and bariatric surgery; HIIT=high intensity interval training

[a] Outcomes known to be associated with exercise training that are not improved by MBS.

Table 2: Data Extracted as a Function of the Subject (Review or Primary Studies)

Subject	Data Extracted
Systematic Review/ Meta-Analysis	Author names, publication year, countries, study design (i.e., meta-analysis or systematic review), objective, PICOS selection criteria, date and databases searched, number of primary studies included, outcomes considered and main findings (including estimated effect size, confidence intervals, sample size, heterogeneity, quality of evidence with tool used, and subgroup analyses when available), conclusions on publication or reporting bias, quality of included articles and tool used, and funding sources
Primary Articles	Population characteristics (pooled sample size, age, sex, BMI), intervention details (duration, type, frequency, intensity, session duration, supervision, and control group type),

Note. PICOS=Population, Intervention, Comparator, Outcomes and Study Design, BMI=Body mass index.

Table 3: Preoperative Exercise Training: Systematic Review Results, Considerations and Conclusions as a Function of Outcome

Authors	Effects	n	k	I^2	Studies included	Special considerations	AMSTAR	Conclusion for review[a] and across reviews[b]	
Body Weight (BW), Body Mass Index (BMI) and Weight Loss (WL) – 20% overlap of primary studies									
Jabbour 2022	**BW:** NS (*k*=3), + (*k*=2)	NR	5	NA	Baillot 2016, Funderburk 2010, Gilbertson 2020, Marcon 2011, Marcon 2017	RCT, BA,IT 1 aquatic exercise intervention	Critically Low	?	Discordant
	BMI: NS (*k*=1), + (*k*=2)	NR	3	NA	Gilbertson 2020, Marcon 2011, Marcon 2017			(+)	
	@1 year follow-up: + (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Lodewijks 2022	**Pre-MBS WL:** NS (k=9), + (k=1)	NR	10	NA	Arman 2021, Baillot 2016, Baillot 2017, Bond 2015a, Bond 2015b, Creel 2016, Funderburk 2010, Gilbertson 2020, Parikh 2012, Marc-Hernandez 2019	RCT, NRCT 4 PAC intervention 1 aquatic exercise intervention 2 publications from the same study (Bond 2015a/b)	Low	(NS)	
	Post-MBS WL: NS (k=1)	NR	1	NA	Parikh 2012			**Inconclusive 1 study**	
	@1 year follow-up: + (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
	BMI: + (k=1)	NR	1	NA	Marc-Hernandez 2019			**Inconclusive 1 study**	
	@1 year follow-up: + (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Durey 2022	**%WL:** MD: 0.94% [-1.61; 3.48]	142	3	70%	Bond 2017a, Creel 2016, Li 2013	RCT 2 PAC intervention 1 conference abstract (Li 2013)	Critically Low	NS	
Herrera-Santelices 2022	**BMI:** SMD: -0.71 [-1.55; 0.12] *very low*	115	4	76%	Arman 2021, Baillot 2016, Baillot 2018, Marcon 2017	RCT 2 publications from the same study (Baillot 2016/2018)	Critically Low	NS	
Schurmans 2022	**BMI @1 year follow-up:** NS (k=1)	NR	1	NA	Baillot 2018	RCT	Low	**Inconclusive 1 study**	
	WL: NS (k=1)	NR	2	NA	Bond 2015b			**Inconclusive 1 study**	
Bellicha 2021	**BW/BMI=** NS (k=1), + (k=2)	NR	3	NA	Baillot 2016, Marc-Hernandez 2019, Marcon 2017	RCT, NRCT	Critically Low	(+)	
	@1 year follow-up: + (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
***Fat mass (FM) – 33% overlap of primary studies**									
Jabbour 2022	**%FM:** NS (*k*=1)	NR	1	NA	Baillot 2016	RCT	Critically Low	**Inconclusive 1 study**	In co

Lodewijks 2022	**FM/Visceral Fat**: + (k=1)	NR	1	NA	Marc-Hernandez 2019	NRCT	Low	**Inconclusive 1 study**	
Herrera-Santelices 2022	**%FM:** SMD: 0.38 [-0.08; 0.84] *moderate*	75	3	0%	Arman 2021, Baillot 2016, Baillot 2018	RCT 2 publications from the same study (Baillot 2016/2018)	Critically Low	NS	
Bellicha 2021	**FM:** NS (k=1), + (k=1) **@1 year follow-up:** NS (k=1)	NR NR	2 1	NA NA	Baillot 2016, Marc-Hernandez 2019 Baillot 2018	RCT, NRCT	Critically Low	**?** **Inconclusive 1 study**	
***Fat-free mass (FFM) and Lean body mass (LBM) – 33% overlap of primary studies**									
Lodewijks 2022	**FFM @1 year follow-up:** + (k=1)	NR	1	NA	Baillot 2018	RCT	Low	**Inconclusive 1 study**	NA
Herrera-Santelices 2022	**FFM:** SMD: - 0.41[-1.00; 0.18] *moderate*	46	2	0%	Arman 2021, Baillot 2018	RCT	Critically Low	NS	
Schurmans 2022	**FFM @1 year follow-up:** + (k=1)	NR	1	NA	Baillot 2018	RCT	Low	**Inconclusive 1 study**	
Bellicha 2021	**LBM:** NS (k=1) **@1 year follow-up:** + (k=1)	NR NR	1 1	NA NA	Marc-Hernandez 2019 Baillot 2018	RCT, NRCT	Critically Low	**Inconclusive 1 study** **Inconclusive 1 study**	
***VO_2max/Maximum Aerobic Capacity – 13% overlap of primary studies**									
Durey 2022	**Pre-MBS VO_2max change:** MD: 0.73 mL/kg/min [0.61; 0.86] **VO2max change at maximal follow up:** MD: mL/kg/min 0.98 [0.05; 1.90]	79 131	3 3	62% 0%	Baillot 2018, Kwok 2016, Li 2013 Baillot 2018, Creel 2016, Li 2013	RCT 1 PAC intervention 2 conference abstracts (Kwok 2016 and Li 2013)	Critically Low	+ +	Discordant
Jabbour 2022	NS (*k*=1, METS), + (*k*=1, VO_2 peak)	NR	2	NA	Baillot 2017, Marcon 2017	RCT, IT	Critically Low	?	
Bellicha 2021	NS (k=2), + (k=1) **@1 year follow-up:** NS (k=1)	NR NR	3 1	NA NA	Baillot 2016, Marc-Hernandez 2019, Marcon 2017 Baillot 2018	RCT, NRCT	Critically Low	(NS) **Inconclusive 1 study**	
6-minute walking test distance (6MWTD) – 22% overlap of primary studies									
Jabbour 2022	NS (*k*=1), + (*k*=2)	NR	3	NA	Baillot 2016, Baillot 2017, Funderburk 2010	RCT, BA 1 aquatic exercise intervention	Critically low	(+)	Concordant
Herrera-Santelices 2022	SMD: 2.59 [1.89; 3.30] *high*	61	2	0%	Arman 2021, Marcon 2017	RCT	Critically Low	+	
Schurmans 2022	+ (k=1) **@1 year follow-up:** NS (k=1)	NR NR	1 1	NA NA	Baillot 2016 Baillot 2018	RCT	Low	**Inconclusive 1 study** **Inconclusive 1 study**	
Bellicha 2021	+ (k=2) **@1 year follow-up:** + (k=1)	NR NR	2 1	NA NA	Baillot 2016, Marcon 2017 Baillot 2018	RCT	Critically Low	+ **Inconclusive 1 study**	

