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Behavioral weight management interventions in metabolic and bariatric surgery: A systematic review and meta-analysis investigating optimal delivery timing

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Summary

Metabolic and bariatric surgery (MBS) yields unprecedented clinical outcomes, though variability is high in weight change and health benefits. Behavioral weight management (BWM) interventions may optimize MBS outcomes. However, there is a lack of an evidence base to inform their use in practice, particularly regarding optimal delivery timing. This paper evaluated the efficacy of BWM conducted pre- versus post- versus pre- *and* post-MBS. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and included pre- and/or post-operative BWM interventions in adults reporting anthropometric and/or body composition data. Thirty-six studies (2,919 participants) were included. Post-operative BWM yielded greater decreases in weight (standardized mean difference [SMD] = −0.41; 95% confidence interval [CI]: −0.766 to −0.049, $p < 0.05$; I^2 = 93.5%) and body mass index (SMD = −0.60; 95% CI: −0.913 to −0.289, $p < 0.001$; I^2 = 87.8%) relative to comparators. There was no effect of BWM delivered *pre-* or joint pre- *and* post-operatively. The risk of selection and performance bias was generally high. Delivering BWM *after* MBS appears to confer the most benefits on weight, though there was high variability in study characteristics and risk of bias across trials. This provides insight into the type of support that should be considered post-operatively.

KEYWORDS
behavioral weight management, BMI, metabolic and bariatric surgery, weight

1 | INTRODUCTION

Weight management remains challenging, particularly in the context of severe obesity; although effective behavioral, pharmacological, surgical, and psychosocial interventions exist,[1,2] healthcare systems remain poorly equipped to support patients in effective long-term weight management.[2–5] Metabolic and bariatric surgery (MBS) is the most durable treatment for severe obesity.[6,7] It is associated with substantial reductions in weight, mortality, and improved comorbidities.[8–10] However, evidence shows notable disparities in post-operative trajectories,[11–13] leading to reoperation rates (2%–78%).[6,11] This includes insufficient weight loss and/or consistent

Abbreviations: 95% CI, 95% confidence interval; BMI, body mass index; BWM, behavioral weight management; FU, follow-up; ITT, intent-to-treat; MBS, metabolic and bariatric surgery; RCT, randomized controlled trial; ROB, risk of bias; RYGB, Roux-en-Y gastric bypass; SD, standard deviation; SMD, standardized mean difference.

weight regain, even as early as 6 months post-MBS,[14–16] with 20%–34% of patients experiencing suboptimal weight loss ≤5 years post-surgery[17,18] and ≤87% of patients regaining weight within 10 years.[16,19,20] These data stress the importance of developing effective adjunct interventions to optimize MBS outcomes.

Behavioral weight management (BWM) is effective in achieving clinically significant weight loss (5%–10% decreases) and improved comorbidities in non-surgically treated obesity.[1,21,22] However, the data are highly variable in the context of MBS,[23–25] with previous reviews limited by only including certain types of BWM interventions (e.g., exercise or psychoeducation only)[23,24,26–31]; the use of observational and non-experimental data[24–28,30–32]; the low number of studies included in meta-analyses (n = 3–9)[23,27,29,32]; and only focusing on a specific time for the intervention, that is, before[25,31] *or* after[25,29,30,32] surgery. As such, although the stark contrast in the pre- versus post-surgical milieu (e.g., differences in pre- vs. post-operative diets, functional capacity, and psychological adaptations after surgery) poses a notable complexity to the delivery of BWM in MBS, one of the major knowledge gaps remains the optimal timing to deliver adjunct BWM. Our objective was to provide a synthesis of the evidence assessing the relative efficacy of BWM delivered pre- versus post-MBS to provide further evidence regarding the optimal delivery timing of the most efficacious interventions in MBS.

2 | METHODS

This registered review (PROSPERO: CRD42017049094) followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[33]

2.1 | Inclusion criteria

Studies testing interventions aimed at improving weight through behavioral/weight-related psychosocial change in adults undergoing MBS were included. Interventions strictly targeting psychosocial status, physical fitness, or muscle strength were excluded.[34–36] Eligible comparators were no intervention, wait list control, usual/standard of care, or treatments not including the hypothesized active ingredient(s) of the experimental intervention. Studies had to report an anthropometric (e.g., weight, body mass index [BMI], and body composition) outcome pre- and post-intervention. Eligible designs included a comparator and consisted of randomized controlled trials (RCT), quasi-RCTs, and controlled before-and-after studies. Observational studies, reviews, abstracts, unpublished literature, and non-French or English publications were excluded.

2.2 | Search method

Searches were conducted in PubMed, PsycINFO, Embase, Scopus, and the Cochrane Controlled Register of Trials initially in June 2016 and updated in February 2020 (see Data S1 for search). Two reviewers (C. A. J. and A. I. D.) screened titles and abstracts and then assessed full-text articles for eligibility (Figure 1). Any disagreements were resolved by consensus or by a third reviewer (S. L. B.).

2.3 | Data extraction

Two reviewers (C. A. J. and L. A. M.) independently extracted data. Study authors were contacted up to three times for missing information. Disagreements were resolved by consensus. All included studies were assessed for risk of bias (ROB) using the Cochrane Collaboration's ROB tool.[37] An *unclear ROB* resulted from insufficient/unclear reporting or an unknown ROB, whereas a *high ROB* resulted from the use of high ROB methods or a failure to report information.

2.4 | Statistical analyses

Comprehensive Meta-Analysis (version 3.3.070)[38] was used to provide the pooled estimates of the mean effect from BWM versus comparators on outcomes (Data S2). Due to their clinical complexity, studies evaluating *pre*, *post*, and *joint* pre- *and* post-operative interventions were analyzed separately. As recommended,[39] two types of outcomes, *final* means and *changes* in means from baseline for weight and BMI, with respective standard deviations (SDs) were analyzed separately (i.e., type of scores sensitivity analysis) and pooled together to calculate standardized mean differences (SMDs) with 95% confidence intervals (95% CIs). Raw differences in means (unstandardized mean differences), expressed as kilograms (kg) and kg/m^2, were also calculated. Random effects models were used given the anticipated high heterogeneity across studies. However, pooled estimations were performed using mixed-effects models for group comparisons. SMD of 0.20, 0.50, and 0.80 were considered as small, medium, and large effects. Statistical heterogeneity was assessed using the Q (df) statistic and the inconsistency index Higgins I^2 test, yielding scores from 0% to 100% interpreted as recommended.[39,40] Sensitivity analyses investigated the impact of methodological aspects: type of score used (final/change) and use of intent-to-treat (ITT) analysis (yes/no). Publication bias was evaluated using funnel plots (Data S3).

3 | RESULTS

3.1 | Study selection

In total, 7,288 reports were screened by examining titles and abstracts (Figure 1), leading to 163 potentially eligible studies. Thirty-six independent trials (with five follow-up [FU] papers) met inclusion criteria, of which 33 were included in meta-analyses of weight (n = 31) and/or BMI (n = 29).

