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Short title: *Review of group-based weight-loss interventions*

Authors and affiliations:

Dr Aleksandra J. Borek*; Email: a.borek@exeter.ac.uk; Tel. +44(0) 1392 726041

Prof. Charles Abraham; Email: c.abraham@exeter.ac.uk; Tel. +44(0) 1392 725925

Ass/Prof. Colin J. Greaves; Email: c.j.greaves@exeter.ac.uk; Tel. +44(0) 1392 722751

Dr Mark Tarrant; Email: m.tarrant@exeter.ac.uk; Tel. +44 (0) 1392 725921

*Corresponding author; all authors have the same postal address:

University of Exeter Medical School, University of Exeter, St. Luke's Campus, Exeter, EX1 2LU, UK

Conflict of interest:

The authors declare that they have no conflict of interest.

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**Group-based diet and physical activity weight-loss interventions: a systematic review
and meta-analysis of randomised controlled trials**

Abstract

Background: Many weight-loss interventions are delivered in groups but evidence on their effectiveness, and characteristics associated with effectiveness, is limited. We synthesised evidence on (1) design and delivery of group-based weight-loss interventions; (2) effectiveness; and (3) associations between intervention characteristics, change techniques and effectiveness.

Methods: Five online databases were searched to May 2017 for randomised controlled trials (RCTs) of group-based diet and/or physical activity interventions for overweight / obese adults ($BMI \geq 25$). Intervention characteristics were synthesised narratively. Mean differences (MD) in weight loss were calculated using a random-effects meta-analysis, and sub-group analyses were conducted to identify moderators of effectiveness.

Results: Forty-seven RCTs reporting 60 evaluations of group-based interventions were included. MD in weight loss between intervention and control groups were -3.49 [95% CI -4.15, -2.84], -3.44 [-4.23, -2.85] and -2.56 kg [-3.79, -1.33] at follow-ups closest to 6, 12 and 24 months, respectively. Explicitly targeting weight loss, men-only groups, providing feedback and dietary goals were significantly associated with greater effectiveness ($p < 0.05$).

Conclusions: Diet and physical activity interventions delivered in groups are effective in promoting clinically meaningful weight loss at 12 months. Intervention design and effectiveness vary considerably between studies, and evidence on what optimises effectiveness of group-based weight-loss interventions remains limited.

Keywords: systematic review, meta-analysis, group-based interventions, weight loss, diet, physical activity

Practitioner points:

- Group programmes can be effective in facilitating weight loss (on average about 3 kg) among overweight and obese adults with many interventions achieving average weight loss of 5% or more of body weight.
- Explicitly targeting weight loss, tailored men-only groups, providing feedback and specific dietary goals to participants are associated with greater weight loss in group-based interventions.
- Group-specific characteristics and components should be considered carefully in intervention design and reported comprehensively to allow accumulation of evidence on how groups promote behaviour change and weight loss, and to facilitate identification of which intervention design characteristics are associated with greater effectiveness.

Accepted manuscript

Background

Reducing the prevalence of obesity is a public health priority. Globally in 2014, 39% of adults were overweight and 13% were obese, and these rates have more than doubled since 1980 (World Health Organization, 2015). Being overweight or obese is associated with numerous health problems, including type 2 diabetes, coronary heart disease, hypertension, osteoarthritis, sleep apnoea, hormonal abnormalities, and some cancers (Guh et al., 2009; World Health Organization, 2015) and consequently an increased mortality risk (Flegal, Kit, Orpana, & Graubard, 2013; Whitlock et al., 2009). This greatly increases health services costs. For example, in the UK, with 61% of adults being overweight or obese, weight-related health problems are estimated to cost over £5 billion annually (Department of Health, 2013).

Obesity-related health risks can be substantially reduced with weight loss of as little as 5% of body weight (Jensen et al., 2014) and a number of interventions have been found to be effective for weight loss and weight loss maintenance (e.g. Avenell et al., 2004; Dombrowski, Knittle, Avenell, Araújo-Soares, & Sniehotta, 2014; Teixeira et al., 2015) and prevention of type 2 diabetes and cardiovascular diseases (e.g. Dunkley et al., 2014; Schwingshackl, Dias, & Hoffmann, 2014). Behaviour change interventions targeting diet and physical activity can be effective in facilitating clinically meaningful weight loss of 3 to 5 kg at 12 months (Greaves et al., 2011) and may be appropriate for a wide range of people as they are less intrusive and, when effective, less costly than pharmacological or surgical treatments. There is, however, considerable variability in effectiveness across studies.

Groups are a common delivery mode for many health interventions because of their assumed time- and cost-effectiveness (as compared to more intensive individual counselling), and because they are thought to provide opportunities for group support and sharing of strategies (Greaves & Campbell, 2007). Systematic reviews of group-based health interventions have

shown them to be effective in diabetes self-management (Deakin, McShane, Cade, & Williams, 2009; Steinsbekk, Rygg, Lisulo, Rise, & Fretheim, 2012) and there is some indication that group-based interventions may be more effective in prompting weight loss than similar treatments delivered individually (Paul-Ebhohimhen & Avenell, 2009).

However, comparisons of interventions using different delivery modes must be treated cautiously because it is often unclear whether there are differences in the change processes and techniques that are employed in, or are specific to, particular delivery modes (Abraham & Michie, 2008). Consequently, it may be unclear whether the selection of delivery mode or of change techniques within that mode promotes greater effectiveness.

Use of various intervention design features and change techniques in behavioural interventions has been found to be associated with increased effectiveness; examples include targeting changes in both diet and exercise, increasing contact intensity, providing opportunities for social support, (Greaves et al., 2011; Shaw, O'Rourke, Del Mar, & Kenardy, 2005) and incorporating self-regulatory change techniques (Dombrowski et al., 2012; Michie, Abraham, Whittington, McAteer, & Gupta, 2009). In addition, understanding and managing change processes specific to group-based interventions is critical to optimising their potential to change members' psychological functioning and behaviour change beyond the group (for a review of these processes and mechanisms see Borek & Abraham, 2018).

