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Which behaviour change techniques within interventions to prevent weight gain and/or initiate weight loss improve adiposity outcomes in young adults? A systematic review and meta-analysis of randomized controlled trials

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Summary

Young adulthood is associated with the highest rate of weight gain compared with any other adult age group. This review evaluates the effectiveness of interventions with adiposity outcomes among young adults and identifies which behaviour change techniques (BCTs) are most effective. BCT utilization was assessed using Michie's 93-item BCT Taxonomy v1. Six electronic databases were searched for randomized controlled trials assessing change in adiposity in young adults (17-35 years) until December 2019; identifying 21,582 articles. Fifty-one studies were included. Meta-analyses for weight (n=19 studies), body mass index (BMI) (n=20 studies), and waist circumference (n=10 studies) demonstrated no significant between-group differences at ≤3 or >3 months. There were no differences between interventions focusing on weight loss or weight-gain prevention. Narrative synthesis showed significant between-group differences in weight change, favouring the intervention in 14/43 (33%) studies. In studies assessing BMI and waist circumference, this was 31% (11/36) and 25% (4/16). Two BCTs had a percentage effectiveness ratio >50% in weight loss interventions; social support (unspecified) and self-monitoring behaviour, and one in weight-gain prevention interventions; and goal-setting (outcome). Findings demonstrate initial potential for these types of BCTs and can help build cumulative evidence towards delivering effective, cost-efficient, and replicable interventions.

KEYWORDS

behaviour change, obesity, young adults

1 | INTRODUCTION

Young adulthood (aged 17-35 years) is associated with the highest rate of weight gain compared with any other adult age group, equating to an annual increase of 0.5 to 1 kg from early to midadulthood.[1,2] The trajectory of weight gain is a concern given the longitudinal associations with obesity, type 2 diabetes, some types of cancer, hypertension, cardiovascular disease, and all-cause mortality.[3]

Abbreviations: BCT, behaviour change technique(s); RCT, randomized controlled trial.

Mr Sharkey contributed to this article prior to his unfortunate passing in May of 2018. His inclusion as an author here recognizes his contributions, although he was unable to approve the final version.

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The rapid weight gain during young adulthood coincides with marked declines in physical activity (PA) and dietary habits.[4-6] Specifically, a longitudinal cohort study among 640 Canadian adolescents demonstrated a 24% decrease in PA (equivalent to 1 MET/day) during a 12-year transition from adolescence to early adulthood. This was even more prominent in young men with a 30% decrease (1.54 METs/day) during this period.[7] Furthermore, a global analysis from 187 countries found young adults (aged 20-29 years) to have the lowest diet quality compared with any other age group. This means they have lower intakes of nutrient-rich foods such as fruits and vegetables, and wholegrains, and higher intakes of energy-dense, nutrient-poor foods such as processed meats and sugar-sweetened beverages.[8] These negative behavioural patterns are attributed to key transitional changes that occur during young adulthood[6] including changes in living situation (ie, moving out of home), social environment and influences (ie, developing stronger peer networks and partner relationships), employment status (ie, starting tertiary education), and financial situation (ie, becoming more financially independent).[9]

Both positive and negative health behaviours established during this transition to adulthood persist through to later life.[10] Therefore, young adulthood represents a critical period for impacting on weight-gain. Until recently, young adults had been neglected in terms of health research and policy. However, there has been a sharp increase in interventions to prevent weight gain and/or initiate weight loss among young adults since the most recent systematic reviews on weight gain prevention (end search date: June 2014)[11] and weight reduction in this group (end search date: March 2008).[12] In particular, there has been a substantial increase in electronic health (eHealth) interventions (defined as use of information and communication technologies for health[13]) in the last decade.[14] For example, this includes the consortium of seven Early Adult Reduction of weight through LifestYle intervention (EARLY) trials from the United States.[15] This calls for an update of the literature to determine effectiveness in a larger pool of studies.

Previous systematic reviews for weight gain prevention[11] and weight loss[12] in young adults demonstrated effectiveness in the short term. In the 21 weight-gain prevention randomized controlled trials (RCTs), there were significant findings for weight and/or body mass index (BMI) between intervention and control groups for nearly half of the studies.[11] The meta-analysis of 14 studies (including RCTs, controlled clinical trials, nonrandomized trials, and cohort studies of interventions) showed significant weight loss in behavioural interventions (−2.40 kg; 95% CI: −5.4 to 0.6) and diet plus exercise interventions (−2.96 kg; 95% CI: −4.4 to −1.5), but these results were only pre-post comparisons and changes were not compared with a control group.[12] Furthermore, the interventions in these reviews were not deconstructed to examine which specific components or "active ingredients" were contributing to their effectiveness. There is a need to unpack the "black box" and clearly report how and when theory has been applied to better understand why interventions achieve or do not achieve the desired outcomes.[16,17] A recent systematic review of 24 eHealth weight management interventions in young adults[16] applied the theory coding scheme[18] to explore the application and extent of reported theory use. While this review did not explicitly compare which specific behaviour change techniques are attributed to effectiveness, it did show that most studies mentioned use of a theory and weight-related outcomes may be enhanced when theoretical constructs are explicitly linked to an intervention technique.[16]

Behavioural weight management interventions are commonly multicomponent, meaning that they include a comprehensive set of strategies to guide changes in diet and activity behaviours that contribute to shifting energy balance and hence lead to weight change. However, clinical trials usually evaluate the effectiveness of the treatment package as a whole. Hence, it is unclear whether all intervention strategies are essential to produce the observed change or whether a more parsimonious set of strategies would be as effective. There has been a growing recognition to better understand which mechanisms of action contribute to positive behaviour change.[19] Michie and colleagues have proposed a taxonomy of defined behaviour change techniques (BCTs) to describe interventions.[20] A BCT is defined as an "observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an 'active ingredient' …"[20] Precise specification of these active ingredients within interventions to prevent weight gain and/or initiate weight loss will help build cumulative evidence towards delivering effective, cost-efficient, and replicable interventions.[21] Therefore, the aims of the current review were the following:

1. evaluate the effectiveness interventions to prevent weight gain and/or initiate weight loss among healthy young adults (aged 17–35 years) and
2. identify the BCTs used in these interventions and determine which are most effective.

2 | MATERIALS AND METHODS

2.1 | Protocol and registration

The conduct of this systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,[22] and the protocol was registered with PROSPERO (CRD42017075795).[23] This review is part of a series of papers from one overarching systematic review search/protocol, which considers the impact of behavioural change interventions on changes in adiposity, diet, and PA in young adults. The current paper presents results for interventions that reported an adiposity outcome (ie, weight, BMI, and waist circumference).

2.2 | Eligibility criteria

2.2.1 | Types of participants

The definition of young adults used in studies includes various definitions based on human development and sociological perspectives.[24,25]

For the current review, a broad age range was included to ensure a range of studies in healthy young adults across the age range of 17 to 35 years. Participants with diagnosed obesity-related medical conditions such as type 2 diabetes or from specific population subgroups, including those with severe mental illness, eating disorders, elite athletes, or pregnancy, were excluded.

2.2.2 | Types of interventions

Behavioural interventions (focusing on diet, PA, and/or treating or preventing obesity), which assessed change in adiposity outcomes, were included. All modalities (eg, face-to-face, print, eHealth, and mHealth) were considered for inclusion. Interventions involving bariatric surgery or antiobesity medications were excluded, so too were studies which primarily investigated the acute impact of weight loss on other clinical biomarkers (eg, insulin). Behavioural interventions were categorized into "weight loss" defined as those enrolling participants with overweight and/or obesity and a key focus on losing weight[26] and "weight gain prevention" defined as prevention of weight gain through maintenance of a healthy body weight or the reversal of small gains to maintain a healthy body weight.[27]

2.2.3 | Types of comparators

Comparison groups with no intervention (eg, waitlist control) and/or active treatments were considered for inclusion.

2.2.4 | Types of outcome measures

Interventions reporting an adiposity measure (ie, weight, BMI, or waist-circumference) at baseline and a minimum of one post-intervention time point were included.

2.2.5 | Types of studies

The study design had to be a RCTs. Both pilot and feasibility RCTs were included.

2.3 | Information sources and search

The systematic literature search sought studies from date of inception to December 2019, with six electronic databases searched. These were MEDLINE (Ovid), CINAHL (EbscoHost), Cochrane Library (Wiley), PsycINFO (Ovid), Science Citation Index (WoS), and Embase (Ovid). Only studies published in English were considered. Focused "text word" and subject heading (MeSH) searches were conducted with papers linked to relevant RCTs, including published study protocol, recruitment or process evaluation papers, or those publishing outcomes at differing follow-up time-points also considered. A search of reference lists of included papers and relevant systematic reviews was also undertaken. In addition, citation searches of the final included papers were conducted in Scopus. The full list of search terms is available in Table S1.