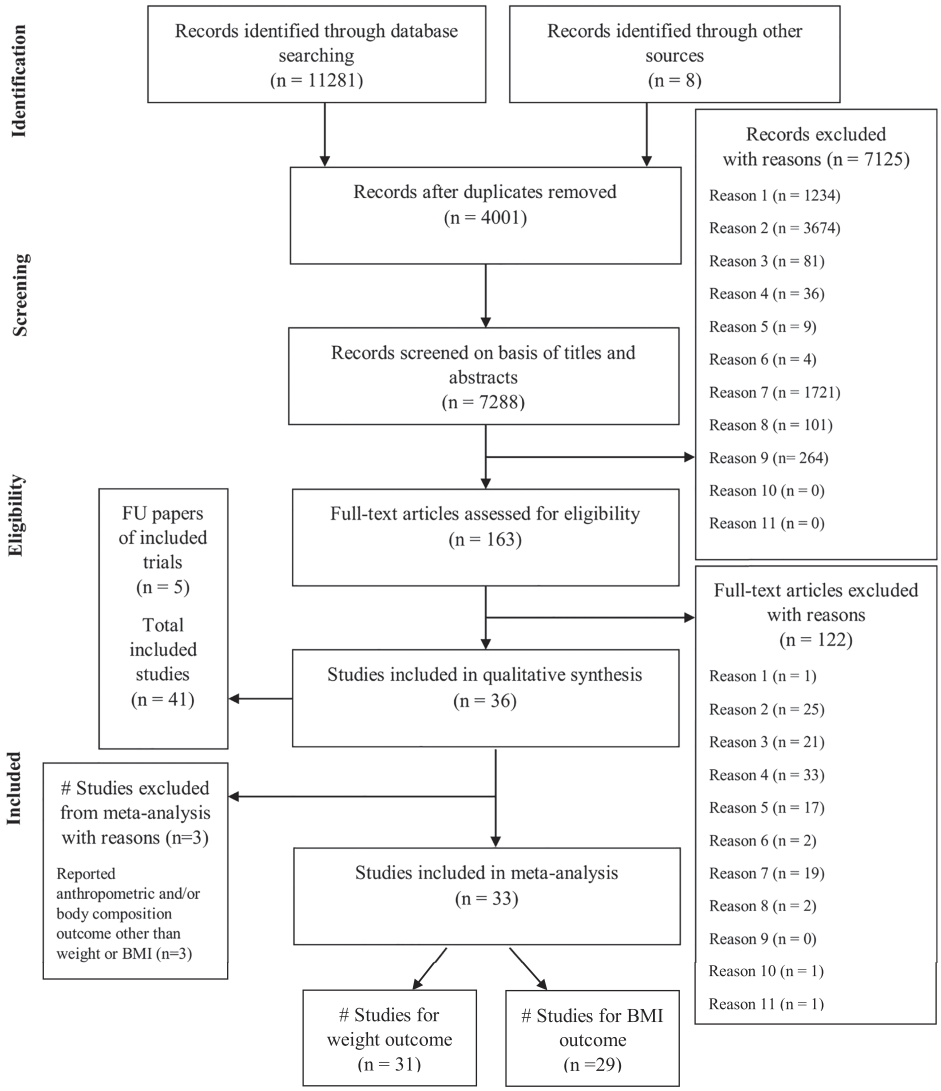

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram. Reason 1 = population type (non-human/animal; non-adult; non-bariatric); Reason 2 = design type (non-interventional study; observational study; uncontrolled study; case study); Reason 3 = intervention type (not designed for weight loss/management); Reason 4 = comparator type (not usual care/standard care/wait list/no intervention; ineligible attention placebo); Reason 5 = measured outcomes (no anthropometric and/or body composition outcome(s); no pre- to post-intervention measure; no new anthropometric and/or body composition outcome(s)); Reason 6 = language (no French; no English); Reason 7 = reviews, books, chapters, theses, editorials, letters to editor, abstracts; Reason 8 = protocols; Reason 9 = guidelines, reports; Reason 10 = full-text unaccessible; Reason 11 = retracted. BMI, body mass index; FU, follow-up

3.2 | Study characteristics

3.2.1 | Designs and participants

Table 1 shows study and participant characteristics. The total sample size was 2,919 (mean [SD] = 81 [53.1]; range = 15–240), which were predominantly white (62%) women (79%) with a mean age of 43 years (SD = 4.8; range = 32–53), a mean baseline weight of 119 kg (SD = 19.3; range = 81.1–152.7), and a mean baseline BMI of 42.8 kg/m^2 (SD = 6.5; range = 29.8–51.6). Most studies were from the United States (47%) or Europe (36%). There were 29 RCTs and a total of 41 experimental interventions versus 36 comparators. The majority (61%) of BWM arms were delivered post-operatively. Time to post-BWM intervention assessment varied across trials (mean [SD] = 7.4 [6.5] months; range = 1–36). Mean post-operative FU was 18.1 (12.8) months (range = 1.5–48). Over three quarters (86%) of studies stated the types of MBS undergone by participants (Roux-en-Y gastric bypass [RYGB] = 63%).

3.2.2 | Reported outcomes

Weight data were reported in 31 (89%) studies,[41,43,44,46,51,53–59,61–65,67–72,74–81] with 15 (48%) reporting absolute weights[41,44,51,53,57,59,63–65,67,68,70,74,78,79] and 11 (35%) reporting weight changes.[43,53,54,56,59,61,69,71,74,77,78] BMI and/or BMI

TABLE 1 Study characteristics (n = 36)

Identification, country	Design	MBS type	Total randomized	Total included (pre- to post-analyses)	Total (%)		Mean (SD)			Time of baseline assessment
					Women	White	Age (years)	Weight (kg)	BMI (kg/m^2)	To start of intervention (months)
Pre-operative										
Kalarchian et al.,[41,42] United States	RCT	RYGB (n = 81); LAGB (n = 56)	240	187	208 (87)	199 (83)	45.2 (11)	NR	47.9 (6.7)	NR
Camolas et al.,[43] Portugal	RCT	NR	94	94	76 (81)	NR	44.9 (13.8)	112.5 (20.4)	43.1 (6.1)	~6
Bond et al.,[44,45] United States	RCT	RYGB (n = 18); AGB (n = 16); SG (n = 2)	80	75	65 (87)	59 (79)	46 (8.9)	120.7 (20.6)	45 (6.5)	~ 3
Gade et al.,[46–48] Norway	RCT	RYGB (n = 67); SG (n = 13)	102	98	69 (68)	NR	42.6 (9.8)	128 (19.1)	43.5 (4.9)	NR
Parikh et al.,[49] United States	Pilot RCT	LAGB (n = 55)	55	NR	55 (100)	NR	46.6 (10.2)	114.3 (19.8)	45.2 (6.9)	6
Heinberg and Schauer,[50] United States	Pilot RCT	NR	73	NR	52 (71)	NR	47.3 (10.8)	116.8 (43.5)	49.6 (9.5)	~3.5
Marcon et al.,[51] Brazil	RCT	NR	66	57	51 (90)	49 (86)	44.1 (11.3)	122.6 (25.4)	47.7 (7.4)	NR
Lemanu et al.,[52] New Zealand	RCT	LSG (n = 88)	102	88	61 (69)	38 (43)	43.8 (7.9)	127 (24.5)	44.7 (6.9)	1–1.5
Marc-Hernandez et al.,[53] Spain[a]	CBA	NR	23	NR	15 (83)	0	40.3 (8)	126.6 (29.7)	45.9 (9.2)	3–6
Post-operative										
Kalarchian et al.,[54] United States	Pilot RCT	RYGB (n = 29); revision to RYGB (n = 4); LAGB (n = 2); VBG (n = 1)	36	NR	32 (89)	27 (75)	52.5 (7.1)	NR	43.1 (6.2)	≥36 (postop)
Kalarchian et al.,[55] United States	Pilot RCT	RYGB (n = 40)	40	40	34 (85)	32 (80)	46.9 (11.1)	87.7 (16.7)	31.3 (5.4)	10–14 (postop)
Chacko et al.,[56] United States	Pilot RCT	RYGB (n = 9); LAGB (n = 6); SG (n = 3)	18	18	15 (83)	13 (72)	NR	NR	NR	2.7 (0.8) years (postop)

(Continues)

TABLE 1 (Continued)