However, it is unclear whether these or other components are associated with greater effectiveness in group-based weight-loss interventions. Moreover, to the best of our knowledge, no systematic review focusing specifically on *group-based* weight-loss interventions has been reported to date. It is unclear, therefore, how effective such groups are and what optimises their effectiveness.

Research questions

This systematic review of randomised controlled trials of group-based diet and physical activity interventions addressed three questions: (1) How are such interventions designed and delivered? (2) How effective are they for weight loss? (3) Which intervention characteristics and change techniques are associated with effectiveness?

Methods

The review was conducted in accordance with Cochrane (Higgins & Green, 2011) and PRISMA (Liberati et al., 2009) guidelines for systematic reviews and meta-analyses.

Search methods

Online databases (Medline, Embase, PsycINFO, CINAHL, and Cochrane) were searched up to 16 May 2017. We used a comprehensive search strategy (see Supplementary File 1) with combinations of terms based on the PICOS model (Population, Intervention, Comparator, Outcomes, Study design) (Liberati et al., 2009). We hand-searched reference lists of included studies and relevant reviews, and searched 'cited by' lists in Google Scholar.

Selection criteria

Population: We selected studies including adults (≥ 18 years old) who were overweight or obese ($BMI \geq 25$ or mean baseline $BMI > 29$). We aimed to synthesise evidence from evaluations of interventions suitable for the general population rather than illness-specific interventions (which may be more intensive and include illness-specific self-management components). Consequently, participants had to be recruited to the included trials without specific comorbidities, major physical impairments, psychological problems or eating disorders and not on the basis of medical conditions or risk factors, such as high blood pressure, blood glucose level, or metabolic syndrome. We included trials in which some

participants had medical problems (these are noted in Table S1 in Supplementary Files) but only when those trials recruited participants using criteria other than their medical condition.

Interventions: We included group-based lifestyle weight-loss interventions. Group-based interventions were defined as interventions delivered (entirely or alongside other delivery modes) in groups of at least three participants who met with at least one facilitator on at least two occasions. Lifestyle interventions had to target changes in diet and/or physical activity and include educational, psychological or behavioural components; interventions involving medications, meal replacements, alternative therapies, and walking or structured exercise groups only were excluded. We included interventions with weight loss outcomes and excluded interventions targeting weight loss maintenance or prevention of weight gain.

Comparators: In order to assess effectiveness we excluded comparisons of two or more substantial interventions. We included comparisons with control groups consisting of no intervention, waiting list or irrelevant intervention (i.e., not focused on diet, physical activity or weight loss), usual care (as defined by study authors) and minimal interventions (e.g., booklet, newsletters or brief consultations).

Outcomes: We included studies with reports of participants' baseline BMI, and either change scores or baseline and follow-up weight available (with any follow-up length).

Study design: We included randomised controlled trials (RCTs) or cluster RCTs.

Other criteria: Full text reports available in English without limit on publication date.

Data collection and analysis

Study selection: Titles and abstracts of the identified studies were screened. Two researchers independently screened a randomly selected sample of 13% of references, with 100% inclusion/exclusion agreement. Full texts of potentially eligible studies were obtained and

screened for eligibility. The same researchers double screened a random sample of 9% of all screened full texts; agreement was reached on 72% of articles without discussion and 100% after discussion. A random 18% of excluded full texts were double screened, with 100% agreement. Finally, all studies in which there was any doubt regarding inclusion were discussed between the authors. The list of included studies is in Supplementary File 2.

Methodological quality: Risk of bias was assessed using the Cochrane Risk of Bias Tool (Higgins, Altman, & Sterne, 2011) (Supplementary File 3). Blinding of participants and personnel was not included in our assessment as this is impossible in group-based interventions. Incomplete and selective reporting and use of intention-to-treat analysis were assessed for weight loss outcomes. When weight loss was not a primary outcome, selective reporting was also assessed for primary study outcomes. Seventeen per cent of included studies were randomly selected and independently assessed by another researcher resulting in 85% initial agreement and 100% agreement after discussion. Unclear cases were discussed with a systematic review expert. Studies were considered as low quality if they were assessed as high or unclear risk of bias on at least three out of six domains (similarly to Schwingshackl, Dias & Hoffmann, 2014). Sensitivity analysis was performed by removing low quality studies.

Quality of descriptions of group interventions: The quality of reporting of group-specific intervention elements was assessed using a reliable checklist of 26 elements of group-based behaviour-change interventions (Borek, Abraham, Smith, Greaves, & Tarrant, 2015). This was assessed on the basis of the main included report and any other referenced and publically available intervention descriptions.

Data extraction and management: Detailed information was extracted by the first author using an extraction form that had been developed, piloted and refined by the authors. Where

more than one report of an included study was identified, the one with the most comprehensive report of weight loss outcomes was selected. Extracted data included study characteristics (study design, sample size, attrition); intervention characteristics (targeted behaviour, delivery modes, setting, contact time); intervention content; participants' characteristics (gender, age, baseline BMI); facilitators' characteristics (professional and personal characteristics, number, training); and weight loss outcomes (changes in weight from baseline at follow up closest to 6, 12 and 24 months). Missing details of weight loss outcomes were sought by contacting the authors on up to three occasions. Where the change scores were unavailable, mean changes in weight were calculated by subtracting the mean weight at baseline from the mean weight at follow up. Missing standard deviations were replaced with mean standard deviations calculated for each group as suggested in the Cochrane Handbook (Higgins, Deeks, & Altman, 2011).¹

Intervention content was initially coded using definitions of types of change techniques² provided by the CALO-RE taxonomy which includes technique types specific to diet and physical activity interventions (Michie et al., 2011). However, intervention reports were often too imprecise to allow distinctions to be drawn between the categories defined by this taxonomy. Only ten previously defined change technique types were observed in five or more interventions. Seven additional, more specific technique types were identified in the reports, namely: 'providing diet goals' and 'providing exercise goals' (specific types of instructions), 'in-class weighing' (a type of outcome feedback), 'supervised exercise' and 'practical activities / skills development' (both involving behavioural practice), 'encouraging /

¹ In one study [45] weight loss was reported separately for three ethnic groups. However, since all three groups received the same intervention (tailored to each ethnic group), we used means that were combined across the three ethnic groups provided by the author.