2.4 | Study selection

Two independent reviewers (L. M. A. and M. J. H., M. C. W., C. E. C., T. S., R. L. H., or E. J. A.) assessed the title, abstract, and keywords of all identified papers. Full articles were retrieved for records that appeared relevant or unclear. These were assessed independently by two reviewers to determine whether they were included or not (L. M. A. and M. C. W., T. S., or R. L. H.), with reasons for exclusion recorded. A third reviewer resolved disagreements (M. J. H.). Where insufficient detail to allow determination of eligibility was provided, the corresponding author was contacted to confirm (n=32), with papers excluded from nonresponding authors.

2.5 | Risk of bias

The Cochrane Collaboration tool was[28] completed by two independent reviewers (L. M. A. and M. J. H., A. B., R. L. H., or M. C. W.). Differences were resolved by a third reviewer when there were any disagreements (M. J. H. or T. S.). Risks of bias results are presented by individual risk components across all studies (as low, unclear, or high risk of bias).

2.6 | Data extraction

One reviewer (T. S.) extracted data, which were cross-checked by a second reviewer (L. M. A. or M. J. H., A. B., R. L. H., or M. C. W.). Data extraction included study characteristics, participant data, study design, intervention components, and outcomes.

2.7 | Coding of BCTs

Utilization of BCTs within interventions was assessed using the 93-item Behaviour Change Taxonomy v1.[20] Two independent reviewers (L. M. A. and M. C. W. with 100% agreement) coded BCTs. To ensure standardized evaluation, reviewers completed a BCT evaluation course online prior to coding (http://www.bct-taxonomy.com/). Importantly, BCTs were only coded when clear evidence of inclusion was identified. The evaluation of use of BCTs was conducted separately for intervention versus control groups. Of interest were BCTs that were utilized in the intervention, but not in the control condition. Peters and colleagues[29] recommended use of this approach to ensure attention is directed to differences between groups. This approach has also been used by Samdal et al.[30] When studies included multiple

intervention arms, BCTs and outcome data were extracted for each intervention arm versus control condition. For those studies with only active intervention arms (ie, new treatment versus old treatment), the group deemed as primary (established in aims or methods) was considered as the intervention group and the other was considered as the control/comparison.

2.8 | Synthesis of results and analytic strategy

2.8.1 | Narrative summary

Several studies reported results in a format that was not compatible for inclusion in the meta-analysis (Figure 1); that is, they reported mean change only and not mean and SD at all time points. For all outcomes aside from weight, BMI, and waist circumference, there were insufficient comparable studies for a meta-analysis. Therefore, results are described in narrative form for all included studies.

2.8.2 | Meta-analysis

Meta-analysis to assess change in weight (kg), BMI (kg/m^2), and waist circumference (cm) was conducted for both intervention and comparator/control groups at each time point. The meta-analysis was conducted using R statistical software (V 3.5.1, Vienna, Austria) using the Metafor package (V 2.0, Vienna, Austria). For each study, the effect at baseline and each time point, expressed as months post baseline, was estimated as the mean difference (mean intervention group-mean control group) using the unbiased option for variance estimates. To account for multiple measures per study, a series of multilevel models were investigated with nested random effects top level being study, then treatment type and time period using REML estimation. The final model contained study and time as nested random effects as the treatment type random effect had zero variance. Moderator variables evaluated as fixed effects in the model were treatment type (weight gain prevention or weight loss), and time was treated as a categorical variable in two versions (as originally reported with 15 different time-points for weight, 14 time-points for BMI, and 9 time-points for waist circumference) and a simplified grouped form with baseline, up to 3 months and greater than 3 months, with interaction between these two tested. There was substantial correlation between time periods, with the time random effect similar in size to study random effects. Hence, the moderator effect for the three-group version of time was estimated at each of the two follow-up time periods as difference from baseline. Residual plots were used to examine homogeneity of variance and normality assumptions. To

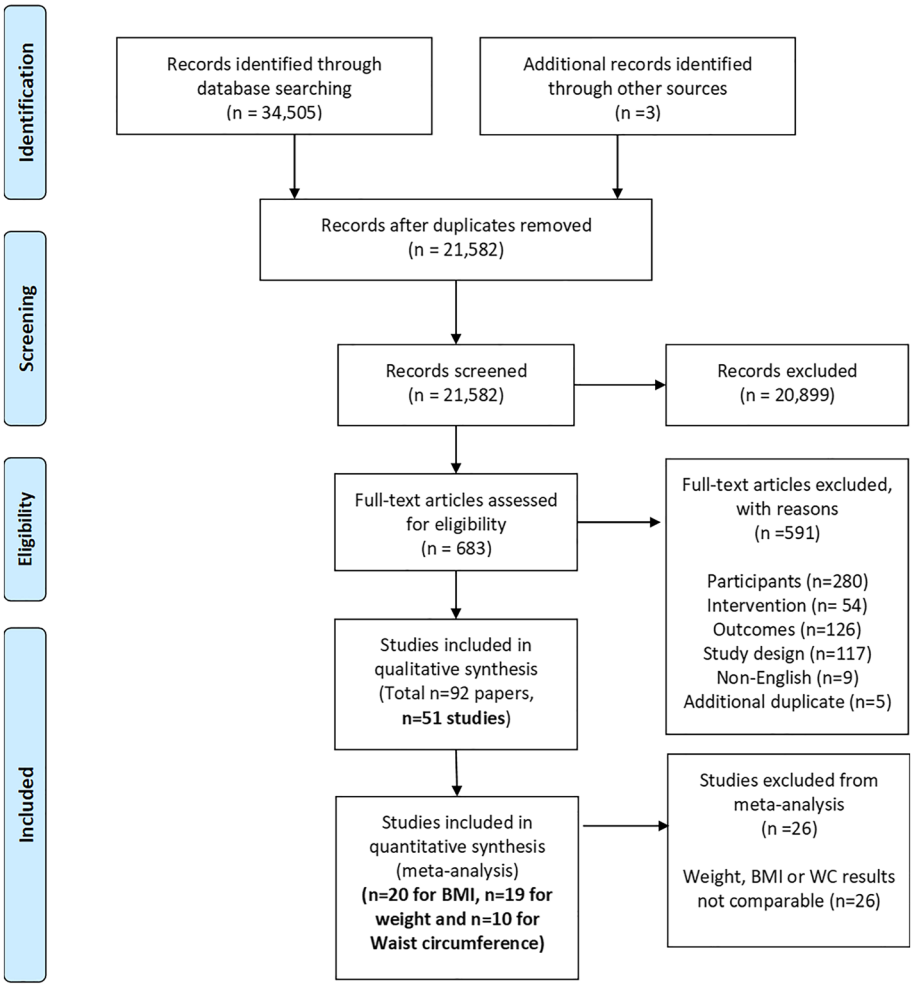

FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of included studies

assess the presence of publication bias, funnel plots were created and visually inspected, and rank correlation was used to test for funnel plot asymmetry. Heterogeneity between studies was observed from the forest plots and differences between averages over time in CI plots.

2.9 | Effectiveness of BCTs

The percentage effectiveness ratio was calculated based on similar reviews[31-33] to identify the BCTs used within an effective intervention. The number of times the technique was reported as a component within effective interventions was divided by the total number of times the technique was reported as an intervention component. Effective interventions were defined as being an intervention where there was a positive and statistically significant change in one or more adiposity outcome variables from baseline, compared with the comparison group. BCTs had to have been reported in a minimum of five studies to be included in the analysis, hence avoiding inflation of results. A plot of effectiveness with 95% credible intervals using a Bayesian approach (beta posterior from a binomial likelihood and conjugate uniform beta prior) was implemented. An overall test of significance was carried out using a contingency table between type and number of BCTs and effectiveness using Monte–Carlo exact chi-squared test (SPSS version 25, Armonk, New York, USA).