Identification, country	Design	MBS type	Total randomized	Total included (pre- to post-analyses)	Total (%)		Mean (SD)			Time of baseline assessment
					Women	White	Age (years)	Weight (kg)	BMI (kg/m^2)	To start of intervention (months)
Dodsworth et al.,[57] Australia	Pilot quasi-RCT	LAGB (*n* = 47)	47	41	38 (81)	NR	44.5 (10.5)	NR	42.1 (7.6)	1.6 weeks (postop)
Gallé et al.,[58] Italy	CBA	LAGB (*n* = 67); LRYGB (*n* = 75)	154	142	122 (79)	NR	32 (10.9)	124.5 (23.3)	43.1 (4.6)	NR (preop)
Nijamkin et al.,[59] United States	RCT	LRYGB (*n* = 144)	144	144	120 (83)	NR	44.5 (13.5)	NR	NR	6 months ± 6 weeks (postop)
Marchesi et al.,[60] Italy	CBA	LRYGB (*n* = 20)	20	17	20 (100)	NR	41.1 (4.61)	81.1 (9.3)	29.8 (3.8)	18 (6.2) (postop)
Papalazarou et al.,[61] Greece	RCT	VBG (*n* = 30)	30	NR	30 (100)	NR	33.1 (5.8)	124.6 (21.6)	46.7 (7.4)	~1–4 weeks (preop)
Sarwer et al.,[62] United States	Pilot RCT	RYGB (*n* = 62); LAGB (*n* = 16)	84	NR	53 (63)	50 (60)	42 (9.9)	152.7 (33.7)	51.6 (9.2)	~2 weeks (preop)
Coen et al.,[63] United States	RCT	RYGB (*n* = 128)	128	128	113 (88)	106 (83)	NR	NR	NR	1–3 (postop)
Shah et al.,[64] United States	RCT	RYGB (*n* = 10); AGB (*n* = 23)	33	28	30 (91)	18 (55)	NR	NR	NR	3 months to 8.5 years (postop)
Wild et al.,[65,66] Germany	RCT	RYGB (*n* = 42); SG (*n* = 66); LAGB (*n* = 3); unknown (*n* = 3)	117	114	80 (70)	NR	NR	148.3 (23.9)	50.1 (6.4)	NR (preop)
Hassannejad et al.,[67] Iran	RCT	RYGB (*n* = 27); SG (*n* = 33)	60	55	45 (75)	NR	NR	NR	NR	1 week (preop)
Campanha-Versiani et al.,[68] Brazil	Quasi-RCT	RYGB (*n* = 60)	60	37	50 (83)	NR	35.9 (12.1)	121.5 (10.1)	42.3 (13.8)	3 (postop)
Herring et al.,[69] United Kingdom	RCT	RYGB (*n* = 8); SG (*n* = 15); AGB (*n* = 1)	24	24	22 (92)	NR	48.4 (8.9)	106.8 (16.7)	39 (5.2)	19.3 (5.4) (postop)
Tucker et al.,[70] United States	RCT	RYGB (10); VBG (*n* = 22)	41	32	21 (66)	NR	40.2 (NR)	142.6 (NR)	NR	NR (preop)
Huck,[71] United States	Quasi-RCT	RYGB (NR); AGB (NR)	15	15	12 (80)	NR	48.5 (10)	96.8 (17.6)	35 (5.71)	5.2 (2.4) (postop)
Mangieri et al.,[72] United States	RCT	NR	56	56	NR	NR	NR	NR	NR	≤12 (postop)

(Continues)

TABLE 1 (Continued)

Identification, country	Design	MBS type	Total randomized	Total included (pre- to post-analyses)	Total (%)		Mean (SD)			Time of baseline assessment
					Women	White	Age (years)	Weight (kg)	BMI (kg/m^2)	To start of intervention (months)
Gallé et al.,[73] Italy	Quasi-RCT	LGB (*n* = 94); LAGB (*n* = 45)	153	139	153 (100)	NR	33 (4.5)	114.4 (9.8)	44.9 (4.6)	3 weeks (preop)
Mundbjerg et al.,[74] Denmark	RCT	RYGB (*n* = 60)	60	52	42 (70)	NR	42.3 (9.1)	99.2 (18.5)	33.7 (5.8)	6 (postop)
Lauti et al.,[75] New Zealand	RCT	SG (*n* = 95)	95	85	70 (74)	36 (38)	46 (8.06)	88.3 (17.32)	30.8 (5.29)	18 (postop)
Lent et al.,[76] United States	Pilot RCT	RYGB (*n* = 33); SG (*n* = 14); BPD/DS (*n* = 3)	50	41	41 (82)	47 (94)	46.9 (10.6)	135 (23.5)	48.8 (6.56)	7 (3.8) (postop)
Hanvold et al.,[77] Norway	RCT	RYGB (*n* = 165)	165	142	123 (75)	NR	45.7 (8.6)	91 (18)	30.9 (4.9)	20 (4.1) (postop)
Pre- and post-operative										
Ogden et al.,[78] United Kingdom	RCT	RYGB (*n* = 162)	162	145	122 (75)	156 (96)	45.2 (10.8)	142.9 (27)	50.7 (7.8)	2 weeks (preop)
Creel et al.,[79] United States	RCT	RYGB (*n* = 81); revision RYGB (*n* = 6); SG (*n* = 10); DS (*n* = 4); AGB (*n* = 6)	150	107	126 (84)	128 (85)	43.2 (11.2)	133.8 (28.4)	47.7 (8.5)	NR (preop)
Lier et al.,[80] Norway[b]	RCT	RYGB (*n* = 87)	99	91	103 (70)	NR	42 (10.4)	131.1 (20.9)	45.2 (5.3)	1.5 (preop)
Swenson et al.,[81] United States[a]	RCT	RYGB (*n* = 43)	43	32	29 (91)	27 (84)	NR	NR	NR	NR (preop)

Abbreviations: (L)AGB, (laparoscopic) adjustable gastric band; BAROS, bariatric analysis and reporting outcome system; BF, body fat; %BF, percent body fat; BFM, body fat mass; BMI, body mass index; BPD, borderline personality disorder; CBA, controlled before-and-after study; DE, dysfunctional eating; DS, duodenal switch; %EBMIL, percent excess BMI loss; EWL, excess weight loss; %EWL, percent excess weight loss; FFM, fat-free-mass; HC, hip circumference; FC, functional capacity; FU, follow-up; HRQoL, health-related quality of life; LBM, lean body mass; MBS, metabolic and bariatric surgery; NA, not applicable; NR, not explicitly reported/unreported; PA, physical activity; postop, post-operative; preop, pre-operative; REE, resting energy expenditure; (L)RYGB, (laparoscopic) Roux-en-Y gastric bypass; SG, sleeve gastrectomy; VBG, vertical banded gastroplasty; WC, waist circumference; WHR, waist-to-hip ratio; WL, weight loss; %WL, percent weight loss; WRQoL, weight-related quality of life.

[a]Multisite study.

[b]Total group data include third arm (non-randomized reference group).

[c]Reported in referenced trial registry.

TABLE 1 (Continued)