² We refer to 'change techniques' rather than 'behaviour change techniques' (or BCTs) as most intervention techniques referred to in taxonomies of BCTs do not directly target behavior but motivation. For example, highlighting the consequences of an action may change attitudes towards a behavior (as explained by, e.g., the Theory of Planned Behavior). This, in turn, may or may not have an effect on intention, which in turn may or may not have an effect on behavior. So for most of these change techniques behavior is a distal target and they are more correctly described as cognitive change techniques (Abraham 2016).

facilitating group discussion' and 'encouraging sharing experiences' (both describing approaches to managing group dynamics). In order to precisely code intervention content, coding instructions, specific to the reports included in this review, were developed for these 17 categories of change technique based on the intervention reports and the published taxonomies (Abraham, 2012; Abraham & Michie, 2008; Michie et al., 2011, 2013) (Supplementary File 4). Reports were coded for the presence or absence of these 17 techniques. Twenty two per cent of the 60 interventions included were randomly selected and independently double coded. The *ACI* statistic was used to assess coding reliability because Cohen's *Kappa* tends to underestimate reliability when there is a low prevalence of the coded categories (Gwet, 2002). Good agreement was observed for all coded technique categories (hereafter abbreviated to "techniques"), that is, *ACI* of at least 0.7 was achieved for all techniques coded (Supplementary File 4). Differences were resolved through discussion.

Data synthesis: The characteristics of included studies, interventions, participants and facilitators were synthesised narratively. Weight loss data from the follow-up points closest to 6, 12 and 24 months from baseline were synthesised in a meta-analysis conducted in RevMan (v5.3). The mean difference (MD) in weight loss was calculated using the inverse variance method and the random effects model. Following the Cochrane Handbook (Higgins, Deeks, & Altman, 2011), in studies that compared more than one group-based intervention with the same control group, the number of participants in the control group was divided between the number of contributing interventions. When outcomes were analysed both without and with the intention-to-treat method, the latter was selected as a more conservative approach. In addition, we calculated the average percentage of weight lost across interventions at follow-ups closest to 6, 12 and 24 months. We also report the number of interventions that achieved average weight loss of 5% or more of initial body weight because this is commonly regarded clinically meaningful.

Sensitivity analyses: Robustness of the findings was assessed by analysing the impact of excluding studies of low quality, studies without intention-to-treat analysis, studies that reported including participants with comorbidities, studies with imputed standard deviations, studies that contributed more than one intervention to the meta-analysis, and studies with a large difference in baseline BMI between the intervention and control groups. Publication bias was investigated visually using funnel plots created in RevMan (Supplementary File 5).

Heterogeneity and moderator analyses: Heterogeneity across studies was assessed with the I^2 statistic, and values over 25% and over 50% were interpreted as indications of moderate and substantial inconsistency respectively (Higgins, Thompson, Deeks, & Altman, 2003).

Reasons for heterogeneity and potential moderators of effects were explored in subgroup analyses using the random effects model. We compared studies with different control groups, intervention aims, behavioural targets, and settings. We also explored differences between interventions with different characteristics (gender composition, contact time, delivery modes, facilitator background) and intervention content (Supplementary File 6).

Results

Search results

Electronic and hand searches identified 7,047 references (see Figure 1). After removing duplicates and screening titles and abstracts, 397 full texts were selected for screening; 57 reports met the review inclusion criteria reporting 47 randomised controlled trials, including 60 independent group-based interventions. Consequently, results relating to study characteristics are based on 47 studies and results pertaining to intervention characteristics

are based on 60 interventions. Most studies (35 of 47, 75%) included just one group-based intervention. A list of the 47 included studies is available in Supplementary File 2.³

<Figure 1 near here>

Methodological quality

Twenty-nine (62%) of the 47 studies were assessed as having overall low quality (high or unclear risk of bias) and 18 (38%) studies were assessed as high quality (low risk of bias) (see Supplementary File 3).

Random sequence generation: One study [36], in which participants were randomly assigned to groups by the author in the order of their entry into the study, was assessed as high, and 29 studies were assessed as low, risk of bias. Seventeen studies had unclear risk of bias due to insufficient detail being available.

Allocation concealment: Two studies were assessed as high risk of bias [4, 36], 32 studies were unclear, and 13 studies reported adequate allocation concealment.

Blinding of outcome assessment: Six studies reported that blinding of outcome assessment was not ensured [2, 11, 21, 41, 43, 46]. Twenty-seven studies were unclear, and 14 studies reported ensuring that the outcome assessors were blinded.

Incomplete outcome data: Twenty-one studies were assessed as high and 23 were assessed as low risk of bias; three were unclear.

Selective reporting: All studies were assessed as low risk of bias when reporting primary study outcomes and weight loss outcomes.

³ Numbers in square brackets refer to the reference numbers in the list of included randomised controlled trials in Supplementary File 2.

Intention-to-treat (ITT) analysis: ITT analysis was reported in 20 studies and omitted from 24 studies. In three studies [11, 29, 39] details were unclear.

Quality of intervention descriptions

The descriptions of group-based interventions, assessed using a checklist (Borek et al., 2015) on the basis of the primary report and any additional referenced descriptions, were incomplete (see Figure S1 in Supplementary Files). On average, reports described just 10 of 26 (39%) elements of good quality reporting, ranging from three to 18 elements across interventions. The most commonly reported were details of the contact time in groups (duration of the intervention, frequency and number of group sessions). By contrast, training of group facilitators, continuity of facilitators' assignment to particular groups, continuity of participants' group membership (i.e. whether they belonged to the same group or could change groups) and details of how the participants were allocated to groups (e.g., self-selected groups or assigned to groups by the investigators) were rarely reported.

Characteristics of included studies

Table S1 in Supplementary Files includes a summary of the study characteristics.

Included studies were published between 1992 and 2017, with just five published before 2000. Twenty-six studies were conducted in the USA, seven in the UK, five in Canada, five in Australia, and four in other countries (Iran, Portugal, Switzerland, the Netherlands). Sample sizes ranged from 34 to 1882 participants (total $N=10,703$) with mean age of participants between 25 and 71 years old (mean 51). Attrition rates varied from 3.9% to 58.5% (mean 22.1%), and reasons for drop out were reported in 26 (55%) studies. Mean BMI at baseline ranged from 29.3 to 39.9 (mean 33.8) in intervention participants and from 26.9 to 41.0 (mean 33.7) in control participants, with an average mean difference between groups of 0.09 (95% CI [-0.11, 0.28]).