3 | RESULTS

3.1 | Description of included studies

The search identified a total of 21,582 abstracts. From this, 51 individual studies (and a total of 92 papers) were included in the review (Figure 1). Table 1 summarizes study characteristics, while Table S2 tabulates detailed study characteristics. Of the 51 included studies, 20 studies were eligible for meta-analysis of BMI,[34-53] 19 studies were eligible for meta-analysis of weight,[35,36,39-41,43-47,49,51-58] and 10 studies were eligible for meta-analysis of waist circumference.[36,40,41,43,48,49,52,53,55,56]

There has been a steep rise in interventions to prevent weight gain and/or initiate weight loss among young adults with over half of the included studies published from 2015 to 2019 (n=26, 51.0%). The majority of the studies focused on weight gain prevention (n=34, 66.7%), rather than weight loss (n=17, 33.3%). For all included studies, mean BMI of participants was 26.5 kg/m^2. As expected, mean BMI was higher in weight loss interventions compared with weight-gain prevention interventions (30.7 kg/m^2 vs 24.6 kg/m^2). Most studies were from the United States (n=32, 62.7%), in a college/university setting (n =33, 64.7%) and in white/Caucasian populations (n=28, 54.9%). Across the included studies, there were a total of 15,931 participants (median: 98, range: 32 to 3059) with a mean age of 22.1 years and greater proportion of studies with participants within the age range category of 17 to ≤ 25 years (47%). The majority of studies included males and females (n=31, 60.8%), with a mean of 28% males. Of the 20 gender-targeted studies, there were a higher proportion, which recruited only females (n=16, 80%) than only males (n=4, 20%). Less than half of the studies included multicomponent interventions (n=20, 39%), while 18 (35%) used eHealth intervention delivery and 13 used a face-to-face (26%) mode. In total, there were 118 study arms (range: 2 to 5 arms). Studies predominantly had two intervention arms (n=38, 75%). Mean intervention duration was 7 months (range: 1-month to 30-months), with the majority being ≤3 months (n=31, 61%). Mean follow-up period from postintervention was 2.8 months (range: no follow-up to 23 months), while the majority had either no follow-up or ≤3 months (n=39, 77%). The mean retention rate was 83% (range 54% to 100%) immediately at intervention completion, with a mean retention rate of 70% (range 11 to 98%) for the longest follow-up point.

3.2 | Risk of bias

Results for the assessment for risk of bias are summarized in Figure 2. For incomplete outcome data (attrition bias), there was a low risk of bias, with more than half the studies (n=29, 57%) adequately describing study attrition and reasons for exclusions from analyses. Procedures used to generate allocation sequences were reported clearly in less than half (n=14, 28%) of the included studies. The majority (n=37, 73%) failed to describe allocation concealment methods. High or unclear risk of bias within studies occurred most frequently for blinding of participants (n=43, 84%), blinding of outcome assessors (n=35, 69%), and intervention deliverers (n=32, 63%). Insufficient detail (n=29, 57% unclear) was provided in the majority of studies to allow evaluation for selective outcome reporting.

3.3 | Effectiveness of adiposity outcomes

3.3.1 | Weight: All included studies

Of the 51 included studies, a total of 43 measured change in weight, with 41 of these having an objective measure of weight[35,36,39-41,43-49,51-79] and two using a self-report measure for weight.[80,81] This includes 19 studies from the meta-analysis and a further 24 studies that reported weight as an outcome with results in a format that was not compatible for inclusion in the meta-analysis. Of these 43 studies, 14 reported statistically significant between-group reductions in weight (as shown in Table S2). Of the 43 studies, 15 were weight loss interventions[35,36,39,46,49,52,54,56,62,64,72,74-76,78] and 28 were weight-gain prevention interventions.[40,41,43-45,47,48,51,53,55,57-61,63,65-71,73,77,79-81] Specifically, for the weight loss studies, four of the 15 (27%) demonstrated significant reductions in weight when compared with control.[36,72,74,75] In the weight-gain prevention interventions, 10 of the 28 (36%) reported a significant difference in weight change between the groups, favouring the intervention.[59,60,63,67-70,77,80,81]

TABLE 1 Summary of study characteristics from 51 interventions with obesity outcomes in young adults

		Total
Publication year	**Before 2005, n, %**	4 (7.8%)
	2005-2009, n, %	4 (7.8%)
	2010-2014, n, %	17 (33.3%)
	2015 to December 2019, n, %)	26 (51.0%)
Country	**United States, n, %**	32 (62.7%)
	Australia, n, %	7 (13.7%)
	Finland, n, %	3 (5.9%)
	Canada, n, %	2 (3.9%)
	Other, n, %	7 (13.7%)
Number of participants	**Total**	15,931
	Mean	312.4
	Median	98
	Range	32 to 3059
Sex	**Female only studies, n, %**	16 (31.4%)
	Male only studies, n, %	4 (7.8%)
	Studies with both males and females, n, %	31 (60.8%)
	Average proportion of males in gender-neutral programs, %	27.6%
Age	**Mean years**	22.1
	17 to ≤25 years, n, %	24 (47.1%)
	17 to ≤30 years, n, %	10 (19.6%)
	17 to ≤35 years, n, %	17 (33.4%)
Ethnicity	**Predominantly white, n, %**	28 (54.9%)
	Predominantly non-white, n, %	7 (13.7%)
	Not reported, n, %	16 (31.4%)
Education	**Current University/college students, n, %**	33 (64.7%)
	Not reported or unclear, n, %	18 (35.3%)
Intervention type	**Weight loss, n, %**	17 (33.3%)
	Weight gain prevention, n, %	34 (66.7%)
BMI, kg/m^2	**Mean for all studies**	26.5
	Mean for weight loss interventions	30.7
	Mean for weight-gain prevention interventions	24.6
Mode of intervention delivery	**eHealth only, n, %**	18 (35.3%)
	Face-to-face only, n, %	13 (25.5%)
	Multi-component, n, %	20 (39.2%)
Setting	**College/University, n, %**	33 (64.7%)
	Community, n, %	14 (27.5%)
	Military, n, %	2 (3.9%)
	Workplace, n, %	1 (2.0%)
	Clinical, n, %	1 (2.0%)
Study arms	**Total**	118
	2 arms, n, %	38 (74.5%)
	3 arms, n, %	11 (21.6%)
	4 arms, n, %	1 (2.0%)
	5 arms, n, %	1 (2.0%)

(Continues)

TABLE 1 (Continued)

		Total
Intervention duration	**Mean duration, months**	7.0 months
	Range	1 month to 30 months
	0 to ≤3-months, n, %	31 (60.8%)
	4 to ≤6-months, n, %	9 (17.6%)
	7 to ≤12-months, n, %	2 (3.9%)
	Greater than 12 months	9 (17.6%)
Length of follow-up from end of intervention	**Mean length, months**	2.8 months
	Range	0 to 23 months
	0 to ≤3-months, n, %	39 (76.5%)
	4 to ≤6-months, n, %	3 (5.9%)
	7 to ≤12-months, n, %	5 (9.8%)
	Greater than 12 months	4 (7.8%)
Retention rate	**Post-intervention, mean %**	83.0%
	Range	54 to 100%
	At longest follow-up point, mean %	69.8%
	Range	11 to 98%

Abbreviation: **BMI:** body mass index.

3.3.2 | Weight: Meta-analysis

Meta-analysis of weight (kg) change outcomes in 19 studies with a total of 22 intervention arms[35,36,39-41,43-47,49,51,53-58,82] for interventions to prevent weight gain and/or initiate weight loss examined two moderator effects. There was no significant time effect (LRT $\chi2(4) = 0.14$, $P = .932$) with a nonsignificant mean change in weight relative to baseline +0.03 kg up to 3 months (95% CI: −1.25, 1.32) and +0.11 kg for >3 months (95% CI: −1.11, 1.32) (Figure 3). When compared with control, there was no significant difference in weight change over time between the weight loss interventions and weight-gain prevention interventions (Wald $\chi2(1) = 0.46$, $P = .80$). Specifically, when compared with control, mean decreases in weight (kg) in weight gain prevention interventions were −1.09 kg up to 3 months (95% CI: −2.74, 0.56) and −1.13 kg for >3 months (95% CI: −2.71, 0.46), and for the weight loss interventions, −1.59 kg up to 3 months (95% CI: −3.65, −0.48) and −1.23 kg for >3 months (95% CI: −3.48, 1.02). However, there were differences (albeit not significant) at baseline (with effect size treated as treatment-control) between weight gain interventions and control (−0.99 kg, 95% CI: −2.44, 0.46) and between weight loss interventions and control (−2.03 kg, 95% CI: −4.09, 0.04), which attenuates the estimated changes at up to 3 months and beyond (Figure S1). The funnel plot (Figure S2) demonstrated no symmetry, indicating that there was no evidence of publication bias to higher values, a nonparametric correlation test supported this (Kendall's tau 0.10, $P = .25$). Plots of the means for the effects are in Figure S3, while model diagnostics are satisfactory and are in