Identification, country	Time of post-intervention assessment: To start of intervention (months)	Other FUs (months postop)	Outcomes	Weight and/or BMI data as primary outcome?	Included in meta-analysis?
Pre-operative					
Kalarchian et al.,[41,42] United States	6 (preop)	6; 12; 24	Weight; %WL; depressive symptoms; binge eating	Yes[c]	Yes (weight)
Camolas et al.,[43] Portugal	6 (preop)	NA	Weight; %WL; %EWL; BMI; metabolic parameters; dietary and PA patterns; eating behavior; self-regulation; perceived competence for dieting; HRQoL	Yes	Yes (weight; BMI)
Bond et al.,[44,45] United States	1.5 (preop)	6	Weight; BMI; PA patterns	No	Yes (weight; BMI)
Gade et al.,[46–48] Norway	2.5 (preop)	12; 48	Weight; BMI; depressive symptoms; anxiety symptoms; DE	No	Yes (BMI)
Parikh et al.,[49] United States	6 (preop)	6	%EWL; BMI; eating behavior; patient activation/health beliefs; PA patterns; medication adherence	NR	Yes (weight; BMI)
Heinberg and Schauer,[50] United States	3 (preop)	NA	BMI; %BF; metabolic parameters	NR	Yes (weight; BMI)
Marcon et al.,[51] Brazil	4 (preop)	NA	Weight; BMI; FC; cardiometabolic profile	Yes	Yes (weight; BMI)
Lemanu et al.,[52] New Zealand	1 to 1.5 (preop)	1.5	%EWL; exercise advice adherence; exercise quantity; physical capacity; surgical recovery	No	Yes (weight; BMI)
Marc-Hernandez et al.,[53] Spain[a]	3 (preop)	NA	Weight; BMI; WC; HC; FM; %FM; FFM; %FFM; visceral fat; basal metabolic rate; cardiometabolic risk; cardiorespiratory fitness; HRQoL	Yes[c]	Yes (weight; BMI)
Post-operative					
Kalarchian et al.,[54] United States	6	12	Weight; %EWL	NR	Yes (weight)
Kalarchian et al.,[55] United States	4	6	%WL; dietary patterns; WRQoL; program satisfaction	Yes	Yes (weight; BMI)
Chacko et al.,[56] United States	3	6	Weight; BMI; WC; feasibility; acceptability; metabolic and inflammatory biomarkers; eating behaviors; eating self-efficacy; PA patterns; HRQoL and WRQoL; depressive symptoms; perceived stress; coping ability; participants' reactions	No	Yes (weight; BMI)
Dodsworth et al.,[57] Australia	6	12	Weight; %WL; %EWL; BMI; WC; %BF; BFM; FFM; dietary patterns	Yes[c]	Yes (weight)
Gallé et al.,[58] Italy	12	NA	%WL; comorbidities remission/improvement	NR	No
Nijamkin et al.,[59] United States	6	NA	Weight; %EWL; EWL; BMI; PA patterns; dietary patterns	Yes	Yes (weight; BMI)

(Continues)

TABLE 1 (Continued)

Identification, country	Time of post-intervention assessment: To start of intervention (months)	Other FUs (months postop)	Outcomes	Weight and/or BMI data as primary outcome?	Included in meta-analysis?
Marchesi et al.,[60] Italy	10	NA	BMI; WC; HC; WHR; %BF; LBM; BFM; sport performance; cardiopulmonary data; laboratory data; depressive symptoms; anxiety symptoms; psychiatric disorders; general psychopathology; HRQoL; surgery satisfaction	NR	Yes (weight; BMI)
Papalazarou et al.,[61] Greece	36	NA	Weight; %EWL; dietary patterns; PA patterns; eating behavior	NR	Yes (weight; BMI)
Sarwer et al.,[62] United States	4	6; 12; 18; 24	%WL; eating behavior; dietary patterns; daily symptoms	Yes	No
Coen et al.,[63] United States	6	NA	Weight; BMI; WC; FM; LBM; visceral and subcutaneous adiposity; insulin sensitivity; glucose effectiveness; cardiorespiratory fitness; metabolic data	No	Yes (weight; BMI)
Shah et al.,[64] United States	3	NA	Weight; WC; HC; %BF; %trunk fat; LBM; metabolic data; physical fitness; dietary and PA patterns; REE; HRQoL and WRQoL	No	Yes (weight)
Wild et al.,[65,66] Germany	12	37.9	Weight; %WL; %EWL; BMI; HRQoL; self-efficacy; depressive symptoms; eating psychopathology	Yes	Yes (weight; BMI)
Hassannejad et al.,[67] Iran	3	NA	Weight; BMI; skeletal muscle mass; %BF; BFM; FFM; aerobic FC; muscle strength; muscle FC; dietary and PA patterns	NR	Yes (weight; BMI)
Campanha-Versiani et al.,[68] Brazil	9	NA	Weight; BMI; %BF; LBM; %LBM; bone mineral content and density; muscle strength; bone turnover markers	NR	Yes (weight; BMI)
Herring et al.,[69] United Kingdom	3	6	Weight; BMI; WC; HC; BFM; FFM; %BF; physical function; cardiovascular data; dietary patterns; PA level; PA self-efficacy	No	Yes (weight; BMI)
Tucker et al.,[70] United States	6	24	Weight; %EW; %EWL; BMI; psychosocial functioning; dietary patterns; PA level; physical symptoms and health	Yes	Yes (weight; BMI)
Huck,[71] United States	3	NA	Weight; BMI; WC; WHR; BFM; FFM; %BF; cardiovascular data; physical fitness, PA patterns	NR	Yes (weight; BMI)
Mangieri et al.,[72] United States	12	24	%EWL; %EBMIL; QoL	Yes	No
Gallé et al.,[73] Italy	12	NA	BMI; BPD diagnosis	Yes	Yes (weight; BMI)
Mundbjerg et al.,[74] Denmark	6.5	12; 24	Weight; BMI; WHR; fat volume; cardiovascular data	Yes	Yes (weight; BMI)
Lauti et al.,[75] New Zealand	12	NA	BMI; %TWL; BAROS score	Yes	Yes (weight; BMI)

(Continues)

TABLE 1 (Continued)

Identification, country	Time of post-intervention assessment: To start of intervention (months)	Other FUs (months postop)	Outcomes	Weight and/or BMI data as primary outcome?	Included in meta-analysis?
Lent et al.,[76] United States	4	NA	%WL; HRQoL; depression; anxiety; self-efficacy; social adjustment; PA level; dietary adherence; DE; treatment tolerability and acceptability	No	Yes (weight; BMI)
Hanvold et al.,[77] Norway	22	NA	Weight; BMI; %WL; %FM; cardiometabolic parameters; energy intake and macronutrient distribution, smoking and PA status	Yes	Yes (weight; BMI)
Pre- and post-operative					
Ogden et al.,[78] United Kingdom	3.8 (postop)	12	Weight; BMI	Yes	Yes (weight; BMI)
Creel et al.,[79] United States	6.5 (postop)	NA	Weight; BMI; PA patterns; exercise tolerance	NR	Yes (weight; BMI)
Lier et al.,[80] Norway[b]	12 (postop)	NA	%WL; dietary and PA patterns; satisfaction with MBS; psychiatric comorbidities; anxiety symptoms; depressive symptoms, HRQoL	No[c]	Yes (weight; BMI)
Swenson et al.,[81] United States[a]	12 (postop)	NA	%EWL; BMI; WC; %BF; BFM; FFM; cellular fluid; total body water; PA patterns, resting metabolism	NR	Yes (BMI)

Abbreviations: (L)AGB, (laparoscopic) adjustable gastric band; BAROS, bariatric analysis and reporting outcome system; BF, body fat; %BF, percent body fat; BFM, body fat mass; BMI, body mass index; BPD, borderline personality disorder; CBA, controlled before-and-after study; DE, dysfunctional eating; DS, duodenal switch; %EBMIL, percent excess BMI loss; EWL, excess weight loss; %EWL, percent excess weight loss; FFM, fat-free-mass; HC, hip circumference; FC, functional capacity; FU, follow-up; HRQoL, health-related quality of life; LBM, lean body mass; MBS, metabolic and bariatric surgery; NA, not applicable; NR, not explicitly reported/unreported; PA, physical activity; postop, post-operative; preop, pre-operative; REE, resting energy expenditure; (L)RYGB, (laparoscopic) Roux-en-Y gastric bypass; SG, sleeve gastrectomy; VBG, vertical banded gastroplasty; WC, waist circumference; WHR, waist-to-hip ratio; WL, weight loss; %WL, percent weight loss; WRQoL, weight-related quality of life.

[a]Multisite study.

[b]Total group data include third arm (non-randomized reference group).

[c]Reported in referenced trial registry.

change was reported in 26 (72%) studies. Weight was mostly (56%) measured using digital or calibrated scales.[41,43,44,50,51,53–57,59,61,64,67,69,71,74,77,80,81] The remainder (44%) provided no (17%)[46,49,58,62,68,72] or insufficient information (28%)[52,60,63,65,70,73,75,76,78,79] about methods of assessment for weight and/or BMI. Over one third (36%) of studies reported weight and/or BMI measures as the primary outcome, whereas 42% did not specify a primary outcome.