Forty-four studies were RCTs and three were cluster RCTs. Twenty-two studies compared interventions to no intervention or waiting list control groups, 10 to irrelevant interventions, in which the targeted change had no relation to weight loss, and 13 to minimal interventions and two to usual care. Participants randomised to minimal interventions or usual care received some elements of weight loss interventions, such as self-directed weight-loss manuals or newsletters [4, 5, 12, 13, 21, 38, 40, 47], self-directed materials with brief individual counselling [2, 22, 25], general weight-loss advice from their general practitioner [6, 30, 44], or internet-based information [10].

Twenty-eight studies targeted weight loss and eight targeted weight loss combined with other outcomes (breast health, physical activity and functioning, prevention of diseases, and well-being). Three studies focused primarily on improvements in physical functioning [2, 6, 15], four on prevention of cardiovascular disease and diabetes [1, 4, 13, 37], and four on other outcomes, such as changes in diet, exercise, fitness, or adherence [9, 21, 24, 35].

How were the included interventions designed and delivered?

Intervention design: Forty-five (75%) of the 60 included interventions targeted changes in both diet and physical activity, 14 targeted diet alone, and one targeted changes in exercise behaviour alone. Twenty-two (37%) used groups alone while 38 combined groups with other modes of delivery. Among these mixed-mode interventions, 12 used multiple modes of delivery, 26 used printed materials (e.g., manuals or booklets), 9 used individual face-to-face counselling, 12 used online materials, emails, apps or armbands, and 8 used telephone calls.

In 31 interventions participants received materials or tools, such as manuals or handouts (27), pedometers or accelerometers (12), and self-monitoring diaries (11). Fourteen interventions were delivered in community (e.g., senior centre, YMCA site, football club, school, church, fitness centre), 8 in healthcare setting (e.g., primary care practice, hospital, family clinic), 3 at universities, and 2 at worksites.

We identified a rationale for using a group-based delivery mode in eight (13%) interventions. These included providing social support, saving time and costs, providing opportunities for sharing experiences, and using a method that had previously been found to be feasible and/or effective. Twenty-four (40%) intervention descriptions included references to theories or mechanisms of behaviour change, most commonly citing social cognitive theory (Bandura, 1986) and the stages of change or transtheoretical model (Prochaska & DiClemente, 1983; Prochaska & Velicer, 1997). Among the 33 (55%) intervention reports that included descriptions of intervention development methods, 19 were developed as adaptations of earlier studies or existing programmes, seven were based on formative research, such as focus groups and consultations with target population and stakeholders, and seven used existing commercial programmes. Twelve (20%) interventions were tailored to ethnic groups, including African American, Latino, and Aboriginal Australian.

Contact time: Active intervention phases lasted between 2 and 24 months (mean 6); the number of sessions varied from 3 to 104 (mean 22); the sessions lasted between 40 and 180 minutes (mean 87). Thirty-two interventions provided weekly sessions, 15 started as weekly meetings and then decreased frequency of the meetings, and six were delivered multiple times each week. Total contact time in groups during the first six months (without extra exercise classes) varied from 4 to 96 hours (mean 17).

Intervention content: The most commonly reported change techniques included in the interventions were: self-monitoring (41 interventions), goal setting (29), barrier identification and problem solving (25), social / peer support (23), providing information (22), relapse prevention (16), providing feedback (15), demonstrating / modelling behaviour (15), stimulus control (11), and providing instruction (10). Additionally, we identified supervised or structured exercise (29 interventions), providing participants with specific dietary goals or meal plans (27) and exercise goals or plans (14), in-class weighing (17), and practical

activities or skills development (e.g. reading food labels, modifying recipes, cooking practice) (11). Moreover, we identified two group management techniques: encouraging group discussions (11 interventions) and encouraging sharing of personal experiences (6). Inclusion of these 17 techniques in each study, together with definitions and coding reliabilities, is reported in Supplementary File 4.

Participants: Thirty-six (60%) interventions included women only and five included men only. In the 19 interventions that included both genders, between 57% and 85% (mean 65%) of participants were female. Mean age of participants was 47 years old (range from 25 to 71). Group size was reported in 20 (33%) interventions and ranged from 3 to 30 participants (mean 12).

Facilitators: Facilitators' professional background was described in 42 (70%) interventions; 11 were delivered by dietitians or nutritionists, six by general practitioners or nurses, four by lay volunteers, three by teachers or coaches, three by graduate students or researchers, two by health workers/educators, and 13 by multidisciplinary teams which mainly included dietitians or nutritionists, exercise instructors, and psychologists or behavioural specialists. Other facilitator characteristics, such as ethnicity or gender, were described in ten (17%) intervention reports. The reported number of facilitators delivering the sessions was either one (six interventions) or two facilitators (nine interventions). In 20 (33%) interventions facilitators were reported to have received some training but training in group facilitation methods was reported in only one intervention. Eleven interventions included a report that facilitators used a protocol / manual to deliver the sessions.

Process evaluation: Attendance at sessions was reported for 41 (68%) interventions, and the percentage of sessions attended (reported in 32 interventions) varied from 21% to 87% (mean 67%). In eight interventions (seven studies) the authors reported that attendance at group

sessions was associated with higher weight loss [10, 16, 22, 31, 35, 41, 46]. Assessment of fidelity or quality of session delivery was reported in only 10 (17%) interventions, and included using observations (4 interventions), audio or video recordings (4), and unspecified methods (2). None of the studies investigated any potential differences in outcomes between groups of participants within the intervention arm.

How effective were the included interventions for weight loss?

Weight loss up to 6 months: Fifty-four comparisons ($n = 6,276$) of weight loss outcomes at up to 6 months were included in our analysis. Three comparisons (from two RCTs) included outcomes at two months [20, 42], 26 at 3-4 months, and 25 at 5-6 months from baseline. Meta-analysis showed a mean difference (MD) in weight loss of -3.49 kg (95% CI [-4.15, -2.84]; $p < 0.00001$) with substantial between-study heterogeneity ($I^2 = 90\%$) (Figure 2). The MD in weight loss varied between studies from -9.9 kg to 0.7 kg. Out of these 54 interventions, 20 achieved 5% or greater loss of initial body weight (with an overall average of 4.09%).