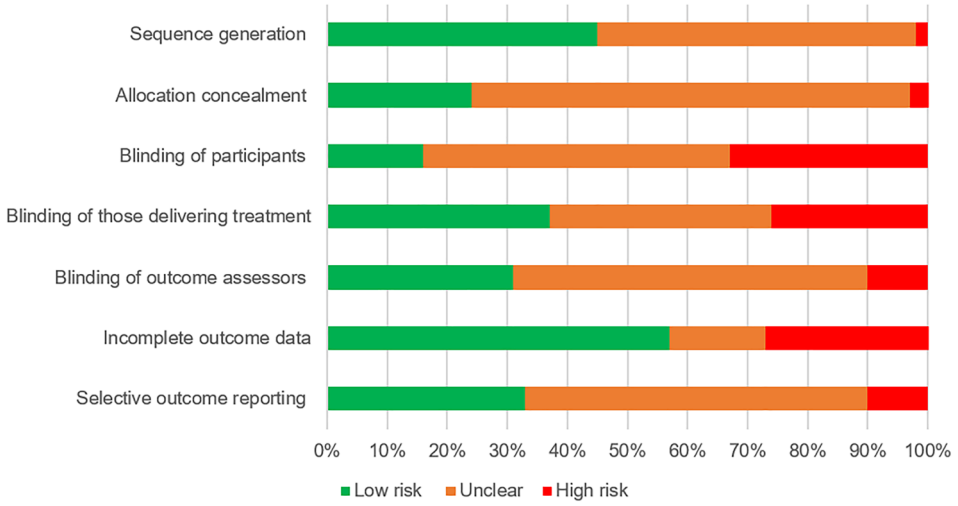

FIGURE 2 Percentage of studies from risk of bias assessment that were categorized as low, high, or unclear risk for individual risk components

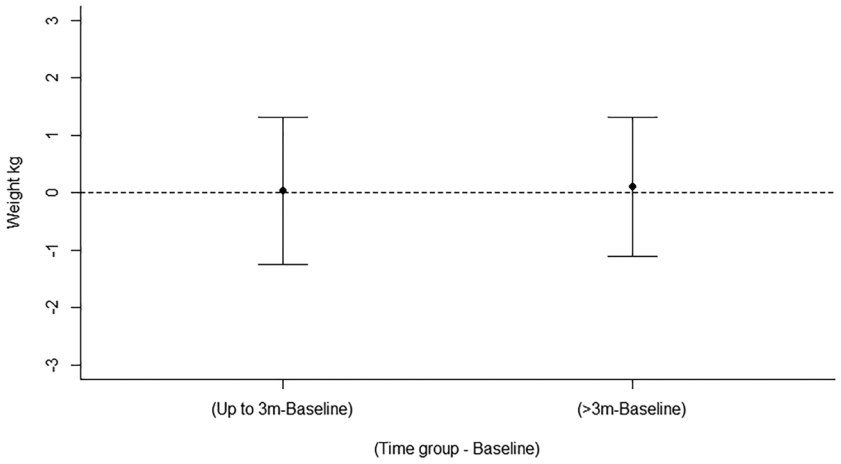

FIGURE 3 Mean differences for all interventions to prevent weight gain and/or initiate weight loss between intervention and control arms in weight (kg) over time

Figure S4. The forest plots showing mean difference (95% confidence interval) over time (months) are in Figure S5.

3.3.3 | BMI: All included studies

A total of 36 studies measured changed in BMI, with 32 of these using an objective measure for BMI,[35-41,43-53,55,59,60,63,64,67,68,71,73,74,78,83-85] while four studies used self-report measures for BMI.[34,42,80,81] This includes the 20 studies from the meta-analysis and a further 16 studies that reported BMI as an outcome, but results were not comparable and therefore not included in the meta-analysis. Of these 36 studies, statistically significant between-group reductions in BMI were reported in 11 studies,[36,37,59,60,63,67,68,74,80,81,84] as shown in Table S2. Of the 36 studies, 11 were weight loss interventions[35,36,39,46,49,52,64,74,78,84,85] and 25 were weight-gain prevention interventions.[34,37,38,40-45,47,48,50,51,53,55,59,60,63,67,68,71,73,80,81,83] Specifically, for the weight loss interventions, 3 of the 11 (27%) demonstrated a significant reduction in BMI when compared with control.[36,74,84] In the weight-gain prevention interventions, eight of the 25 (32%) reported a significant difference in BMI change between the groups, favouring the intervention.[37,59,60,63,67,68,80,81]

3.3.4 | BMI: Meta-analysis

Meta-analysis of BMI in 20 studies with a total of 26 intervention arms[34-53] for interventions to prevent weight gain and/or initiate weight loss examined two moderator effects. There was no significant time effect (LRT $\chi 2(4) = 0.78$, $P = .678$) with a nonsignificant mean decrease in BMI relative to baseline −0.05 kg/m^2 up to 3 months (95% CI: −0.39, 0.27) and −0.14 kg/m^2 for >3 months (95% CI: −0.44, 0.16) (Figure 4). As was the case with weight, there was no significant difference in BMI between weight loss interventions and weight-gain prevention interventions when compared with control (Wald $\chi 2(1) = 0.25$, $P = .88$). Specifically, when compared with control, mean decreases in BMI in weight gain prevention interventions were −0.24 kg/m^2 up to 3 months (95% CI: −0.55, 0.07) and −0.30 kg/m^2 for >3 months (95% CI: −0.58, -0.03), and for the weight loss interventions, −0.26 kg/m^2 up to 3 months (95% CI: −1.03, 0.51) and −0.39 kg/m^2 for >3 months (95% CI: −0.93, 0.14). However, there were differences (albeit not significant) at baseline (with effect size treated as treatment-control) between weight gain interventions and control (−0.20 kg, 95% CI: −0.47, 0.06) and between weight loss interventions and control (−0.09 kg, 95% CI: −0.69, 0.50), which attenuates the estimated changes at up to 3 months and beyond (Figure S6). The funnel plot (Figure S7) demonstrated no symmetry, indicating that there was no evidence of publication bias to higher values, a nonparametric correlation test supported this (Kendall's tau 0.11, $P = 0.18$). Plots of the means for the effects are in Figure S8, while model diagnostics are satisfactory and are in Figure S9. The forest plots showing mean difference (95% CI) over time (months) are in Figure S10.

3.3.5 | Waist circumference: All included studies

When all studies were considered, there were a total of 16 studies that measured changes in waist circumference.[36,40,41,43,48,49,52,53,55,56,59,60,63,73,74,78] This includes the 10 studies from the meta-analysis and a further six studies that reported waist circumference as an outcome, but results were not comparable and therefore not included in the meta-analysis. Of these 16 studies, statistically significant between-group reductions in waist circumference were reported in four studies[36,59,60,74] as shown in Table S2. Of the 16 studies, 6 were weight loss interventions[36,49,52,56,74,78] and 10 were weight-gain prevention interventions.[40,41,43,48,53,55,59,60,63,73] Specifically, for the weight loss interventions, two of the six (33%) demonstrated a significant reduction in waist circumference when compared with control.[36,74] In the weight-gain prevention interventions, two of the 10 (20%) reported a significant difference in waist circumference change between the groups, favouring the intervention.[59,60]

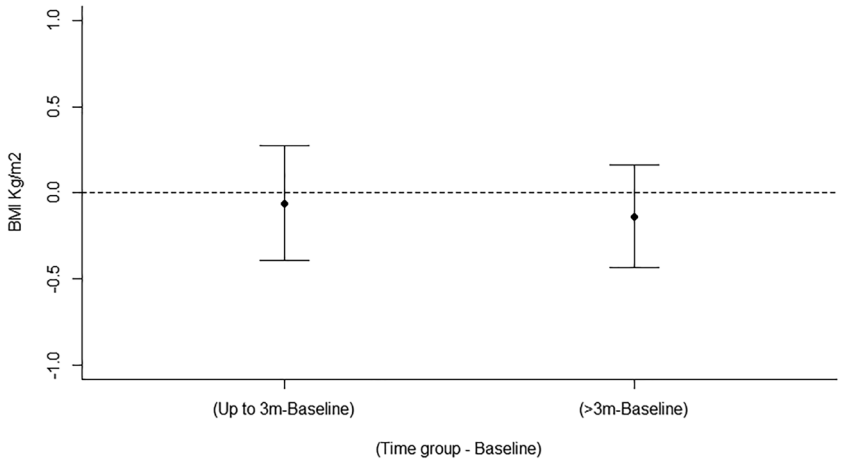

FIGURE 4 Mean differences for all interventions to prevent weight gain and/or initiate weight loss between intervention and control arms in body mass index (BMI) (kg/m2) over time

3.3.6 | Waist circumference: Meta-analysis

Meta-analysis of waist circumference in 10 studies with 11 intervention arms[36,40,41,43,48,49,52,53,55,56] for interventions to prevent weight gain and/or initiate weight loss examined two moderator effects. There was no significant time effect (LRT $\chi 2(4) = 0.10$, $P = .9523$) with a nonsignificant mean decrease in waist circumference relative to baseline −0.14 cm up to 3 months (95% CI: −1.22, 0.93) and −0.15 cm for >3 months (95% CI: −1.19, 0.89) (Figure 5). When compared with control, there was no significant difference in waist circumference between weight loss interventions and weight-gain prevention interventions (Wald $\chi 2(1) = 0.39$, $P = 0.82$). Specifically, when compared with control, mean decrease in waist circumference in weight gain prevention interventions were −0.02 cm up to 3 months (95% CI: −1.34, 1.30) and +0.04 cm for >3 months (95% CI: −1.36, 1.45), and for the weight loss interventions, −0.98 cm up to 3 months (95% CI: −4.40, 2.45) and −0.64 cm for >3 months (95% CI: −2.68, 1.38) (Figure S11). The funnel plot (Figure S12) demonstrated no symmetry, indicating that there was no evidence of publication bias to higher values, a nonparametric correlation test supported this (Kendall's tau 0.00, $P = 1.00$). Plots of the means for the effects are in Figure S13, while model diagnostics are satisfactory and are in Figure S14. The forest plots showing mean difference (95% confidence interval) over time (months) are in Figure S15.