3.2.3 | Experimental interventions

Over a third (34%) of experimental arms were physical activity only, 12% were structured dietary[50,55,57,81] or dietary counseling only,[62] 12% were psychosocial-based, and 41% were multicomponent, that is, comprised ≥2 of the aforementioned components. Theoretical underpinnings were stated for 27% of the interventions,[43,44,46,51,56,58,73,76,79,80] including self-determination theory (33%)[43,44,79]; transtheoretical model (22%)[43,44]; theory of planned behavior (11%)[44]; social cognitive theory (11%)[44]; and cognitive–behavioral theories (20%).[46,51,56,58,73,76,80]

As detailed in Data S4, the majority (90%) of experimental interventions lasted ≥3 months (median = 6; range = 1–36). Most (78%) were delivered in person[41,43,44,49–51,53,54,56,58–62,64,65,68,69,71–74,76–81] and either individually (39%),[41,44,49,52,53,55,61,67,68,70,72,73,75,78,81] in a group (24%),[49,51,56,59,65,71,73,76,77,80] or both (5%).[54,58] Delivery format was not clearly defined for 32% of interventions.[43,46,50,51,57,60,62–64,69,74,79] Trial interventionists were primarily psychologists/therapists (24%) and dieticians/nutritionists (20%). Interventionist was unspecified for 15% of interventions.

3.2.4 | Comparison interventions

Comparators were heterogeneous in content, duration, and intensity. Poor reporting of intervention characteristics rendered summarizing difficult. Thirty-four (94%) comparators were active treatments. These were mainly (64%) usual or standard care. Most (71%) were delivered in both study arms and mainly consisted of in-person advice-giving consultations with surgical teams. A minority (14%) included formal BWM strategies such as self-monitoring and problem solving.[41,43,55,56,64] Non-active comparators (6%) were wait list[54] and no-intervention controls.[60]

3.3 | ROB assessment

As seen in Figure 2 and detailed in Data S5, at least half of studies had a high risk of *selection* and/or *performance bias*. "Random sequence generation" and/or "allocation concealment" domains were judged high risk in 69% of studies due to non-reporting[41,43,49,50,54,55,59,61–64,67,70,72,74,76,77,81] or use of non-randomized designs.[53,57,58,60,68,71,73] Double blinding is almost impossible to achieve in behavioral trials, but participants' expectancies can be used to adjust for a lack of blinding, with all studies rated high risk for "blinding" due to lack of blinding/expectation measurement. "Intervention fidelity" was rated high risk in 94% of studies, mainly due to non-reporting (79%). Strategies to improve fidelity (e.g., manuals and scripts) were used in 19% of studies,[43,44,62,65,78–80] but none of these reported formal verifications of the experimental manipulation. Half of the studies were rated high risk for "treatment adherence," which was often (61%) not reported.[43,46,50,52,53,58,64,75,78,79,81] High ROB domains slightly differed across *pre*, *post*, and *joint* pre- and post-operative trials, but performance *bias* was consistently judged high risk.

3.4 | Meta-analysis findings for weight

3.4.1 | Pre-operative trials

Weight data were pooled for eight pre-operative trials (Figure 3). This included 10 experimental arms and 650 participants ($n_{experimental}$ = 316; $n_{comparison}$ = 334). There was no effect of BWM on weight (SMD = −0.07; 95% CI: −0.32 to 0.19, p = 0.623) with high heterogeneity of effects (Q = 33.2, p < 0.001; I^2 = 72.9%). The absolute mean

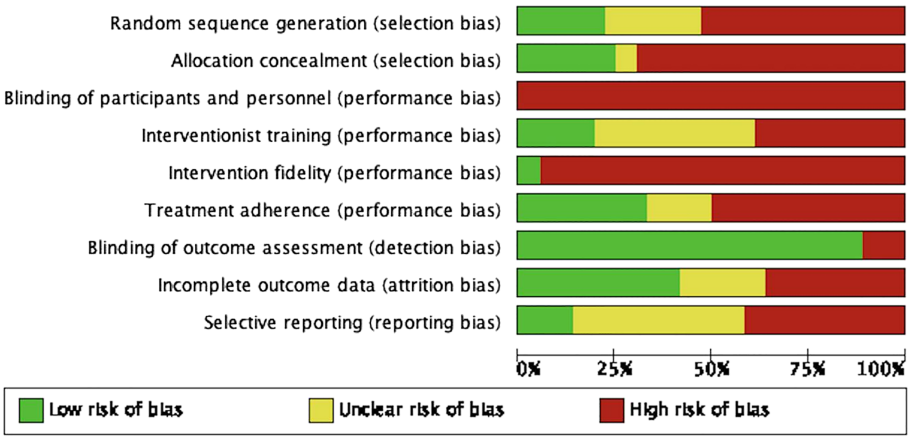

FIGURE 2 Risk of bias presented as percentages across all studies

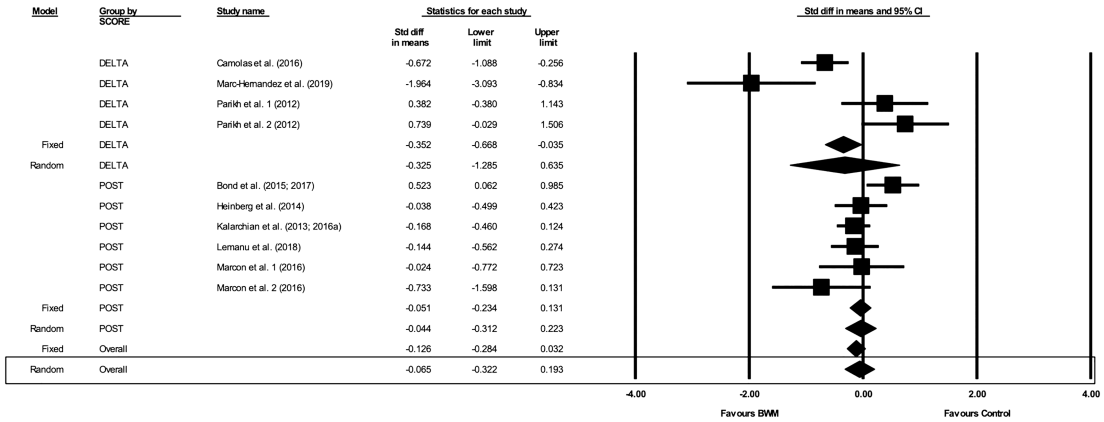

FIGURE 3 Forest plot demonstrating the impact of BWM versus comparators on weight in pre-operative trials. BWM, behavioral weight management, CI, confidence interval

difference in weight between arms was −1.13 kg (95% CI: −4.12 to 1.87; p = 0.460), and the heterogeneity of the effects was high (Q = 34.9, p < 0.001; I^2 = 74.2%; Data S6). Sensitivity analysis did not show differences in the pooled estimates by type of score (p = 0.582) nor use of ITT analysis (p = 0.149).

3.4.2 | Post-operative trials

From the 20 studies and 22 experimental interventions (1,223 participants, $n_{experimental}$ = 651; $n_{comparison}$ = 572), there was a statistically significant difference favoring BWM (SMD = −0.41; 95% CI: −0.766 to −0.049, p < 0.05; Figure 4), though there was considerable heterogeneity (Q = 321.51, p < 0.001; I^2 = 93.5%). The absolute mean difference in weight between arms was −4.94 kg (95% CI: −10.985 to 1.109, p = 0.109), and heterogeneity was considerable (Q = 2472.67, p < 0.001; I^2 = 99.2%; Data S6). Sensitivity analyses revealed significant differences in the pooled effects as a function of ITT analysis (p < 0.05), with SMDs of −0.46 and −1.63 for studies that did (p = 0.05) and did not (p < 0.05) conduct ITT analysis, respectively. There was also an impact of type of scores used (p = 0.011), suggesting greater effects for studies using change scores (SMD = −2.51; p < 0.05) compared with those using post-intervention values (SMD = −0.31; p = 0.104).