<Figure 2 near here>

Weight loss closest to 12 months: Twenty-four comparisons ($n = 6,042$) of weight loss outcomes at 9-12 months from baseline were suitable for inclusion in our analysis. Four comparisons (from three RCTs) included outcomes at nine months [21, 24, 38], one at 10 months [31], and 19 at 12 months. Meta-analysis showed a MD in weight loss of -3.44 kg (95% CI [-4.23, -2.85]; $p < 0.00001$) with large between-study heterogeneity ($I^2 = 88\%$) (Figure 3). The MD in weight loss varied between studies from -9.6 kg to 0 kg. Out of these 24 interventions, the percentage of weight loss of initial body weight could be calculated for 23. Of these 23 interventions, 14 achieved 5% or greater loss of initial body weight (with an overall average of 4.82%).

<Figure 3 near here>

Weight loss closest to 24 months: Nine comparisons ($n = 2,613$) of weight loss at 18-24 months from baseline were suitable for inclusion in our analysis. Two comparisons included outcomes at 18 months [26, 41] and seven included outcomes at 24 months. Meta-analysis showed a MD in weight loss of -2.56 kg (95% CI [-3.79, -1.33]; $p < 0.0001$) also with large between-study heterogeneity ($I^2 = 81\%$) (Figure 4). The MD in weight loss varied between studies from -6.2 kg to 1.3 kg. Out of the eight interventions that resulted in weight loss, three achieved 5% or greater loss of initial body weight (with an overall average of 4.08%).

<Figure 4 near here>

Sensitivity analyses: We conducted sensitivity analyses on weight loss outcomes at up to 6 months (Supplementary File 5). Excluding studies with low quality, no intention-to-treat analysis, and studies that contributed multiple comparisons resulted in smaller MD in weight loss (-3.1, -3.3 and -3.4 kg respectively). By contrast, excluding studies that reported including participants with comorbidities, studies with more than one BMI point difference between intervention and control groups at baseline, and studies with imputed standard deviations (-3.8, -3.8 and -4.4 kg respectively) tended to generate somewhat larger effects on weight loss. Only removing studies with imputed standard deviations resulted in a statistically significant difference ($p = 0.0008$). Visual inspection of the funnel plots (Supplementary File 5) suggested a small study bias at up to 6 months; removal of one outlier [20] did not change the MD in weight loss (-3.5 kg; 95% CI [-4.16, -2.84]). Funnel plots of weight loss at up to 12 and 24 months showed no outliers.

Which intervention characteristics are associated with effectiveness?

We conducted several subgroup analyses comparing weight loss at up to 6 months between studies with different intervention characteristics and content. They are reported in Supplementary File 6; here we report statistically significant results.

Intervention design: Interventions targeting weight loss were on average significantly more effective as interventions with other primary outcomes, such as prevention of diabetes or cardiovascular diseases (MD in weight loss: -4.01 kg vs. -1.65 kg, $p < 0.0001$). Interventions including men only (-5.50 kg) showed higher MD in weight loss than mixed-gender groups (-4.28 kg) or women-only groups (-2.62 kg, $p = 0.0007$). Moreover, interventions involving only groups showed higher effect size than mixed-mode interventions (-4.77 vs. -2.79 kg, $p = 0.01$). Interventions in which facilitator training was not reported showed higher effect size than interventions including reports of the facilitator training (-4.37 vs. -2.18 kg, $p = 0.0009$). Interventions that included reports of theory or mechanisms of change showed lower effect size than interventions that did not report using theory (-2.57 vs. -4.09 kg, $p < 0.00001$). No other intervention design features (e.g. setting, contact time, facilitators' profession) were significantly associated with intervention effectiveness (see Supplementary File 6).

Intervention content: We compared interventions that reported inclusion of each of the 17 coded change techniques to those that did not report inclusion of each technique. These subgroup analyses showed that interventions described as providing feedback to participants showed somewhat greater MD in weight loss than interventions that did not specify inclusion of this technique (-4.46 vs. -3.19 kg, $p = 0.04$); interventions described as providing dietary goals or meal plans to participants showed greater MD in weight loss than interventions not said to use this technique (-4.59 vs. -2.72 kg, $p = 0.009$). Moreover, interventions that included reports of encouraging group discussion showed lower MD in weight loss than those without it (-1.87 vs. -3.9 kg, $p = 0.02$). No other technique types coded, or combinations thereof, were associated with increased effectiveness (Supplementary File 6).

Discussion

We identified 60 group-based weight-loss interventions from 47 RCTs. The interventions varied considerably in setting, contact time, group size, facilitators' background, and

intervention content. The mean difference in weight loss also varied considerably across interventions, but, overall, these group-based interventions were effective in promoting weight loss of 3.5 kg at 6, 3.4 kg at 12 and 2.6 kg at 24 months from baseline. Moderator analyses showed that explicitly targeting weight loss (as opposed to other primary outcomes), men-only groups, and including feedback was significantly associated with intervention effectiveness. The analyses also revealed that many other intervention components and types of change techniques did not discriminate between more or less effective interventions. However, the findings generated by these moderator analyses must be treated with caution because of the observed poor quality of reporting of intervention design and content. These data highlight the need for further investigation to identify the reasons for the observed variability in intervention effectiveness.

Some interventions achieved weight loss of 5% or more of initial body weight which has been regarded as clinically meaningful (Avenell et al., 2004; Espeland, 2007; Katz et al., 2005), with 23 of the 24 interventions reporting 12 month outcomes achieving an average of 4.82% of initial body weight. Such levels of weight loss are associated with reductions in key cardiovascular risk factors and prevention of type 2 diabetes in populations who are at high risk (Hamman et al., 2006). The most effective of the identified interventions (and high quality studies) demonstrate considerable potential. For example, Foster-Schubert et al. (2012) observed MD in weight loss of 8.2 kg at 12 months (in the diet group) and Kuller et al. (2012) showed MD in weight loss of 6.2 kg at 18 months. Both these studies were judged to have low risk of bias. Systematically and progressively developing new interventions on the basis of successful interventions is likely to enhance the effectiveness of real-world services, which often achieve much lower effect sizes (around 2 kg at 12 months) (Dunkley et al., 2014). Moreover, when effective, group-based delivery modes can help reduce costs, compared to one-to-one interventions (Ali, Echouffo-Tcheugui, & Williamson, 2012).