3.3.7 | Skeletal muscle mass

Nine studies assessed the change in skeletal muscle mass (SMM), either reported as kilograms and/or percentage difference.[40,46,51,52,59,60,63,64,71] Of these, none demonstrated a significant between group intervention effect at any time point when compared with control.

3.3.8 | Body fat mass

A total of 14 studies measured body fat mass (BFM) as either kilograms and/or percentage difference.[40,46,48,51-53,55,58-60,63,64,71,78] Of these, two studies demonstrated a significant intervention effect when compared with control.[60,78] Both of these studies were gender-tailored with the first being a weight-gain prevention study that was specific to young adult men.[60] At 3 months, there was a difference in BFM of −1.4 kg (95%CI: −2.5, −0.3 kg) between the HEYMAN multicomponent intervention and waitlist control group. The second

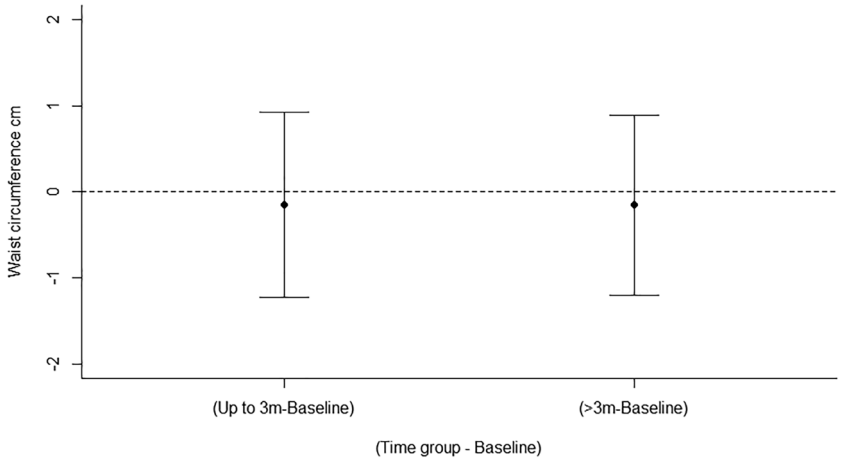

FIGURE 5 Mean differences for all interventions to prevent weight gain and/or initiate weight loss between intervention and control arms in waist circumference (cm) over time

study was an *e*health weight loss program (Be Positive Be Healthe) for young women with overweight or obesity.[78] At 6 months, there was a difference in BFM of 3.1 kg (*P*=.02) between the intervention group and waitlist control group.

3.3.9 | Waist-to-hip ratio (WHR)

Change in waist-to-hip ratio (WHR) was assessed in five studies.[46,48,49,52,59] Of these, one study reported a between-group decrease in WHR at the end of the program at 13 months (–0.05 vs. +0.02, *P* <.05).[59] This study ("Health Hunters") was a weight-gain prevention intervention among high-risk young women with familial predisposition for obesity. The intervention group received an individualized behavioural program focusing on diet, PA, and other lifestyle factors.

3.3.10 | Probability of losing 5% and 10% body weight

One study measured the probability of losing 5% and 10% body weight.[36] This study (Project SMART) was a 2-year, theory-based, weight loss intervention that was delivered via Facebook, mobile apps, text messaging, emails, a website, and technology-mediated communication with a health coach. There was a significant intervention effect for probability of losing 5% body weight at 6 months (*P*=.05) but not at 12, 18, or 24 months. There was no effect for probability of losing 10% body weight at any time point.

3.3.11 | Hip circumference, skinfolds, waist-to-height ratio, and percentage weight loss

Four studies assessed change in hip circumference (cm),[43,49,52,59] one study assessed change in skinfolds,[46] one study assessed change in waist to height ratio,[49] and two measured change in percentage weight loss.[64,85] Of these, none demonstrated a significant between group intervention effect at any time point when compared with control.

3.4 | Behaviour change techniques

3.4.1 | Description of behaviour change techniques applied

BCTs that were identified within the 60 active intervention arms are presented in Table 2. Of 93 BCTs in the taxonomy, 55 were coded one or more times, with a total of 436 BCTs coded across the active intervention arms. Across all interventions arms, a median of six BCTs were employed (range: one to 25), with those coded most frequently being: "Instruction on how to perform a behaviour" (n=29), "goal setting behaviour" (n=28), "self-monitoring of behaviour" (*n*=25), "feedback on behaviour" (*n*=24), and "social support (unspecified)" (*n*=23). BCTs applied separately to weight loss studies (n=19 active intervention arms) and weight gain prevention studies (n=41 active intervention arms) are also presented in Table 2. For weight loss interventions, 39 BCTs were coded one or more times with a total of 140 BCTs coded across the intervention arms. A median of six BCTs were employed (range: one to 15), with those coded most frequently being: "goal setting behaviour" (*n*=11), "feedback on behaviour" (*n*=10) and "self-monitoring of behaviour," and action planning and "prompts/cues" (all n=9). For weight gain prevention interventions, 49 BCTs were coded one or more times with a total of 296 BCTs coded across the intervention arms. A median of 6 BCTs were employed (range: 1 to 25), with those coded most frequently being: "instruction on how to perform a behaviour" (*n*=22), "goal setting behaviour" (n=17), and "self-monitoring of behaviour" (n=16).

3.5 | Effectiveness of BCTs

BCT percentage effectiveness ratio for 48 studies is presented in Figure 6. Reporting of results in one study was not sufficiently clear to determine between group differences,[76] while two studies had no difference in coded BCTs between intervention and control groups.[46,51] To meaningfully report BCT effectiveness, only those identified in at least five studies (n=29) were included for overall analysis [25].

Four BCTs had an effectiveness ratio >50%. These were "goal setting (outcome)" (effective in five out of seven or 71.4% of interventions), "self-monitoring of outcome(s) of behaviour" (effective in seven out of 12 or 58.3% of interventions), "social reward" (effective in four out seven or 57.1% of interventions), and "social support (unspecified)" (effective in 12 out of 23 or 52.2% of interventions).

A contingency table comparing type of BCT versus effectiveness for improving adiposity outcomes was used to test overall significance. There was no significant relationship demonstrated based on results of the Monte-Carlo exact chi-squared test ($\chi^2(28)=23.8$, *P*=.71). This indicates that none of the BCTs were significantly different to the overall mean value.

For weight loss interventions, there were 10 BCTs identified in at least five studies. Of these two had an effectiveness ratio >50% (Figure 7). These were "social support (unspecified)" (effective in 5 out of 8 or 62.5% of interventions) and "self-monitoring of behaviour" (effective in 5 out of 9 or 55.6 % of interventions). There was no significant relationship demonstrated based on results of the Monte-Carlo exact chi-squared test ($\chi^2(9)=2.7$, *P*=.98). This indicates that none of the BCTs were significantly different to the overall mean value.