Muscle strength and functional capacity – 50% overlap of primary studies									
Jabbour 2022	**Sit to stand test:** NS (*k*=1), + (*k*=1)	NR	2	NA	Baillot 2016, Baillot 2017	RCT,BA 2 publications from the same study (Baillot 2016/2018)	Critically Low	?	Discordant
	Arm curl: + (*k*=2)	NR	2	NA	Baillot 2016, Baillot 2017			+	
	Leg strength/muscle quality: + (*k*=3)	NR	3	NA	Baillot 2016, Baillot 2017, Baillot 2018			+	
Bellicha 2021	NS (k=1), + (k=1)	NR	2	NA	Baillot 2016, Marc-Hernandez 2019	RCT, NRCT	Critically Low	?	
	@1 year follow-up: NS (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Resting heart rate (RHR) – 33% overlap of primary studies									
Schurmans 2022	NS (k=2)	NR	2	NA	Baillot 2016, Baillot 2018	RCT 2 publications from the same study (Baillot 2016/2018)	Low	**Inconclusive only 2 publications same study**	NA
Marshall 2020	MD: -3.06 bpm [-5.65; -0.47] *very low level of evidence*	111	4	0%	Pre-MBS (Baillot 2014/Baillot 2018); Post-MBS (Castello 2011, Huck 2015, [Mundberg 2018a/Mundberg 2018b, Stolberg 2018a/Stolberg 2018b])	RCT, NRCT *k*=3 (6 publications) post-MBS intervention 1 PAC intervention Mistakenly considered Baillot 2014/2018 as one study	Low	**Inclusive as pre/post-MBS results are combined**	
Blood pressure (BP) – 28% overlap of primary studies									
Schurmans 2022	NS (k=2)	NR	2	NA	Baillot 2016, Baillot 2018	RCT 2 publications from the same study (Baillot 2016/2018)	Low	**Inconclusive only 2 publications same study**	Concordant
Jabbour 2022	**DBP:** NS (*k*=2), + (*k*=1)	NR	3	NA	Baillot 2016, Funderburk 2010, Marcon 2017	RCT 1 aquatic exercise intervention	Critically Low	(NS)	
	SBP: NS (*k*=2), + (*k*=1)	NR	3	NA	”			(NS)	
Bellicha 2021	NS (k=2), + (k=1)	NR	3	NA	Baillot 2016, Marcon 2017, Marc-Hernandez 2019	RCT, NRCT	Critically Low	(NS)	
	@1 year follow-up: NS (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Marshall 2020	**DBP:** MD: -1.31 mmHg [-2.33; -0.29] *very low level of evidence)*	251	6	23%	Pre-MBS (Baillot 2014/ Baillot 2018); Post-MBS (Castello 2011, [Coen 2015a/Coen 2015b/Nunez-Lopez 2017/Woodlief 2015], Huck 2015, Onofre 2017, [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018b])	RCT, NRCT *k*=5 (11 publications) post-MBS intervention 1 PAC intervention Mistakenly considered Baillot 2014/2018 as one study	Low	**Inclusive as pre/post-MBS results are combined**	
	SBP: MD: -1.59 mmHg [-3.74; 0.56] *very low level of evidence*	239	5	27%	Pre-MBS (Baillot 2014/Baillot 2018); Post-MBS (Castello 2011, [Coen 2015a/Coen 2015b/Nunez-Lopez 2017/Woodlief 2015], Huck 2015, [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018b])			**Inclusive as pre/post-MBS results are combined**	
Quality of Life (QoL) – 19% overlap of primary studies									

Herrera-Santelices 2022	SMD: 0.88 [-0.23; 1.99] *moderate*	53	3	67%	Arman 2021, Baillot 2018, Funderburk 2010	RCT 1 aquatic exercise intervention	Critically Low	NS	Discordant
Lodewijks 2022	+ (*k*=2, 1 for physical functioning, general health perceptions, mental health and social functioning, and 1 for all except role-emotional)	NR	2	NA	[Bond 2015a/Bond 2015b], Marc-Hernandez 2019	RCT,NRCT 1 PAC intervention study (Bond 2015a/b)	Critically Low	+	
Schurmans 2022	+ (k=1 except role-emotional domain)	NR	1	NA	Bond 2015b	RCT 1 PAC intervention	Low	**Inconclusive 1 study**	
	@1 year follow-up: NS (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Bellicha 2021	NS (k=1), + (k=1)	NR	2	NA	Baillot 2016, Marc-Hernandez 2019	RCT, NRCT	Critically Low	?	
	@1 year follow-up: NS (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Glucose and lipid metabolism – 0% overlap of primary studies									
Jabbour 2022	**SI:** NS (*k*=1)	NR	1	NA	Gilbertson 2020	NRCT	Critically Low	**Inconclusive 1 study**	NA
	Adipokines: NS (*k*=1)	NR	1	NA	”			**Inconclusive 1 study**	
Bellicha 2021	**Glucose:** NS (k=1), + (k=1)	NR	2	NA	Marcon 2017, Marc-Hernandez 2019	RCT, NRCT	Critically Low	?	
	Lipid Profile: NS (k=1), + (k=1)	NR	2	NA	”			?	
Physical activity – 20% overlap of primary studies									
Lodewijks 2022	+ (k=4)	NR	4	NA	Baillot 2016, Baillot 2018, [Bond 2015a/Bond 2015b], Parikh 2012	RCT, NRCT 2 PAC intervention 2 publications from the same study (Baillot 2016/2018) however mistakenly considered as separate studies	Critically Low	+	NA
	@1 year follow-up: + (k=1)	NR	1	NA	Baillot 2018			**Inconclusive 1 study**	
Bellicha 2021	**Habitual physical activity @ 1 year follow-up:** + (k=1)	NR	1	NA	Baillot 2018	RCT	Critically Low	**Inconclusive 1 study**	
Adverse events – Overlap not applicable									
Durrey 2022	RR: 6.00 [0.27; 131.34] * Post-surgery adverse events not during exercise	22	1	NA	Li 2013	RCT Conference abstract	Critically Low	**Inconclusive 1 study**	NA
Length of hospital stay – 0% overlap of primary studies									
Durrey 2022	NS ≠ bw intervention and control	22	1	NA	Li 2013	RCT Conference abstract	Critically Low	**Inconclusive 1 study**	Inconclusive
Jabbour 2022	+ (*k*=1)	NR	1	NA	Gilbertson 2020	NRCT	Critically Low	**Inconclusive 1 study**	