Overall, the results support continued use of group-based intervention to promote weight loss.

Despite acceptance of the importance of using theory and evidence in developing behaviour change interventions (e.g., Craig et al., 2008), and the potential impact of using theory on intervention effectiveness (Albarracín et al., 2005; Taylor, Conner, & Lawton, 2012), we found references to theories, and descriptions of intervention development methods, in only about half of the included studies. Moreover, we found that interventions that included reports of using theory showed lower effect sizes than those that did not report it. This, however, might be due to a limitation of conducting such analyses based on study reports. It, nevertheless, highlights the need for more explicit use and reporting of theory and, in particular, clarification of the links between specified change mechanisms that are articulated in theories and the change techniques that are employed to target those mechanisms (Abraham & Michie, 2008; Bartholomew, Parcel, Kok, Gottlieb, & Fernandez, 2016; Michie & Johnston, 2012).

Our review found that men-only groups were almost seven times less frequent than women-only groups. Other literature also shows that men have been under-represented in weight-loss interventions. For instance, a review of this field found that only 5% of lifestyle weight-loss interventions were delivered exclusively for men with men representing only 27% of the study populations (Pagoto et al., 2012). Despite this, our review found that interventions delivered to men only were on average twice as effective as interventions delivered to women only (-5.5 vs. -2.6 kg). This is in line with evidence for the management of obesity among men, which shows that men benefit from group-based weight-loss programmes (Robertson et al., 2014) and on average lose over 5 kg of weight compared to no-intervention controls (Young et al., 2012). Obesity and overweight prevalence among men is similar or higher than

among women (Public Health England, 2015; World Health Organization, 2015) and our results further emphasise the need to engage men in weight-loss interventions.

Increasing numbers of systematic reviews aim to identify particular types of intervention techniques targeting specified change mechanisms, such as induction of cognitive dissonance (technique type) to change attitudes towards a behaviour pattern (a mechanism to promote motivation), and to assess whether their inclusion tends to increase or decrease effectiveness (Dombrowski et al., 2012; Hartmann-Boyce, Johns, Jebb, Aveyard, & Behavioural Weight Management Review Group, 2014; Michie et al., 2009). We found that inclusion of most of the intervention technique types we could identify were *not* associated with effectiveness, apart from some positive effect of providing feedback and dietary goals / meal plans to participants. We also found that reporting of facilitator training, encouragement of group discussions and use of theory were negatively associated with weight loss. It is possible that detailed intervention content does not influence effectiveness. It is also possible that training facilitators or ensuring that they encourage group discussions may decrease intervention effectiveness (for example, in groups with low cohesion and trust). However, such findings are perhaps more likely to reflect inconsistent reporting across studies. Inclusion of particular intervention techniques and characteristics is also generally confounded by other differences between interventions and such unassessed differences (that may or may not be reported) could generate differences in effectiveness. It is important, therefore, to remember that spurious findings may result from multiple exploratory analyses (Higgins & Green, 2011). This emphasises the need for caution when interpreting associations between specific intervention characteristics and effectiveness when all differences between interventions are not controlled (Peters, Bruin, & Crutzen, 2015).

Reporting of group characteristics (e.g., group size and composition, facilitator characteristics, the intended facilitation style) was found to be poor with an average of 10

only characteristics reported from a list of 26 that have been recommended as essential reporting for replication of group-based interventions (Borek et al., 2015). This is important because group characteristics can influence individual change in groups and so should be considered when designing and delivering group interventions (Borek & Abraham, 2018; Hoddinott, Allan, Avenell, & Britten, 2010) and in sub-group analyses of effectiveness (Murphy & Johnson, 2006). Sub-group analyses comparing sets of interventions that do or do not include particular features is only possible if evaluations describe and assess such characteristics rigorously. For example, although it has been shown in other domains that facilitators' demographic characteristics (e.g., matched facilitator-recipient gender) predicts intervention effectiveness (Durantini, Albarracín, Mitchell, Earl, & Gillette, 2006), only 17% of our intervention descriptions included these details. More comprehensive reporting of groups could help identify key change mechanisms and so optimise future design of group-based interventions (Borek et al., 2015; Hoddinott et al., 2010).

A number of included studies found that greater attendance at the group sessions was associated with larger weight loss (Carnie et al., 2013; Foster-Schubert et al., 2012; Heshka et al., 2003; Østbye et al., 2009; Samuel-Hodge et al., 2009; Stolley et al., 2009; West et al., 2011). Interestingly, we found a large variation in attendance at group sessions (as low as 21% of sessions attended). This highlights the need for interventions to improve participant engagement and for study reports to clarify attendance figures across group sessions. Similarly, we found variation in attrition between interventions and reasons were reported in just over half of the included studies. Thus, future studies should investigate and report reasons for attrition more consistently.

Finally, we found that interventions compared to usual care or minimal interventions were 0.7 kg less effective than those compared to no intervention. This is consistent with differences in effect sizes noted in other reviews of weight loss (Waters, George, Chey, &

Bauman, 2012) and other interventions (de Bruin et al., 2010), and highlights the importance of taking into account the nature of comparison groups when assessing effectiveness (Abraham, Johnson, de Bruin, & Luszczynska, 2014).

In summary, the main implication of this review is that group-based diet and physical activity programmes can be recommended to overweight and obese adults as an effective treatment for overweight and obesity. They may be particularly beneficial when explicitly targeting weight loss, including tailored groups for men only, and involving feedback and specific diet goals / plans. No further recommendations can be made due to limitations of the current literature. Future research should prioritise improving the reporting of descriptions of the characteristics and processes involved in group-based delivery, and explore their role in influencing intervention outcomes. Moreover, future reviews should compare effectiveness and cost-effectiveness of different modes of delivery accounting for change mechanisms targeted and change technique types included.