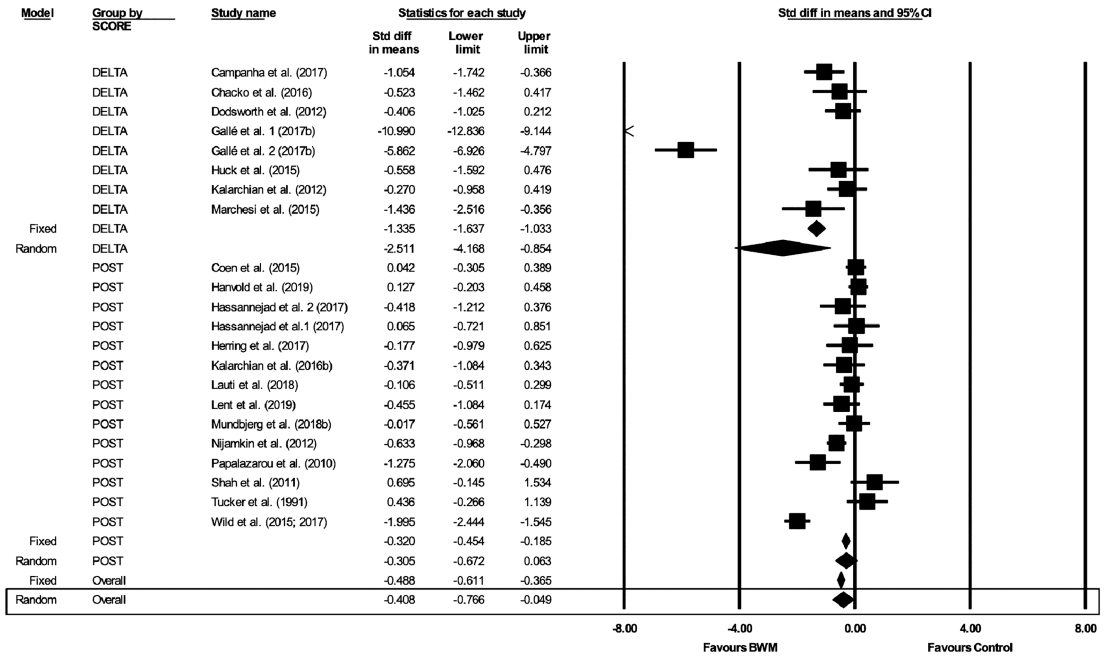

FIGURE 4 Forest plot demonstrating the impact of BWM versus comparators on weight in post-operative trials. BWM, behavioral weight management, CI, confidence interval

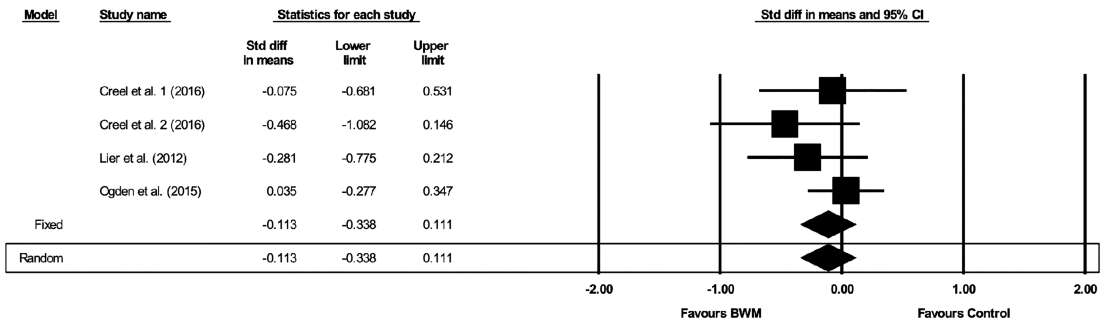

FIGURE 5 Forest plot demonstrating the impact of BWM versus comparators on weight in joint pre- and post-operative trials. BWM, behavioral weight management, CI, confidence interval

3.4.3 | Pre- and post-operative trials

Weight data were pooled for three pre- and post-operative trials including four experimental conditions ($n_{experimental}$ = 164; $n_{comparison}$ = 144; Figure 5). There was no effect of BWM (SMD = −0.11, 95% CI: −0.338 to 0.111, p = 0.323) with low heterogeneity (Q = 2.611, p = 0.456; I^2 = 0%). The absolute mean difference in weight between arms was −2.68 kg (95% CI: −7.255 to 1.887, p = 0.250) with low heterogeneity (Q = 2.335, p = 0.506; I^2 = 0%; Data S6).

3.5 | Meta-analysis findings for BMI

3.5.1 | Pre-operative trials

BMI data were pooled from eight pre-operative trials, including 10 experimental arms and 558 participants ($n_{experimental}$ = 288; $n_{comparison}$ = 270; Figure 6). There was a trend for a significant effect favoring BWM (SMD = −0.33; 95% CI: −0.683 to 0.019, p = 0.06), with high heterogeneity of study effects (Q = 35.50, p < 0.001; I^2 = 74.6%). The mean BMI loss difference between conditions was −0.97 kg/m^2 (95% CI: −1.697 to −0.244, p < 0.05), and heterogeneity of effects was moderate (Q = 23.627, p < 0.05; I^2 = 61.9%; Data S7). Sensitivity analyses did not show differences in the pooled effect by use of ITT analysis (p = 0.207) nor type of score (p = 0.324).

3.5.2 | Post-operative trials

BMI data were pooled from 17 post-operative trials (19 experimental arms; $n_{experimental}$ = 590; $n_{comparison}$ = 523; Figure 7). There was an effect favoring BWM (SMD = −0.60; 95% CI: −0.913 to −0.289, p < 0.001), but heterogeneity was considerable (Q = 146.98, p < 0.001; I^2 = 87.8%). The mean BMI loss difference was −2.55 kg/m^2 (95% CI: −3.672 to −1.430, p < 0.001) favoring BMW, with considerable heterogeneity (Q = 265.162; p < 0.001; I^2 = 93.2%;

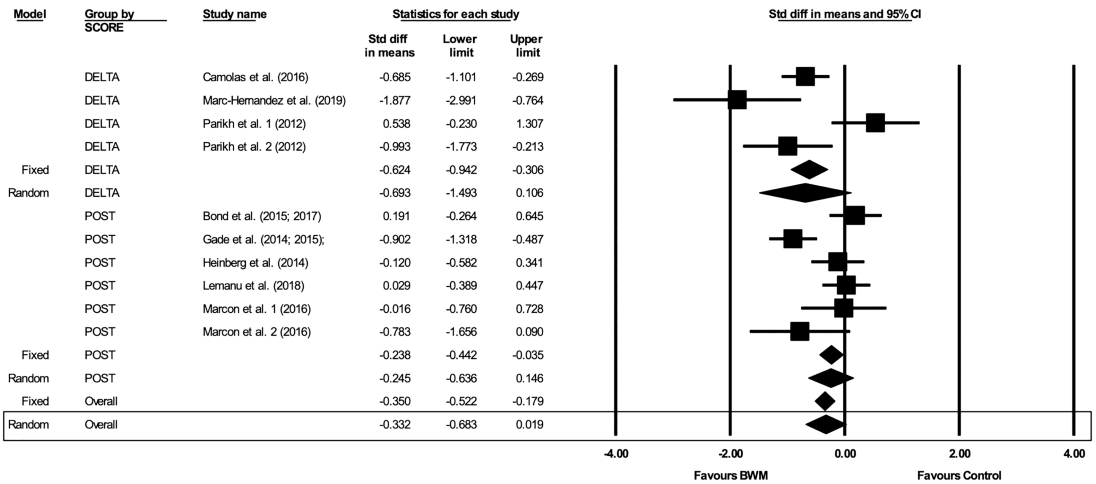

FIGURE 6 Forest plot demonstrating the impact of BWM versus comparators on body mass index in pre-operative trials. BWM, behavioral weight management, CI, confidence interval