Note. * interpret these results with caution due to unreliable measurements in adults with obesity. RR=risk ratio, MD=mean difference, SMD=standardized mean difference, NS=non significant, NR=not reported, NA=not applicable, k=number of studies, n=subsample size, I^2=degree of heterogeneity, MBS=metabolic and bariatric surgery RCT=randomized control trial, NCRT=non-randomized control trial, PAC=physical activity counselling. Individual review conclusions highlighted in dark grey were not factored into the overall conclusion for the outcome.

[a] + = significant benefits from a meta-analysis, or 100% concordance for significant benefits between studies in a systematic review, (+) = partial concordance (≥ 67%) for significant benefits between studies in a systematic review, ?= discordance between studies in a systematic review, (NS)=partial concordance (≥ 67%) for non significant benefits between studies in a systematic review, NS=non significant benefits from a meta-analysis, or 100% concordance for non significant benefits between studies in a systematic review

[b] conclusion determined by following flow diagram (see Appendix P)

Table 4: Postoperative Exercise Training: Systematic Review Results, Considerations and Conclusions as a Function of Outcome

Authors	Effects	n	k	I^2	Studies included	Special considerations	AMSTAR	Conclusion for review[a] and across reviews[b]	
Weight Loss (WL) ≥ 12 months post-MBS									
Bond 2023	SMD: - 2.26 [-2.07; 1.55]	189	5	0%	Coleman 2017, Herring 2017, Marc-Hernandez 2020, Mundberg 2018a, Shah 2011	Only RCT	Low	**NS**	NA
Body Weight (BW) and Body Mass Index (BMI) – 24% overlap of primary studies									
Gasmi 2022	**BMI**: SMD: −0.93 [−1.65; −0.20]	341	5	85%	Freitas 2017, Herring 2017, Marc-Hernandez 2020, Oppert 2018, Sellberg 2019	Only RCT	Critically Low	+	Discordant
Schurmans 2022	**BMI:** + (k=3; 1 only at 24 months), NS (k=7)	NR	10	NA	Castello 2011, Castello 2013, Coen 2015a, Coen 2015b, Hassanejad 2017, Herring 2017, Huck 2015, Mundberg 2018a, Nunez-Lopez 2017, Stolberg 2018a	RCT, NRCT 5, 2, and 2 publications from 3 interventions (Carnero 2017/Coen 2015a/Coen 2015b/Nunez-Lopez 2017/Woodlief 2015; Castello 2011/2013; Mundberg 2018a/Stolberg 2018a)	Low	**(NS)**	
	BW: + (k=4; 1 only at 24 months post-MBS), NS (k=10)	NR	14	NA	Carnero 2017, Castello 2011, Castello 2013, Coen 2015a, Coen 2015b, Daniels 2018, Hassanejad 2017, Herring 2017, Huck 2015, Mundberg 2018a, Nunez-Lopez 2017, Shah 2011, Stolberg 2018a, Woodlief 2015			**(NS)**	
Boppre 2021	**BMI:** MD: -0.84 kg/m^2 [-1.60; -0.08]	401	7	0%	Castello 2011, Coen 2015b, Hassanejad 2017, Herring 2017, Mundberg 2018a, Oppert 2018, Tardif 2020	Only RCT	Critically Low	+	
	BW: MD: -2.51 kg [-4.74; -0.27]	496	10	0%	Castello 2011, Coen 2015b, Coleman 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Mundberg 2018a, Oppert 2018, Shah 2011, Tardif 2020			+	
Bellicha 2021	**BW:** MD: -1.8 kg [-3.2; -0.4]	NR	13	35%	Campanha-Versiana 2017, Castello 2011, Coen 2015b, Coleman 2017, Daniels 2018, Hassanejad	RCT, NRCT	Critically Low	+	