For weight-gain prevention interventions, there were 25 BCTs identified in at least five studies. Of these, one had an effectiveness ratio >50% (Figure 8). This was "goal setting (outcome)" (effective in four out of six or 66.7% of interventions). There was no significant relationship demonstrated based on results of the Monte-Carlo exact

TABLE 2 Behaviour change techniques used[a]

Behaviour Change Technique	All Studies (n=60 Active Arms)[b]		Weight Loss Studies (n=19 Active Arms)		Weight-Gain Prevention Studies (n=41 Active Arms)	
	N	%	N	%	N	%
1.1 Goal setting (behaviour)	28	46.7	11	57.9	17	41.5
1.2 Problem solving	19	31.7	4	21.1	15	36.6
1.3 Goal setting (outcome)	7	11.7	1	5.3	6	14.6
1.4 Action planning	21	35.0	9	47.4	12	29.3
1.5 Review behavioural goals	11	18.3	3	15.8	8	19.5
1.6 Discrepancy between behaviour and goals	2	3.3	2	10.5	0	0
1.7 Review outcome goal(s)	2	3.3	0	0	2	4.9
1.8 Behavioural contract	2	3.3	0	0	2	4.9
1.9 Commitment	2	3.3	1	5.3	1	2.4
2.1 Monitoring of behaviour by others without feedback	1	1.7	1	5.3	0	0
2.2 Feedback on behaviour	24	40.0	10	52.6	14	34.1
2.3 Self-monitoring of behaviour	25	41.7	9	47.4	16	39.0
2.4 Self-monitoring of outcome(s) of behaviour	12	20.0	4	21.1	8	19.5
2.6 Biofeedback	1	1.7	0	0	1	2.4
2.7 Feedback on outcome(s) of behaviour	8	13.3	3	15.8	5	12.2
3.1 Social support (unspecified)	23	38.3	8	42.1	15	36.6
3.2 Social support (practical)	7	11.7	2	10.5	5	12.2
3.3 Social support (emotional)	7	11.7	3	15.8	4	9.8
4.1 Instruction on how to perform the behaviour	29	48.3	7	36.8	22	53.7
4.4 Behavioural experiments	1	1.7	0	0	1	2.4
5.1 Information about health consequences	14	23.3	3	15.8	11	26.8
5.2 Salience of consequences	3	5.0	1	5.3	2	4.9
5.3 Information about social and environmental consequences	1	1.7	0	0	1	2.4
5.6 Information about emotional consequences	5	8.3	0	0	5	12.2
6.1 Demonstration of the behaviour	16	26.7	3	15.8	13	31.7
6.2 Social comparison	5	8.3	2	10.5	3	7.3
6.3 Information about others' approval	1	1.7	0	0	1	2.4
7.1 Prompts/cues	20	33.3	9	47.4	11	26.8
8.1 Behavioural practice/rehearsal	19	31.7	6	31.6	13	31.7
8.2 Behaviour substitution	8	13.3	1	5.3	7	17.1
8.3 Habit formation	7	11.7	4	21.1	3	7.3
8.4 Habit reversal	5	8.3	2	10.5	3	7.3
8.6 Generalization of target behaviour	2	3.3	1	5.3	1	2.4
8.7 Graded tasks	10	16.7	1	5.3	9	22.0
9.1 Credible source	10	16.7	5	26.3	5	12.2
9.2 Pros and cons	2	3.3	1	5.3	1	2.4
9.3 Comparative imagining of future outcomes	2	3.3	1	5.3	1	2.4
10.1 Material incentive (behaviour)	4	6.7	0	0	4	9.8
10.2 Material reward (behaviour)	3	5.0	0	0	3	7.3
10.4 Social reward	7	11.7	2	10.5	5	12.2
10.8 Incentive (outcome)	2	3.3	2	10.5	0	0
10.9 Self-reward	2	3.3	2	10.5	0	0
10.10 Reward (outcome)	2	3.3	2	10.5	0	0

(Continues)

TABLE 2 (Continued)

Behaviour Change Technique	All Studies (n=60 Active Arms)[b]		Weight Loss Studies (n=19 Active Arms)		Weight-Gain Prevention Studies (n=41 Active Arms)	
	N	%	N	%	N	%
10.11. Future punishment	2	3.3	0	0	2	4.9
11.2 Reduce negative emotions	9	15.0	3	15.8	6	14.6
12.1 Restructuring the physical environment	1	1.7	0	0	1	2.4
12.3 Avoidance/reducing exposure to cues for the behaviour	5	8.3	0	0	5	12.2
12.5 Adding objects to the environment	17	28.3	6	31.6	11	26.8
12.6 Body changes	3	5.0	1	5.3	2	4.9
13.2 Framing/reframing	5	8.3	0	0	5	12.2
13.4 Valued self-identify	3	5.0	0	0	3	7.3
15.1 Verbal persuasion about capability	2	3.3	2	10.5	2	4.9
15.3 Focus on past success	2	3.3	0	0	2	4.9
15.4 Self-talk	2	3.3	0	0	2	4.9
16.3 Vicarious consequences	3	5.0	2	10.5	1	2.4

Abbreviations: BCTs: behaviour change techniques.
[a]Median number of BCTs used in interventions = 5; range: 1–25.
[b]BCTs that were identified within the 60 active intervention arms for all studies, n=19 active intervention arms for weight loss studies and n=41 active intervention arms for weight gain prevention interventions.

chi-squared test ($\chi^2(24)=21.7$, $P=.61$). This indicates that none of the BCTs were significantly different to the overall mean value.

Figure 9 presents the percentage ratio of effective versus non-effective interventions by number of BCTs, highlighting that no relationship exists based on whether fewer or more BCTs are utilized. The overall test of significance using a contingency table indicates that there was no significant relationship (Monte-Carlo exact chi-squared test, $\chi2(17)=20.7$, $P=.23$).

Similar results occur when separated by weight loss interventions (Monte-Carlo exact chi-squared test, $\chi^2(11)=13.6$, $P=.22$) (Figure 10) and weight gain prevention interventions (Monte-Carlo exact chi-squared test, $\chi^2(15)=19.3$, $P=.16$) (Figure 11).

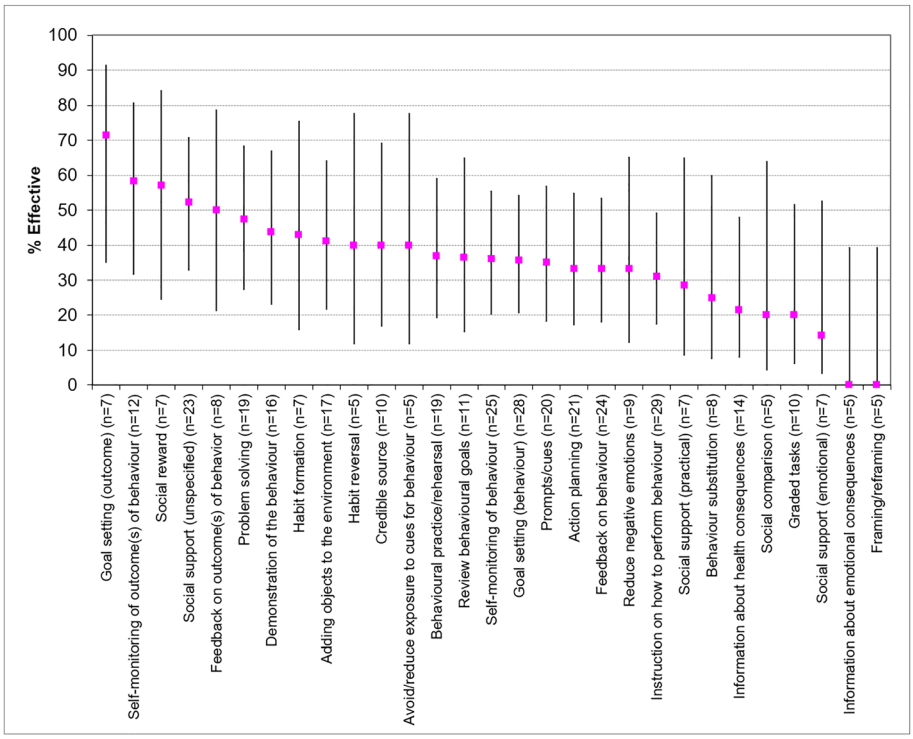

FIGURE 6 Percentage effectiveness of behaviour change techniques

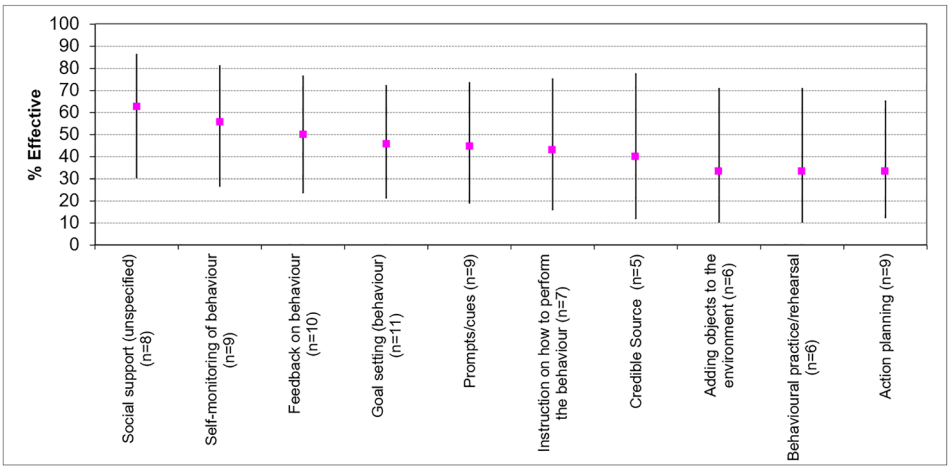

FIGURE 7 Percentage effectiveness of behaviour change techniques in weight loss interventions