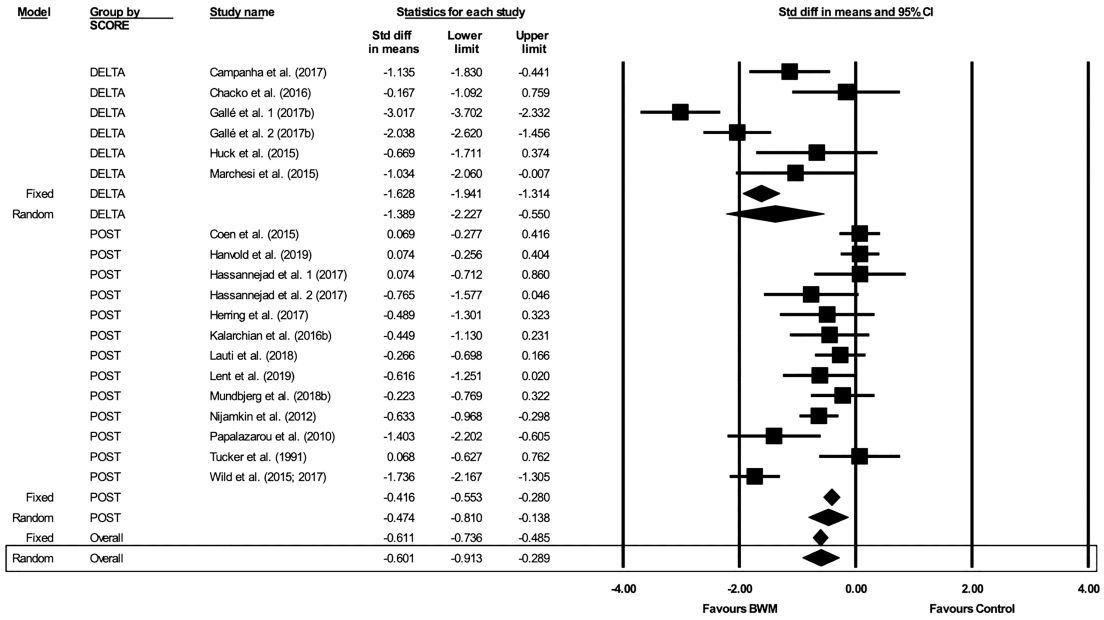

FIGURE 7 Forest plot demonstrating the impact of BWM versus comparators on body mass index in post-operative trials. BWM, behavioral weight management, CI, confidence interval

Data S7). There were no differences in the pooled effect by use of ITT analysis (p = 0.325). However, there was evidence (p < 0.05) suggesting that studies using change scores showed a greater effect (SMD = −1.39; p = 0.001) than studies with post-intervention measures (SMD = −0.47; p < 0.05).

3.5.3 | Pre- and post-operative trials

BMI data were pooled from five experimental arms (360 participants; $n_{experimental}$ = 203; $n_{comparison}$ = 157) in pre- and post-operative trials (Figure 8). There was no effect of BWM (SMD = −0.16; 95% CI: −0.370 to 0.052, p = 0.139), and heterogeneity was low (Q = 1.71, p = 0.788; I^2 = 0%). The mean BMI loss difference between conditions was −1.12 kg/m^2 (95% CI: −2.557 to 0.311, p = 0.125), with low heterogeneity (Q = 1.61, p = 0.808; I^2 = 0%; Data S7).

4 | DISCUSSION

This systematic review assessed the efficacy of BWM on weight outcomes in MBS, specifically around optimal delivery timing. Our meta-analysis showed that BWM delivered *after* MBS yielded significant weight loss relative to comparators. The magnitude of the effect was small and moderate for weight and BMI change, respectively. Results did not reveal significant benefits of BWM delivered *pre*-operatively or across the MBS process (i.e., *pre*- and *post*-operatively). There was, nevertheless, a trend for a positive effect of *pre*-operative BWM on BMI, which might not have appeared for our other outcome partly

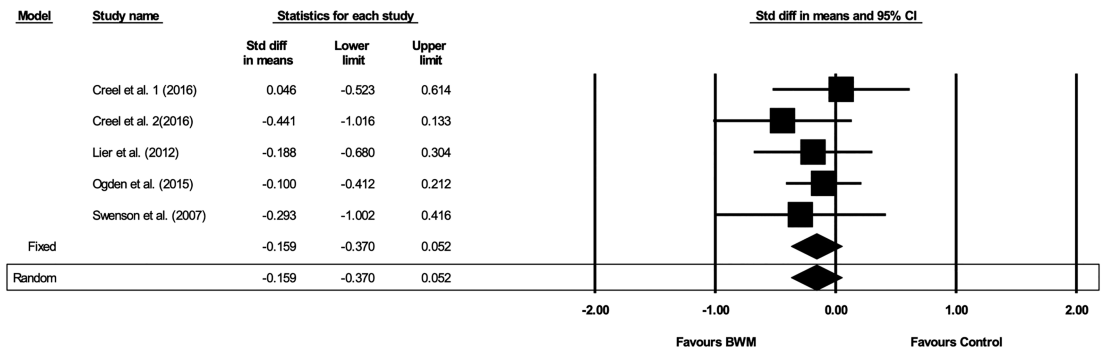

FIGURE 8 Forest plot demonstrating the impact of BWM versus comparators on body mass index in joint pre- and post-operative trials. BWM, behavioral weight management, CI, confidence interval

due to differing studies in the weight and BMI meta-analyses. When looking at the magnitude of the pooled effects and 95% CIs across the three time points, there was little overlap between post-MBS intervention and the other times, suggesting that there may be a unique benefit of post-operative BWM.

This result is consistent with another meta-analysis[23] evaluating the efficacy of controlled experimental designs of pre- and post-operative BWM interventions. It found that post-operative BWM improved weight loss at 12 and 24 months post-MBS. However, this study had stricter inclusion criteria than the current review (e.g., start within 12 months post-surgery, ≥6 months FU, and having fixed FU time points), which reduced their study sample size (N = 8), limiting power and generalizability. Of note, it included ≤2 *pre*-operative trials for 12 months post-MBS outcomes, meaning they were not able to compare between intervention timing, versus our paper that included enough studies to compare across surgical time points. Collectively, data[24,32,82,83] suggest that the optimal timing to deliver BWM may be post-operatively. Consistent with previous literature,[84] we hypothesize that the post-operative period may create a momentum that favors patients' engagement in and receptivity toward adopting weight loss and persistent maintenance behaviors. Weight nadir is typically reached within 2 years post-MBS.[15,16] This "honeymoon phase" is characterized by its seemingly effortless but rapid and drastic weight loss and accompanied feelings of excitement toward achieving desired weight goals and/or the expected associated gains (e.g., improved self-confidence and body image, comorbidities resolution/improvement) and motivation for change.[85,86] This time window may thus leave patients more prone to believe that successful weight management is more achievable than ever before. Qualitative data suggest that pre-operative patients may be preoccupied with all the information needed and provided to them before MBS (e.g., some reported feeling overwhelmed by the high volume of information presented and need to seek missing or converging information).[87] This could partially explain why the pre-operative period may be suboptimal for BWM. It should be noted that guidelines on the management of bariatric patients tend to disproportionately focus on pre-operative care.[7,88] However, this is primarily to identify potential contraindications for surgery and reduce surgical risks and complications, rather than to enhance weight loss/maintenance. Although the 2020 Canadian adult obesity guidelines provide extensive information on the complex multidisciplinary care approach needed across the surgical spectrum,[2] current official recommendations provide limited to no formal or explicit guidance (e.g., clear recommendations on type/intensity/duration of specific intervention components) on longer term post-operative care beyond medical and nutritional instructions to prevent complications and general physical activity prescriptions.[2,88,89] Yet, there is accumulating evidence of unmet needs among post-operative patients and a lack of holistic and consistent support for patients across different centers.[85,90–93] Finally, although we only found a trend for an effect favoring pre-operative BWM on BMI, this is consistent with previous studies[1,24,25] suggesting that some pre-operative interventions positively impact weight outcomes when measured immediately following BWM. However, sustained post-operative outcomes of these interventions have not been consistently supported.[1,24,25]