					2017, Herring 2017, Huck 2015, Mundberg 2018a, Onofre 2017, Oppert 2018, Shah 2011, Stegen 2011				
Morales-Marroquin 2020	**BW**: NS (*k*=4), + (*k*=2)	NR	6	NA	Hassanejad 2017, Herring 2017, Huck 2015, Mundberg 2018b, Oppert 2018, Stegen 2011	RCT, NRCT All interventions include a resistance training component	Low	**(NS)**	
Carretero-Ruiz 2019	**BW:** SMD: 0.15 [-0.02; 0.32]	NR	16	0%	Campanha-Versiana 2017, Casali 2011, Castello 2011, Coen 2015b, Coleman 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Huck 2015, Marchesi 2015, Mundberg 2018a, Oliviera 2016, Onofre 2017, Rojhani-Shirazi 2015, Shah 2011, Stegen 2011	RCT, NRCT Respiratory (*k*=1), and physiotherapy (*k*=1) interventions 2 PAC study	Low	**NS**	
Ren 2018	**BMI:** WMD: -0.40 kg/m^2 [-0.81; 0.00] *Moderate level of evidence*	259	5	44%	NR	Only RCT	Low	+	
	BW: WMD: -1.94 kg [-3.18; -0.69] *Moderate level of evidence*	347	8	51%	Castello 2011, Coen 2015b, Coleman 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Mundberg 2018a, Shah 2011			+	
Waist Circumference (WC) – 20% overlap of primary studies									
Gasmi 2022	SMD: -0.18 [−0.79; 0.43] Based on final data intervention vs. control groups not pre-post difference	42	2	0%	Herring 2017, Marc-Hernandez 2020	Only RCT	Critically Low	**NS (different measure)**	Concordant
Boppre 2021	MD: -4.14 cm [-8.16; -0.12]	201	4	9%	Castello 2011, Coen 2015a, Herring 2017, Shah 2011	Only RCT	Critically Low	+	
Ren 2018	WMD: -5.25 cm [-10.48; -0.03] *Low level of evidence*	198	4	94%	NR	Only RCT	Low	+	
***Fat Mass (FM) – 24% overlap of primary studies**									
Gasmi 2022	SMD: -0.08 [−0.54; 0.38]	74	3	0%	Hassanejad 2017, Marc-Hernandez 2020, Ricci 2020	Only RCT Whole-body electromyostimulation with dynamic exercise (k=1)	Critically Low	**NS**	Discordant
Boppre 2021	MD: -0.49 kg [-1.71; 2.69]	173	2	0%	Coen 2015b, Oppert 2018	Only RCT, DXA FM measurment	Critically Low	**NS**	
Bellicha 2021	MD: -2.1 kg [-3.7; -0.5]	NR	8	50%	Coen 2015b, Hassanejad 2017, Herring 2017, Huck 2015, Marchesi 2015, Oppert 2018, Shah 2011, Stegen 2011	RCT, NRCT	Critically Low	+	
Morales-Marroquin 2020	NS (*k*=4), + (*k*=2)	NR	6	NA	Campanha-Versiana 2017, Hassanejad 2017, Herring 2017, Huck 2015, Oppert 2018, Stegen 2011	RCT, NRCT All interventions include a resistance training component	Low	**(NS)**	

Ren 2018	WMD: -3.35 kg [-7.99; 1.29] *Low level of evidence*	186	3	95%	NR	Only RCT	Low	**NS**	
***Fat-Free Mass (FFM) and Lean Body Mass (LBM) – 24% overlap of primary studies**									
Roth 2022	**FFM:** Ex. vs. C = SMD: 0.39 [-0.01; 0.78] *Very Low level of evidence*	132	3	0%	Campanha-Versiana 2017, Castello 2011, Murai 2019	RCT, NRCT	Moderate	**NS**	Concordant for LBM / Discordant for FFM
	Ex+Protein vs. Protein = SMD: 0.25 [-1.15; 1.65] *Low level of evidence*	91	2	0%	Hassanejad 2017, Oppert 2018			**NS**	
	Ex + Protein + vit. D + $Ca2^{+}$ vs. Control = SMD: 5.16 [4.60; 5,71] *Moderate level of evidence*	220	1	NA	Muschitz 2016			**Inconclusive 1 study**	
Gasmi 2022	**FFM:** SMD: 0.23 [−0.31; 0.77]	54	2	0%	Hassanejad 2017, Marc-Hernandez 2020	Only RCT	Critically Low	**NS**	
Schurmans 2022	**LBM:** NS (k=5)	NR	5	NA	Castello 2011, Coen 2015a, Coen 2015b, Nunez-Lopez 2017, Shah 2011	RCT, NRCT 3 publications from 1 intervention (Coen 2015a/b, Nunez-Lopez 2017)	Low	**NS**	
	FFM: + (k=2, 1 only for combined E/R vs control and 1 only at 24 weeks), NS (k=3)	NR	5	NA	Hassanejad 2017, Herring 2017, Huck 2015, Nunez-Lopez 2017, Shah 2011			**?**	
Boppre 2021	**LBM:** MD: 0.87 [-0.65; 2.40]	201	3	0%	Coen 2015b, Oppert 2018, Shah 2011	Only RCT	Critically Low	**NS**	
Bellicha 2021	**LBM:** MD: 0.7 kg [-0.2; 1.6]	NR	10	45%	Campanha-Versiana 2017, Castello 2011, Coen 2015b, Hassanejad 2017, Herring 2017, Huck 2015, Marchesi 2015, Oppert 2018, Shah 2011, Stegen 2011	RCT, NRCT	Critically Low	**NS**	
Morales-Marroquin 2020	**FFM:** NS (*k*=5), + (*k*=1 only for combined E/R vs control)	NR	6	NA	Campanha-Versiana 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Huck 2015, Stegen 2011	RCT, NRCT All interventions include a resistance training component	Low	**(NS)**	
Ren 2018	**FFM:** WMD: 0.53 kg [-1.88; 2.94] *Very low level of evidence*	58	2	71%	NR	Only RCT	Low	**NS**	
Bone Mineral Density (BMD) – 58% overlap of primary studies									
Roth 2022	Ex vs. C, SMD: 0.51 [0.01; 1.01] *Moderate level of evidence*	63	1	NA	Murai 2019	RCT	Moderate	**Inconclusive 1 study**	Concordant
	Ex + Protein + vit. D + $Ca2^{+}$ vs C, SMD: 3.88 [3.43; 4.34] *Moderate level of*	220	1	NA	Muschitz 2016			**Inconclusive 1 study**	