Strengths and limitations

To our knowledge this is the most comprehensive systematic review of RCTs of *group-based* weight-loss interventions. Its strengths include consideration of content and reporting quality as well as use of Cochrane reviewing methods and adherence to PRISMA reporting standards. However, a number of limitations should be acknowledged. Identification of group-based interventions was challenging because many studies did not include a description of a delivery mode in a title or abstract or provided ambiguous descriptions of groups. Thus, our search strategy might have failed to identify some relevant studies. We included only published reports of studies, and did not search for unpublished literature. Our comparisons of interventions were based on published study reports, protocols and other publically available descriptions of the interventions. We acknowledge, however, that more detailed characterisation of intervention content is achieved when descriptions in intervention

manuals (rather than published articles) are considered (Abraham & Michie, 2008). Future research could extend our work by examining intervention manuals. Like all systematic reviews, the quality of this review is limited by the quality of included studies and the quality of reporting of those studies. Our assessment of methodological quality found that study quality was mixed. Sensitivity analyses showed that studies with higher quality, intention-to-treat analysis and imputed standard deviations showed higher effect sizes. However, overall, study quality did not change the significance of the effect and or the size of the effect by more than 1 kg. Thus, the main findings seem fairly robust.

Conclusions

Overall, this review shows that group-based interventions targeting diet and/or physical activity can generate clinically meaningful weight loss up to 24 months. This encourages continued use and evaluation of group-based, weight-loss interventions. Better reporting of group characteristics, facilitator training competence and style, and of intervention content is needed to allow identification of features that most likely optimise effectiveness.

Systematically and progressively developing new interventions on the basis of the most successful available interventions is likely to enhance future effectiveness.

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List of Supplementary Files (online)

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Supplementary File 1. Electronic search strategy

Supplementary File 2. List of included studies (with references)

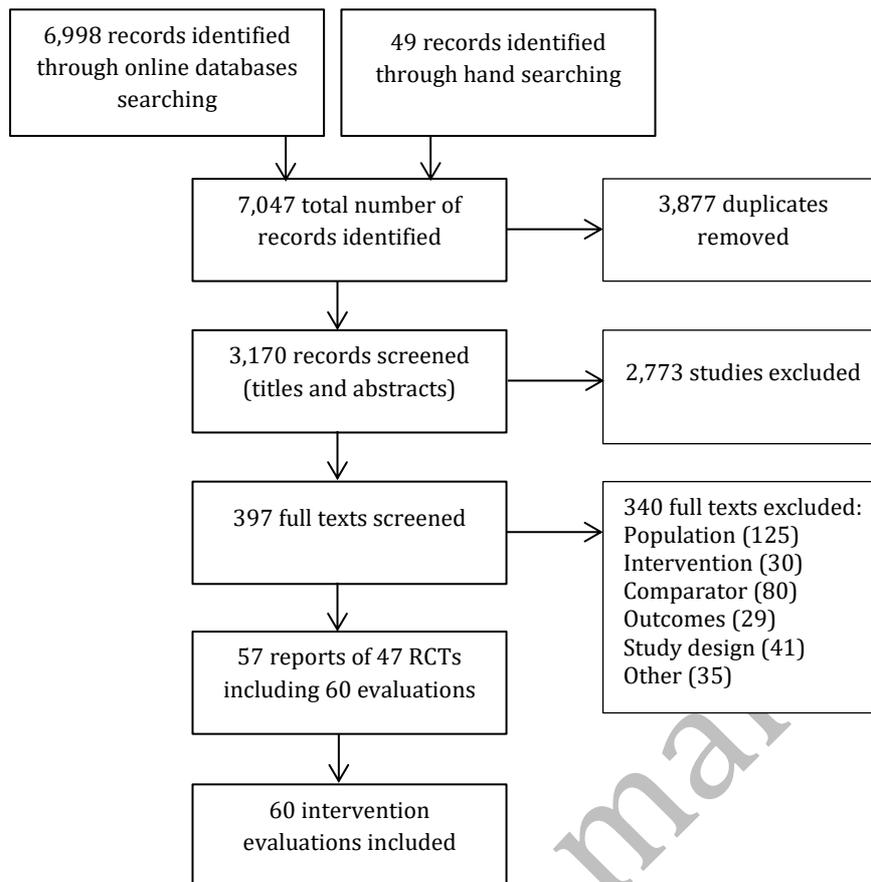
Supplementary File 3. Risk of bias assessments

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Supplementary File 5. Sensitivity analyses and funnel plots