4.1 | Limitations of included studies

This review's conclusions should be interpreted in light of limitations of the included studies. The extant literature is marked by a notably high ROB, that is, lack of standardization and methodological rigor. For example, our sensitivity analyses showed that the effects of *post*-operative BWM on weight varied as a function of the type of analyses conducted (ITT yes/no), suggesting a selection bias impact on our results.[94] Sensitivity analyses also revealed differences in pooled effects by type of score, which may reflect an impact of randomization (change scores reflecting non-randomized and post-values reflecting randomized studies), further supporting potential selection bias. Second, the quality of reporting was a major limitation. Most studies failed to adequately measure and/or report details around interventionist training, intervention fidelity, and/or adherence, which are fundamentally tied to internal and construct validity.[94] Third, none of the studies reported using standardized frameworks for intervention development/testing.[95] Fourth, few studies explicitly reported using established behavior change theories as the basis for the interventions, which might not have ensured robustness, but could have helped improve their pertinence and success rate.[96–98] Finally, studies generally did not report explicit information on their inclusion criteria regarding the participant weight status (e.g., poor weight loss and weight regain) for post-operative interventions, potentially introducing bias.

4.2 | Review limitations

There was generally high statistical heterogeneity, which could reduce internal validity, though it might increase the generalizability of findings. Second, the high ROB in included trials could have led to internal and construct validity issues (e.g., contamination effect) and, consequently, influenced statistical findings in either direction. Third, we could have experienced a lack of statistical power due to the low number of trials included in some meta-analyses and/or the fact that BWM interventions were tested against active (and potentially efficacious) comparators. Another issue relating to comparators is that experimental participants received some elements of the comparator in 73% of cases: a ceiling effect could have occurred, potentially leading to an underestimation of our effects. The conclusions that can be drawn from this review are also limited by the fact that we did not explore the potential impact of patient or intervention characteristics on the results. For example, because weight trajectories differ across post-surgical time points and procedures,[14] the specific timing of post-operative BWM and type of MBS should be considered as potential covariates of the intervention effects. In our review, few studies[54,58,62,64,70,73] stratified results according to types of MBS with close to half combining multiple procedures. We did perform an

exploratory analysis investigating the effect of specific MBSs in post-operative trials (Data S8). These results suggested a greater effect of BWM in vertical banded gastroplasty (SMD = −1.4; $p < 0.05$) relative to other procedures. However, with the exception of RYGB, all other surgery types only had one study that could be included, so these results need to be interpreted with caution. Finally, although a myriad of outcomes (e.g., quality of life and cardiometabolic profile) should be considered when investigating the efficacy of BWM in MBS, this review was restricted to weight/BMI.

4.3 | Implications

A significant implication from this review is that more focus should be placed on developing, testing, and implementing BWM *post*-MBS. We were not able to determine what works specifically, for whom or under which conditions, but we showed that post-operative interventions may prove efficacious for weight-related outcomes and merit further attention. As evidenced by non-surgical obesity data, even a small–modest weight loss consistent with the relative amounts of weight loss found for post-operative trials in this study (∼5 kg) may translate into clinically significant and relevant health improvements.[99–102] BWM may have the potential to compensate or alleviate some of the undesirable effects sometimes occurring post-MBS (e.g., reoperation, resurgence of comorbidities, and psychological distress). Of note, readers should cautiously *avoid* inferring that intervening *before* MBS has proved ineffective or that attention should be diverted away from the pre-operative period, where the emphasis is more on reducing surgical complications and education rather than weight loss.[2,7] On the basis of weight-related outcomes, we suggest that structured BWM intervention may be *optimally* delivered post-operatively. Another implication is that higher research standards need to be attained before firm conclusions can be drawn regarding the efficacy of BWM in MBS. Future studies should consider the following recommendations:

1. Using systematic approaches for intervention development and testing.[95,103,104] These models encourage the adoption of an integrated knowledge translation approach, including stakeholders in the process and improving clinical relevance, effectiveness, and uptake of interventions. They avoid a one-size-fits-all approach to BWM,[105] accelerate, and optimize the field's research agenda.[95,103,104]
2. Because weight outcome variability is high, future studies should explicitly explore the potential impacts of surgery type and patient characteristics (e.g., weight status and comorbidities) on intervention effects.
3. Exploring the *specific* timings of BWM across the *post*-MBS period (e.g., 1-month versus 1-year post-surgery) and the optimal timing of other adjunct MBS interventions.
4. The complexity of obesity and the process of MBS should be recognized by increasingly focusing on non-weight-related outcomes.[2] Systematic investigations of the impact of non-weight-related measures in response to BWM are desperately needed.
5. Using standardized reporting guidelines[94,106] to ensure transparency and reproducibility, including improved reporting of intervention arms content and delivery details.[107]
6. Reducing, evaluating, and reporting potential validity threats and ROB. Performance bias should be targeted by developing and reporting strategies to improve/assess interventionist competency, intervention fidelity, and adherence.

Based on the current review and recent guidelines, best bariatric care practice in the absence of more conclusive evidence for BWM is the adoption of a holistic multidisciplinary approach to the treatment of severe obesity. Patients should *minimally* be provided with specialized individually tailored support and monitoring based on a comprehension evaluation of potential facilitators and barriers to post-operative BWM.[2,108] It should be noted that such an approach may improve patients' attendance to surgical FUs by giving them a sense of accountability, understanding, and support in dealing with post-operative challenges.[91,105,109]

5 | CONCLUSION

The significant BWM effects found in this meta-analysis should be cautiously interpreted as a *potential* for post-MBS BWM interventions to be superior to other time points in improving weight. This suggests that more attention should be placed on post-operative care when developing, delivering, and testing adjunctive interventions for weight loss and/or maintenance.

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AUTHOR CONTRIBUTIONS

C. A. J., S. L. B., and K. L. L. conceptualized and designed the study. C. A. J. conducted database searches. C. A. J., A. I. D., and L. A. M. conducted screening and/or data extraction. S. L. B. resolved discrepancies to obtain consensus. C. A. J., P. A. B. R., and S. L. B. planed the analyses. P. A. B. R. conducted the analyses. C. A. J. and S. L. B. drafted the manuscript. All authors (C. A. J., S. L. B., K. L. L., P. A.

B. R., A. I. D., L. A. M., P. Y. G., and R. P.) contributed to interpretation and presentation of the results, provided a critical evaluation of the manuscript, and approved the final version.

CONFLICT OF INTERESTS

The authors have no conflicts of interest to report. Dr Bacon has received consultancy fees from Merck for the development of behavior change continuing education modules, speaker fees from Novartis and Janssen, and has served on advisory boards for Bayer, Sanofi, and Sojecci Inc., none of which are related to the current article. Dr Lavoie has served on the advisory board for Schering-Plough, Takeda, AbbVie, Almirall, Janssen, GSK, Astellas, Novartis, Boehringer Ingelheim (BI), and Sojecci Inc. and received sponsorship for investigator-generated research grants from GSK and AbbVie, speaker fees from GSK, Astra-Zeneca, Astellas, Novartis, BI, Takeda, Janssen, AbbVie, Merck, Bayer, Pfizer, and Air Liquide and support for educational materials from Merck, none of which are related to the current article. Dr Pescarus has received speaker fees from Boston Scientific for work unrelated to the current article.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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