	evidence								
Diniz-Sousa 2022	**Total hip:** SMD: 0.37 [0.02; 0.71] *Very low certainty evidence*	340	4	50%	Campanha-Versiana 2017, Diniz-Sousa 2021, Murai 2019, Muschitz 2016	RCT, NRCT	Moderate	+	
	Lumbar spine: SMD: 0.41 [0.19; 0.62] *Low certainty evidence*	341	4	19%	”			+	
	Femoral neck: SMD: 0.63 [0.19; 1.06] *Low certainty evidence*	112	2	0%	Diniz-Sousa 2021, Murai, 2019			+	
	1/3 radius: SMD: 0.58 [0.19; 0.97] *Low certainty evidence*	112	2	0%	”			+	
Bellicha 2021	SMD: 0.44 [0.21; 0.67]	NR	3	0%	Campanha-Versiana 2017, Murai 2019, Muschitz 2016	RCT, NRCT	Critically Low	+	
Morales-Marroquin 2020	+ (*k*=2)	NR	2	NA	Campanha-Versiana 2017, Murai 2019	RCT, NRCT All interventions include a resistance training component	Low	+	
***Vo2max/peak – 42% overlap of primary studies**									
Boppre 2022	**VO₂max:** MD: 0.26 L/min [-0.11; 0.63]	NR	3	0%	Mundberg 2018b, Nunez-Lopez 2017, Shah 2011	Only RCT	Critically Low	**NS**	
Schurmans 2022	**VO₂max:** + (k=4), NS (k=2)	NR	6	NA	Coen 2015a, Coen 2015b, Huck 2015, Nunez-Lopez 2017, Shah 2011, Woodlief 2015	RCT, NRCT 4 publications from 1 intervention (Coen 2015a/b, Nunez-Lopez 2017, Woodlief 2015)	Low	**(+)**	
Bellicha 2021	**VO₂max:** SMD: 0.70 [0.35; 1.06]	NR	8	42%	Coen 2015a, Huck 2015, Marchesi 2015, Mundberg 2018b, Onofre 2017, Oppert 2018, Shah 2011, Stegen 2011,	RCT, NRCT	Critically Low	+	Discordant
Carretero-Ruiz 2021	**VO₂max/peak relative to body weight:** ES: 0.67 [0.29; 1.06] (MD: 1.25 ml/kg/min [0.48; 2.02])	N	6	23%	Auclair 2021, Huck 2015, Marchesi 2015, Onofre 2017, Shah 2011, Stegen 2011	RCT, NRCT	Critically Low	+	
	VO₂max/peak: ES: 0.32 [0.07; 0.57]	NR	5	0%	Auclair 2021, Coen 2015a, Mundberg 2018b, Onofre 2017, Stegen 2011			+	
Da Silva 2019	**VO₂max:** SMD: 0.43 [0.16; 0.70]	215	7	0%	Coen 2015a, Huck 2015, Marchesi 2015, Nunez-Lopez 2017, Onofre 2017, Shah 2011, Stegen 2011	Only RCT 2 publications from 1 intervention (Coen	Critically Low	+	

						2015a, Nunez-Lopez 2017)			
6 Minute Walking Test Distance (6MWTD) – 33% overlap of primary studies									
Schurmans 2022	NS (k=3)	NR	3	NA	Castello 2011, Castello 2013, Coleman 2017	RCT 2 publications from 1 intervention (Castello 2011/2013) Caveat: unclear conclusions in both review and original study articles	Low	**NS**	Discordant
Bellicha 2021	SMD: 1.46 [0.27; 2.66]	NR	5	89%	Castello 2011, Coleman 2017, Hassanejad 2017, Herring 2017, Stegen 2011	RCT, NRCT	Critically Low	+	
Ren 2018	WMD: 29.67 m [25.97; 33.37] *Low level of evidence*	65	2	0%	Castello 2011, Coleman 2017	Only RCT	Low	+	
Muscle Strength – 27% overlap of primary studies									
Vieira 2022	**1-RM Upper muscle=** ES: 0.71 [0.41; 1.01] *Very low level of evidence*	NR	4	0%	Campanha-Versiana 2017, Gil 2021, Hassanejad 2017, Stegen 2011	RCT, NRCT	Low	+	Concordant
	1-RM Lower muscle= ES: 1.37 [0.84; 1.91] *Very low level of evidence*	NR	5	46%	Campanha-Versiana 2017, Daniels 2018, Gil 2021, Kelley 2019, Stegen 2011			+	
	Sit-to stand= ES: 0.60 [0.20–1.01] *Very low level of evidence*	NR	8	69%	Coleman 2017, de Oliviera 2021, Gil 2021, Hassanejad 2017, Kelley 2019, Lamarca 2021, Mundberg 2018b, Stegen 2011			+	
	Dynamometer= ES: 0.46 [0.06–0.87] *Very low level of evidence*	NR	4	31%	Diniz-Sousa 2021, Kelley 2019, Lamarca 2021, Mundberg 2018b			+	
	Handgrip test= ES: 0.11 [-0.42–0.63] *Very low level of evidence*	NR	6	73%	de Oliviera 2021, Gallé 2020, Herring 2017, Huck 2015, Noack-Segovia 2019, Stegen 2011			NS	
Schurmans 2022	+ (k=1)	NR	1	NA	Daniels 2018	RCT	Low	**Inconclusive 1 study**	
Bellicha 2021	SMD: 0.82 [0.48; 1.16]	NR	8	42%	Campanha-Versiana 2017, Coleman 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Mundberg 2018b, Oppert 2018, Stegen 2011	RCT, NRCT	Critically Low	+	
Morales-Marroquin 2020	+ (*k*=5, 1 only for combined E/R v control and 1 for exercise+protein supplementation)	NR	5	NA	Campanha-Versiana 2017, Daniels 2018, Hassanejad 2017, Herring 2017, Oppert 2018	RCT, NRCT All interventions include a resistance training component	Low	+	
Resting Heart Rate (RHR) – 30% overlap of primary studies									