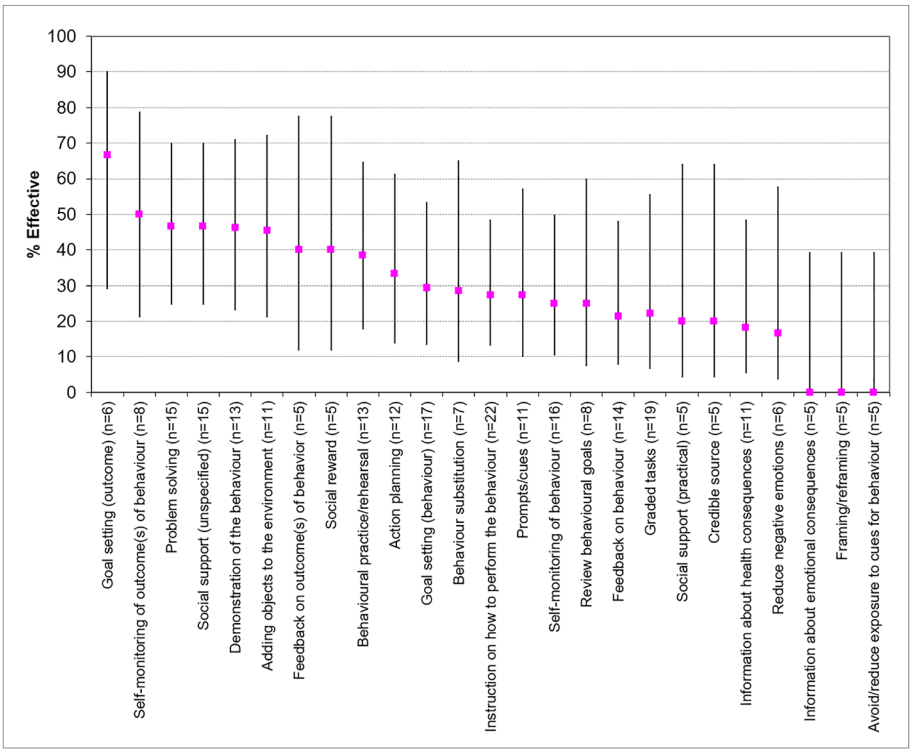

FIGURE 8 Percentage effectiveness of behaviour change techniques in weight-gain prevention interventions

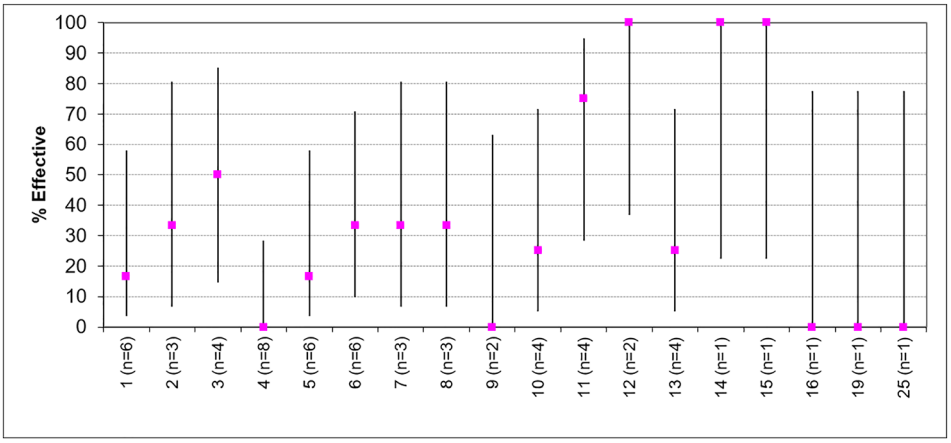

FIGURE 9 Percentage effectiveness of interventions by number of behaviour change techniques

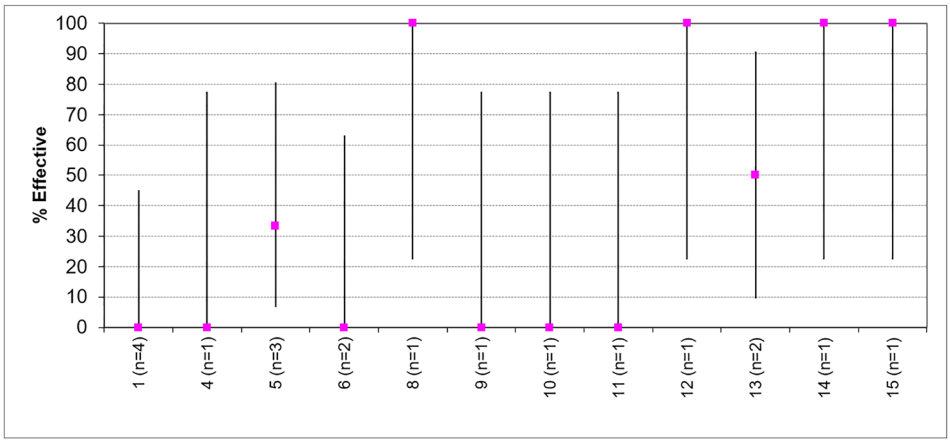

FIGURE 10 Percentage effectiveness of weight loss interventions by number of behaviour change techniques

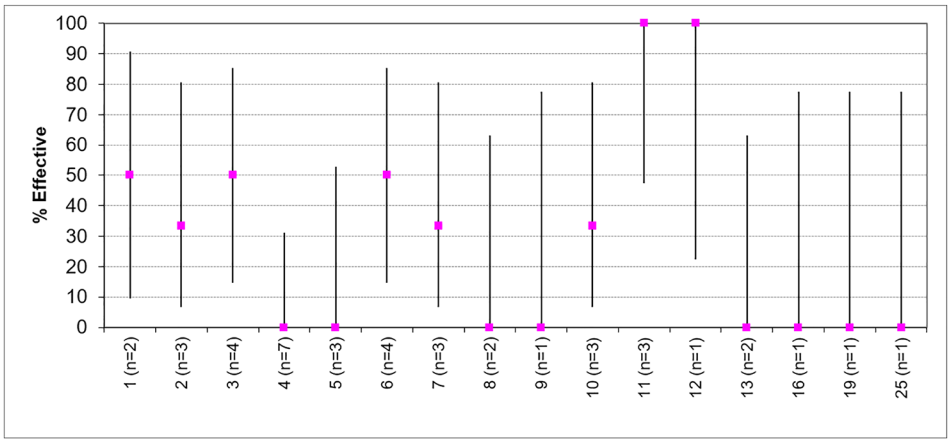

FIGURE 11 Percentage effectiveness of weight-gain prevention interventions by number of behaviour change techniques

4 | DISCUSSION

To our knowledge, this is the largest systematic review and meta-analysis of adiposity outcomes in healthy young adult populations receiving either weight loss or weight gain prevention interventions. These findings demonstrate the increased research attention being directed to this area, with the number of published interventions more than doubling in the last 5 years. The meta-analyses for weight (n=19 studies), BMI (n=20 studies), and waist circumference (n=10 studies) demonstrated that there were no significant differences between intervention and control groups at either ≤3 months or >3 months. Also, there were no differences on outcomes between interventions focusing on either weight loss or weight-gain prevention. The narrative synthesis showed that for studies with weight as an outcome, significant between group differences were evident in 14 out of 43 studies or 33%. In studies assessing BMI, waist circumference, and waist-to-hip ratio, BFM and SMM significant between group differences at any time point were established in 31% (11 of 36), 25% (four of 16), 20% (one of five), 14% (two of 14), and 0% (0 of nine) of studies. Four BCTs demonstrated a percentage effectiveness ratio >50%; these were goal setting (outcome), self-monitoring of outcome(s) of behaviour, social reward, and social support (unspecified). Although the overall test of significance demonstrated no significant relationship between type of BCT and effectiveness, it does demonstrate initial potential for these types of BCTs. These findings can help build cumulative evidence towards delivering effective, cost-efficient, and replicable interventions.