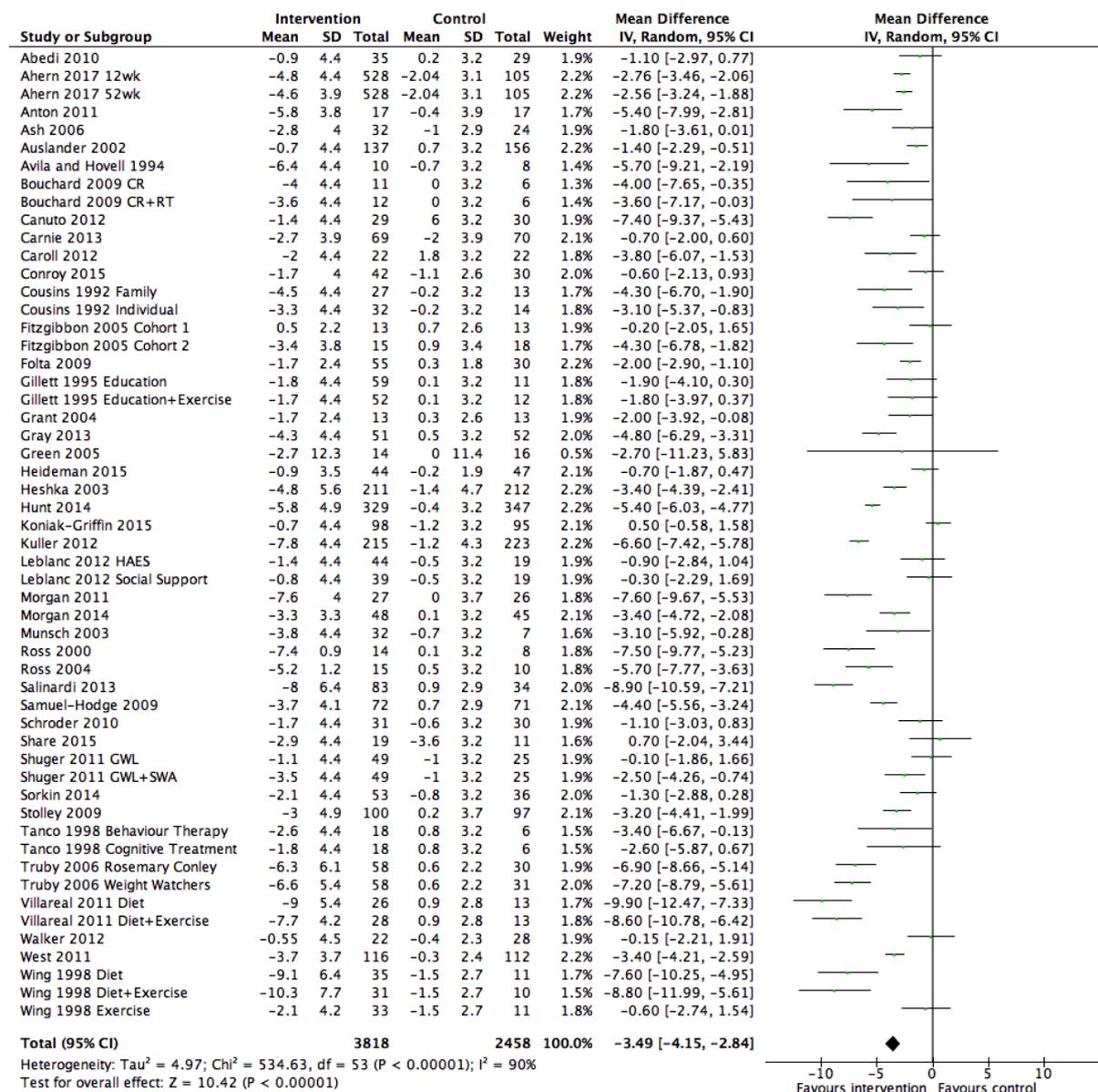
Supplementary File 6. Moderator analyses

Figure 1. Flow diagram of the study selection process



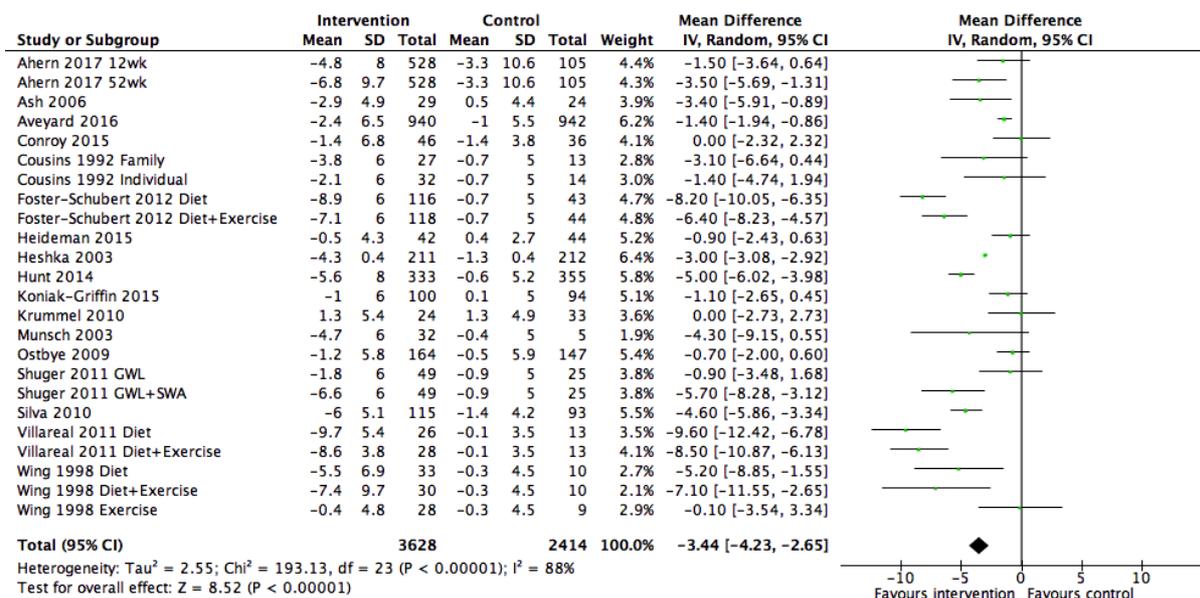
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Figure 2. Mean difference in weight loss up to 6 months



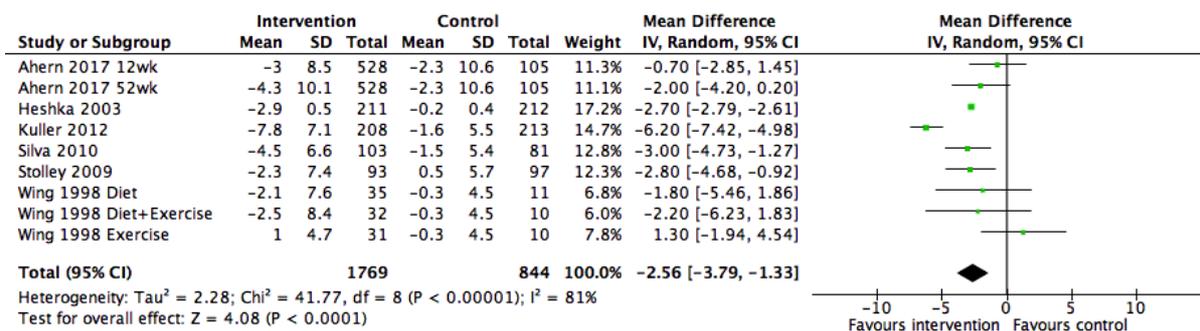
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Figure 3. Mean difference in weight loss closest to 12 months



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Figure 4. Mean difference in weight change closest to 24 months



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