Boppre 2022	MD: -2.05 bpm [-6.64; 2.54]	NR	3	0%	Castello 2011, Herring 2017, Mundberg 2018a	Only RCT	Critically Low	**NS**	Discordant
Schurmans 2022	NS (k=3)	NR	3	NA	Castello 2013, Huck 2015, Mundberg 2018a	RCT	Low	**NS**	
Carretero-Ruiz 2021	ES: -0.44 [-0.75; -0.02] (MD: -3.93 bpm [-6.54; 1.31])	NR	5	0%	Castello 2011, Huck 2015, Herring 2017, Marchesi 2015, Mundberg 2018a	RCT, NRCT	Critically Low	+	
Marshall 2020	MD: -3.06 bpm [-5.65; -0.47] *Very low level of evidence*	111	4	0%	Pre-MBS (Baillot 2018/Baillot 2014); Post-MBS (Castello 2011, Huck 2015, [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018c])	RCT, NRCT *k*=1 (2 publications) pre-MBS intervention Mistakenly considered Baillot 2014/2018 as one study	Low	**Inclusive as pre/post-MBS results are combined**	
Ren 2018	WMD: -4.39 bpm [-8.11; -0.68] *Low level of evidence*	94	3	0%	NR	Only RCT	Low	+	
Blood Pressure (BP) – 33% overlap of primary studies									
Boppre 2022	**SBP** MD: − 5.33 mmHg [-8.99; -1.66] *Moderate certainty evidence*	314	6	0%	Auclair 2021, Castello 2011, Coen 2015b, Herring 2017, Munderberg 2018a, Shah 2011	Only RCT	Critically Low	+	Concordant for DBP Discordant for SBP
	DBP MD: -2.66 mmHg [-6.72; 1.40]	NR	6	59%	”			**NS**	
Schurmans 2022	**SBP:** NS (k=4) + (k=1)	NR	5	NA	Castello 2011, Coen 2015a, Herring 2017, Huck 2015, Mundberg 2018a	RCT	Low	**(NS)**	
	DBP: NS (k=2), + (k=2, 1 only at 24 months post-MBS)	NR	4	NA	Castello 2011, Coen 2015a, Mundberg 2018a, Shah 2011			**?**	
Carretero-Ruiz 2021	**SBP:** ES: -0.16 [-0.40; 0.08] (MD = -2.65 mmHg [-7.32; -1.11])	NR	5	0%	Coen 2015b, Herring 2017, Huck 2015, Mundberg 2018a, Shah 2011	RCT, NRCT	Critically Low	**NS**	
	DBP: ES: -0.12 [-0.446, 0.21] (MD: -1.41 mmHg [-5.56, 2.75])	NR	5	34%	”			**NS**	
Bellicha 2021	**SBP:** MD: -4.2 mmHg [-9.3; 1.0]	NR	4	47%	Coen 2015b, Herring 2017, Huck 2015, Shah 2011	RCT, NRCT	Critically Low	**NS**	
	DBP: MD: -2.3 mmHg [-8.5; 3.9]	NR	4	77%	”			**NS**	
Marshall 2020	**SBP:** MD: -1.59 mmHg [-3.74; 0.56] *Very low level of evidence*	239	5	27%	Pre-MBS (Baillot 2014/2018); Post-MBS (Castello 2011, [Coen 2015a/Coen 2015b/Nunez-Lopez 2017, Woodlief 2015], Huck 2015, [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018c])	RCT, NRCT *k*=1 (2 publications) pre-MBS intervention Mistakenly considered Baillot	Low	**Inclusive as pre/post-MBS results are combined**	

	DBP: MD: -1.31 mmHg [-2.33; -0.29] *Very low level of evidence*	251	6	23%	Pre-MBS (Baillot 2014/2018); Post-MBS (Castello 2011, [Coen 2015a/Coen 2015b/Nunez-Lopez 2017, Woodlief 2015], Huck 2015, Onofre 2017, [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018c])	2014/2018 as one study		**Inclusive as pre/post-MBS results are combined**	
Ren 2018	**SBP:** WMD: -4.12 mmHg [-6.68; -1.55] *Low level of evidence*	229	4	6%	NR	Only RCT	Low	+	
	DBP: WMD: -3.56 mmHg [-8.61; 1.48] *Very low level of evidence*	229	4	83%	”			**NS**	
Quality of Life (QoL) – 33% overlap of primary studies									
Schurmans 2022	NS (k=2) except for general health domain	NR	2	NA	Shah 2011, Stolberg 2018b	Only RCT	Low	**NS**	Concordant
Bellicha 2021	**Physical.:** MD: -2.5 [-5.1; 0.2]	NR	2	0%	Oppert 2018, Shah 2011	Only RCT	Critically Low	**NS**	
	Mental: MD: 3.9 [-0.5; 8.3]	NR	2	0%	”			**NS**	
Glucose Metabolism – 30% overlap of primary studies									
Boppre 2022	**Insulin:** MD: -1.58 µIU/mL [-5.14; 1.98]	NR	4	71%	Coen 2015b, Dantas 2020, Mundberg 2018a, Shah 2011	Only RCT	Critically Low	**NS**	Concordant
	Glucose: MD: 0.94 mg/dL [-3.31; 5.19]	NR	4	0%	”			**NS**	
	HOMA-IR: MD: 1.39 [-1.30; 4.08]	NR	2	89%	NR			**NS**	
	HbA1c: MD: -0.65 mmol/mol [-2.22; 0.93]	NR	2	0%	NR			**NS**	
Schurmans 2022	**Insulin sensitivity:** + (k=3) NS (k=1)	NR	4	NA	Coen 2015a, Coen 2015b, Nunez-Lopez 2017, Woodlief 2015	RCT 4 publications from 1 intervention (Coen 2015a/b, Nunez-Lopez 2017, Woodlief 2015)	Low	**Inconclusive all 4 publications same study**	
	AIRg and Di: + (k=1), NS (k=1)	NR	2	NA	Coen 2015b, Woodlief 2015			**Inconclusive only 2 publications same study**	
	SPISE: NS (k=1)	NR	1	NA	Mundberg 2018[a]			**Inconclusive 1 study**	
	HOMA-IR: NS (k=2)	NR	2	NA	Mundberg 2018a, Nunez-Lopez 2017			**NS**	
	Glucose effectiveness: + (k=1)	NR	1	NA	Coen 2015b			**Inconclusive 1 study**	
Bellicha 2021	**HOMA-IR** SMD: 0.14 [-0.10; 0.38]	NR	2	0%	Coen 2015b, Mundberg 2018a	RCT	Critically Low	**NS**	
Marshall 2020	**Fasting insulin**.MD: 4.88 pmol/L [-2.09; 11.84] (low level of evidence)	180	2	0%	[Coen 2015a/Coen 2015b/Nunez-Lopez 2017/Woodlief 2015], [Mundberg 2018a/Mundberg 2018b/Stolberg 2018a/Stolberg 2018c]	RCT	Low	**NS**	