4.1 | Effectiveness of interventions on adiposity outcomes

Findings from this narrative synthesis and the meta-analyses confirm the difficulties in making positive changes to the weight and body composition of young adults. These findings appear to be weaker when compared with other meta-analyses in this group. Specifically, a meta-analysis of eight weight-gain prevention interventions found that young adults (18-35 years) in the intervention group lost a mean 0.87 kg (n=388), compared with controls (n=193) who gained 0.86 kg.[86] However, at the time that the analysis was published, there was only a small body of evidence in this field with only eight studies included. When compared with the meta-analysis in this current review on weight, there are over double the number of studies (n=19). As such, this may have attenuated the overall effect. Furthermore, another published meta-analysis of 14 weight loss studies in young adults showed significant reductions in weight in behavioural interventions (−2.40 kg; 95% CI: −5.4 to 0.6) and diet plus exercise interventions (−2.96 kg; 95% CI: −4.4 to −1.5).[12] However, additional study designs were included (ie, controlled clinical trials, nonrandomized trials, and cohort studies) and these results were

only pre-post comparisons with changes not compared with the control group.[12]

The narrative synthesis demonstrated that 17 of the 51 studies had a significant intervention effect on at least one adiposity outcome when compared with control. When comparing these 17 effective studies versus the 34 studies that had no intervention effect, there were some evident differences. Specifically, the interventions deemed effective were predominantly conducted in a community setting (53% vs 15%) and fewer carried out in a university setting (47% vs 74%). This shows the potential of community-based interventions on positively changing adiposity measures in this group. It also demonstrates that an increased focus may be required for university students, due to elements of their environment that are setting specific. It is likely that a university setting was chosen out of convenience, particularly as this setting has the potential to engage large numbers of students and has an extensive range of facilities, technology, and resources.[87] However, many of the interventions were not specifically targeted or tailored to university students, which may have attenuated any effects. In addition, the mean retention rate in the 17 effective studies was higher at the end of the intervention (85.3% vs 81.5%) compared with those studies that had no intervention effect. Also, participants in those considered effective were slightly older (23.6 years vs 21.3 years), the intervention duration was longer (9.2 months vs 5.8 months), and the mean sample size was lower (164 vs 386). It is likely the larger sample size in the noneffective studies may have had less intervention dose as budget and timeline considerations will all be heightened with greater numbers. Sample size should be based on power calculations for RCTs, and more guidance is required to help establish optimum intervention dose related to achieving the primary outcome (ie, weight gain prevention or weight loss), including duration and the number of intervention components.

In contrast to the meta-analysis results, the narrative synthesis also showed a greater proportion of weight-gain prevention interventions to be effective in improving weight outcomes (36% vs 27% of studies demonstrated significant intervention effect compared with control) and BMI outcomes (32% vs 27%). This difference in findings could be due to the large number of studies not able to be included in meta-analyses, and given this, brings into question which set of findings are more correct. Another perspective is that the difference may be related to participants' stage of readiness to lose weight, as there is some evidence demonstrating that individuals with overweight or obesity (ie the majority of included participants) are more likely to be in pre-contemplation/contemplation stages than action/maintenance.[88] The greater number of weight-gain prevention interventions may have skewed results, but initial results are promising and may suggest more effort be directed towards weight-gain prevention at the population level.

4.2 | Effectiveness of behaviour change techniques

This review compared the individual BCTs in effective versus noneffective interventions to identify which specific BCTs may be agents of change. Self-regulation strategies including goal setting (outcome) and self-monitoring outcome(s) of behaviour were effective BCTs. Examples of these techniques in interventions were (a) participants set a goal to lose 0.5 kg per week as an outcome of changed eating patterns and (b) participants were instructed to weigh themselves each day and record weight on a graph to increase exercise behaviour. The effectiveness of these self-regulation strategies are comparable to a systematic review of 24 *e*Health interventions in young adults, which reported self-regulation skills (goal setting and self-monitoring) as key strategies for weight management. Notably, all studies in that review which had positive weight-related outcomes implemented some form of self-monitoring.[14] Goal setting requires the participant to set or agree on a goal defined in terms of a positive outcome of wanted behaviour, while self-monitoring requires deliberate attention to the participant's own actions, as well as the conditions under which they occur, and their immediate and long-term effects.[89] Research indicates that goal setting and self-monitoring of key behaviours are associated with successful initial weight loss and weight maintenance.[90-92]

Another effective BCT is "social reward" (also known as positive reinforcement), which consists of verbal or nonverbal reward if there has been effort and/or progress in performing the behaviour.[20] An example of this technique within an intervention includes congratulating the participant each day they go to the gym. The psychology behind social reward originates from the Skinner's operant conditioning model, which is based on the assumption that studying a behaviour's cause and its consequences is the best way to understand and regulate it.[93] This model has evolved from the law of effect, which states that a behaviour that is followed by pleasant or desirable consequences is likely to be repeated.[93]

No difference in the number of BCTs relative to effectiveness for adiposity outcomes were identified in this current review. This is consistent with other systematic reviews in other population groups.[32,94] Incorporating a greater number of BCTs does not necessarily lead to greater efficacy, but the utility of the individual BCTs may be more important.

The individual BCTs in effective versus noneffective interventions were also compared separately for weight loss and weight-gain prevention interventions. In weight loss interventions, social support (unspecified) and self-monitoring of behaviour were effective BCTs. While in weight-gain prevention interventions, goal setting (outcome) was the only effective BCT. It appears that there are differences in the effective BCTs; however, as with the BCTs overall, there were no significant relationships between type of BCT and effectiveness for weight loss or weight-gain prevention interventions separately. Although, the effective BCTs identified are consistent with reviews of weight loss and weight-gain prevention interventions in general adult populations.[95,96] Therefore, these BCTs demonstrate initial potential for the respective intervention types. Despite this, the literature on BCTs has focused on individual BCTs in relation to effectiveness but not on how much they are emphasized relative to other techniques within an intervention.[97] It is possible that a combination of BCTs are required for intervention effectiveness.[97] Rather than solely looking

at BCTs in relation to intervention effectiveness, it may also be useful to address other areas of intervention specificity such as treatment delivery (mode, duration, and intensity) and adaptability (by whom) to help unpack the "black box" of interventions for identifying useful intervention strategies.

4.3 | Strengths and limitations of included studies

The risk of bias assessment found studies provided sufficient detail for describing study attrition and reasons for exclusions from analyses. However, many studies either failed to provide the necessary detail or were "high risk" for selective outcome reporting, sequence generation, allocation concealment, and blinding of participants, personnel, and/or outcome assessors. There was a lack of diversity in studies with an overrepresentation of female populations, Caucasian samples, and within university/college settings. Coding of BCTs was challenging due to insufficient detail in reporting of intervention components. This is likely a result of journal constraints, which preclude a thorough description of the intervention.[17] The meta-analysis was limited by a small number of studies due to heterogeneity in reporting of results.

4.4 | Strengths and limitations of this review

Strengths of this review include a comprehensive search strategy, two independent reviewers at each stage of the review, the use of the Cochrane Collaboration's Tool for assessing risk of bias,[28] robust statistical analysis, and a robust method to code the BCTs, using the most recent and comprehensive taxonomy of BCTs available.[20] Despite insufficient detail in reporting of intervention components, 100% agreement was achieved for coding of BCTs. Greater attempts could have been made to contact the authors of the included papers or obtain unpublished protocols to gather more information on the BCTs used in each intervention. A limitation of this review was the restriction of studies published in English language only. Also, a percentage effectiveness ratio was utilized to determine the effective BCTs as this approach has been implemented in similar reviews.[31,33] However, this approach uses a binary categorization as effective or not effective but does not consider the size of the effect. Further, if behaviour change theory had been explored in addition to BCTs, this would have provided insight into the underpinning mechanisms of action, and by basing the BCT effectiveness ratio on behavioural outcomes as opposed to adiposity outcomes, the results may have differed.[33] Finally, this review did not assess the degree of emphasis or the quality of implementation of BCTs within interventions.

5 | CONCLUSION

Findings from this systematic review and meta-analyses confirm the challenges in making a positive impact on weight and body composition in young adults. There is initial potential for the following BCTs: goal setting (outcome), self-monitoring of outcome(s) of behaviour, social reward, and social support (unspecified). However, due to the lack of studies including each BCT, this review could not identify which BCTs are imperative to success. Further studies are required before confirming which BCTs can be considered as having greater effectiveness than others.

Recommendations for research

- Future research must adequately describe the BCTs used in interventions by publishing intervention protocol papers and/or including a checklist of the BCTs utilized as supplementary material of each publication.
- Reporting of studies must adhere to the CONSORT checklist to provide clearer descriptions of study methods. In particular, greater clarity for selective outcome reporting, sequence generation, allocation concealment, and blinding of participants, personnel, and/or outcome assessors.
- Reporting of outcomes at each time-point with mean and standard deviations will enable greater exploration of studies in meta-analysis.
- Narrative synthesis showed weight gain prevention interventions to be promising and may suggest more effort be directed towards these types of interventions at the population level.
- Due to the heterogeneity within young adults, there must be greater attention placed on recruiting diverse samples of young adults. In particular, more males, different ethnicities, and samples from a variety of social economic backgrounds.
- The effectiveness of BCTs are underpinned by a variety of factors relating to their implementation, including the degree of emphasis and quality of implementation within interventions as well as the intervention mode of delivery. As such, future research should provide full detail on these factors to allow for further exploration and differentiation of BCT effectiveness

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CONFLICT OF INTEREST

No conflict of interest statement.

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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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