	Fasting glucose MD: 0.05 mmol/L [-0.14; 0.24] (low level of evidence)	180	2	0%	”			**NS**	
Lipid Metabolism – 27% overlap of primary studies									
Boppre 2022	**TC** MD: -3.08 mg/dL [-12.04; 5.87]	NR	5	0%	Coen 2015b, Dantas 2020, Mundberg 2018a, Shah 2011, Tardif 2020	Only RCT	Critically Low	**NS**	Concordant for TG.LDL and TC Discordant for HDL
	HDL MD: 0.61 mg/dL [-3.05; 4.28]	NR	5	26%	”			**NS**	
	LDL MD: -8.17 mg/dL [-20.35; 4.00]	NR	5	57%	”			**NS**	
	TG MD: -8.38 mg/dL [-19.81; 3.04]	NR	5	0%	”			**NS**	
Schurmans 2022	**Blood lipids:** NS (k=1), + (k=1 for HDL-C)	NR	2	NA	Coen 2015a, Mundberg 2018a	RCT,	Low	**Inconclusive unclear variables**	
Carretero-Ruiz 2021	**HDL** ES: 0.22 [0.01; 0.43]	NR	6	0%	Coen 2015b, Dantas 2020, Marchesi 2015, Mundberg 2018b, Shah 2011, Tardif 2020	RCT, NRCT	Critically Low	+	
Bellicha 2021	**LDL** SMD: -0.18 [-0.46; 0.09]	NR	3	0%	Coen 2015b, Mundberg 2018a, Shah 2011	RCT, NRCT	Critically Low	**NS**	
	HDL SMD: 0.10 [-0.16; 0.37]	NR	4	0%	Coen 2015b, Marchesi 2015, Mundberg 2018a, Shah 2011			**NS**	
	TG SMD: 0.01 [-0.26; 0.27]	NR	4	0%	”			**NS**	
Marshall 2020	**TG** MD: 0.01 mmol/L [-0.15; 0.16] (low level of evidence)	180	2	0%	[Coen 2015a/Coen 2015b/Nunez-Lopez 2017/Woodlief 2015], [Mundberg 2018a/Mundberg 2018b, Stolberg 2018a/Stolberg 2018c]	RCT	Low	**NS**	
	HDL MD: -0.00 mmol/L [-0.01; 0.01] (low level of evidence)	180	2	0%	”			**NS**	
	LDL MD: -0.06 mmol/L [-0.21; 0.09] (low level of evidence)	180	2	0%	”			**NS**	
	TC MD: -0.08 mmol/L [-0.26; 0.11] (low level of evidence)	180	2	0%	”			**NS**	

Note. * interpret these results with caution due to unreliable measurements in adults with obesity. RR=risk ratio, MD=mean difference, SMD=standardized mean difference, NS=non significant, NR=not reported, NA=not applicable, *k*=number of studies, *n*=subsample size, I^2=degree of heterogeneity, MBS=metabolic and bariatric surgery RCT=randomized control trial, NCRT=non randomized control trial, PAC=physical activity counselling. Individual review conclusions highlighted in dark grey were not factored into the overall conclusion for the outcome.

[a] + =significant benefits from a meta-analysis, or 100% concordance for significant benefits between studies in a systematic review, (+) =partial concordance (≥ 67%) for significant benefits between studies in a systematic review, ? =discordance between studies in a systematic review, (NS) =partial concordance (≥ 67%)

for non significant benefits between studies in a systematic review, NS =non-significant benefits from a meta-analysis, or 100% concordance for non significant benefits between studies in a systematic review.

[b] conclusion determined by following flow diagram (see Appendix P).

Table 5: Pooled Percentage Feasibility and Acceptability Data from Baillot et al, 2022 [6]

Effects	*k*	arms	I^2	Studies included
Attendance rate (exercise arm): 84.3% [77.0; 90.7]	8	10	0%	Baillot 2016, Castello 2011, Herring 2017, Huck 2015, Lamarca 2021, Marcon 2017, Murai 2019, Picó-Servant 2019
Dropout rate (exercise arm): 5.0% [1.1; 10.5]	18	19	60%	Arman 2021, Baillot 2016, Castello 2011, Coen 2015b, Coleman 2017, Daniels 2017, Gilbertson 2020, Herring 2017, Marc-Hernandez 2019, Marc-Hernandez 2020, Marchesi 2015, Marcon 2017, Murai 2019, Onofre 2017, Oppert 2018, Picó-Servant 2019, Shah 2011, Tardif 2020
Enrollment rate (both groups): 43% [30; 57]	18	18	94%	Arman 2021, Baillot 2016, Campanha-Versiani 2017, Castello 2011, Coen 2015b, Coleman 2017, Diniz Souza 2020, Gilbertson 2020, Hassanejad 2017, Herring 2017, Lamarca 2021, Marc-Hernandez 2020, Marcon 2017, Mundberg 2018a, Murai 2019, Onofre 2017, Oppert 2018, Tardif 2020
Refusal rate (both groups) 22.6% [10.0; 38.2]	16	16	95%	Arman 2021, Baillot 2016, Campanha-Versiani 2017, Castello 2011, Diniz Souza 2020, Gilbertson 2020, Hassanejad 2017, Herring 2017, Lamarca 2021, Marc-Hernandez 2020, Marcon 2017, Mundberg 2018a, Murai 2019, Onofre 2017, Oppert 2018, Tardif 2020
Retention rate (exercise arm): 87.1% [79.6; 93.0]	23	26	80%	Arman 2021, Baillot 2016, Campanha-Versiani 2017, Castello 2011, Coen 2015b, Coleman 2017, Daniels 2017, Gilbertson 2020, Herring 2017, Lamarca 2021, Marc-Hernandez 2019, Marc-Hernandez 2020, Marchesi 2015, Marcon 2017, Mundberg 2018a, Murai 2019, Muschitz 2016, Onofre 2017, Oppert 2018, Picó-Servant 2019, Shah 2011, Stegen 2011, Tardif 2020

Note. All effects were pooled percentages. Sample size was not reported in any of the analyses and all analyses included both randomized and non randomized control trials. *k* =number of primary articles, I^2=measure of heterogeneity.

Figure 1: PRISMA Flow Diagram

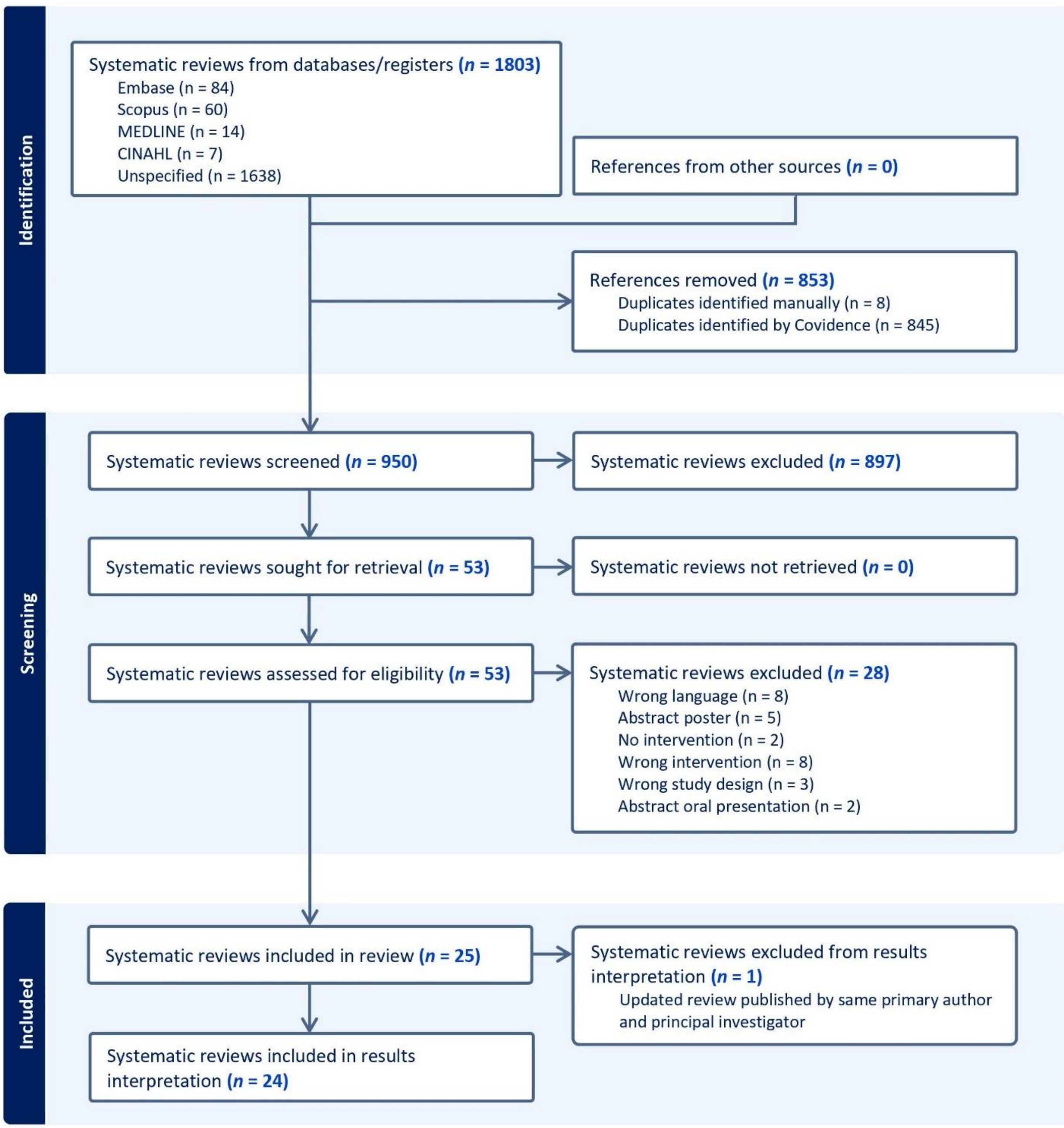

Figure 2: Summary of Outcome Conclusions Pre- and Post-MBS

Operational Definitions

Exercise training = physical activity that was planned, structured, and repeated (e.g., endurance and/or resistance training)

Physical activity counselling = interventions to increase physical activity motivation using behaviour change techniques

What We Currently Know

Beneficial Characteristics of Exercise Training Programs

Exercise training that combines endurance/ resistance
→ + systolic blood pressure

Exercise training that lasts > 12 weeks
→ + systolic blood pressure

What We Think We Know

Effects of Exercise Training

Pre MBS Exercise Training

Exercise training
→ + BMI
→ + 6-minute walking test
→ NS quality of life

Exercise training and physical activity counselling
→ + VO_2max

Post MBS Exercise Training

Exercise training
→ + body weight and BMI
→ + waist circumference
→ + bone mineral density
→ + 6-minute walking test
→ + muscle strength
→ + systolic blood pressure
→ NS weight loss ≥12 months post-MBS
→ NS fat mass
→ NS fat-free and lean body mass[a]
→ NS VO_2max
→ NS resting heart rate
→ NS diastolic blood pressure
→ NS fasting insulin and fasting glucose
→ NS total cholesterol, triglycerides, or low-density lipoprotein
→ NS high-density lipoprotein

Beneficial Characteristics of Exercise Training Programs

Exercise training that combines endurance/ resistance
→ + body weight and BMI
→ + triglycerides

Exercise training starting < 6 months post MBS
→ NS body weight and BMI

Exercise training starting > 6 months post MBS
→ + body weight and BMI

Feasibility and Acceptability

Exercise training has:
- high attendance rates
- high retention rates
- low drop out rates
- low risk of serious exercise adverse events

What We Still Don't Know

Effects of Exercise Training

Pre MBS Exercise Training

Impact of exercise training on:
- fat mass
- fat-free and lean body mass[a]
- muscle strength
- resting heart rate
- blood pressure
- glucose/lipid metabolism
- physical activity
- adverse surgical events
- hospital stay length

Post MBS Exercise Training

Impact of exercise training on:
- quality of life
- HOMA-IR, HbA1c, insulin sensitivity, AIRg, Di, SPISE and glucose effectiveness

Pre and Post MBS Exercise Training

Impact of exercise training on any variable in the long-term (i.e., > 12 months)

Beneficial Characteristics of Exercise Training Programs

Impact of:
- **exercise training starting > 6 months post MBS on** systolic blood pressure
- **exercise training starting ≥ 12 months post MBS on** body weight

Feasibility and Acceptability

- adherence rates to prescribed exercise training programs
- impact of exercise training characteristics (i.e., timing, modality, duration etc.) on feasibility and acceptability outcomes

Note. The flow diagram used to categorize each outcome, and a summary of these categorizations, are presented in Appendix P and R respectively. The second column is titled "what we think we know" to demonstrate the lack of absolute conclusions. BMI=body mass index, HOMA-IR=homeostatic model assessment for insulin resistance, HbA1c=hemoglobin A1C, AIRg=acute insulin response to glucose, Di=disposition index, SPISE=single-point insulin sensitivity estimator.

[a] lean body mass=weight of your muscles, bones, ligaments, tendons, and internal organs, while fat free mass=total body mass – fat mass.