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**Mindfulness-Based Interventions for Adults who are Overweight or Obese:
A Meta-Analysis of
Physical and Psychological Health Outcomes**

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Abstract

Objective: To evaluate the impact of mindfulness-based interventions on psychological and physical health outcomes in adults who are overweight or obese.

Methods: We searched 14 electronic databases for randomised controlled trials (RCTs) and observational design (OD) studies that met eligibility criteria. Comprehensive Meta-Analysis software was used to compute the effect size estimate Hedge's g .

Results: Fifteen studies measuring post-treatment outcomes of mindfulness-based interventions in 560 individuals were identified. The average weight loss was 4.2 kg. Observed effects were *large* for improving Eating Behaviours ($g = 1.08$), *medium* for Depression ($g = 0.64$), Anxiety ($g = 0.61$), and Eating Attitudes ($g = 0.57$), and *small* for body mass index (BMI; $g = 0.47$) and Metacognition ($g = 0.38$) outcomes. Moderator analyses found therapeutic effects for BMI ($g = 0.43$), Anxiety ($g = 0.53$), Eating Attitudes ($g = 0.48$) and Eating Behaviours ($g = 0.53$) remained significant when examining results from higher quality RCTs alone. There was no efficacy advantage for studies exceeding the median dose of 12 hours of face to face intervention. Studies utilising an ACT approach provided the only significant effect for improving BMI ($g = 0.66$), while mindfulness approaches produced *medium* to *large* ($g = 0.58 - 1.68$) effects across a range of psychological health and eating related constructs. Finally, the limited longitudinal data suggested maintenance of BMI ($g = 0.85$) and Eating Attitudes ($g = 0.75$) gains at follow-up were only detectable in lower quality OD studies.

Conclusions: Mindfulness-based interventions may be both physically and psychologically beneficial for adults who are overweight or obese, but further high quality research examining the mechanisms of action are encouraged.

Introduction

Overweight and Obesity

Overweight and obesity are major health problems, causing adverse physical health effects that lead to increased disability and mortality (1, 2). The second leading cause of preventable death, overweight and obesity is associated with type 2 diabetes, stroke, heart disease and certain types of cancer for adults worldwide (3, 4). In addition to poorer physical health outcomes, overweight and obesity is also associated with increased rates of depression and anxiety, and reduced quality of life (5-9). Such psychological comorbidities subsequently impact negatively on weight loss treatment adherence and outcomes (10, 11). The social, economic and personal costs of overweight and obesity are high (12, 13), emphasising an urgent need for effective weight control interventions.

Numerous widely-used weight management interventions have been developed that aim to modify diet and exercise behaviours. Results of such behavioural modification programs are varied (14), with limited attention paid to psychological functioning. Most programs result in short-term weight loss and comorbidity improvement, yet in the medium- to long-term weight is typically regained and comorbidity improvements lost (15-18). Comparatively, psychological interventions hold the potential to improve the wellbeing of individuals who are overweight or obese whilst simultaneously augmenting their weight control efforts.

Psychological Outcomes and Mindfulness

Existing psychological weight-loss interventions typically target motivation, goal setting, and manage lapses in diet and exercise with the goal of improving health behaviours (19). These cognitive behaviour therapy (CBT) approaches, however, are not routinely utilised to address

psychological outcomes such as depression, anxiety, stigma, social isolation, and decreased self-efficacy (19) that exist in opposition to an individual's weight control goals. Mindfulness-based interventions offer an alternate psychologically orientated approach that could address these gaps in weight control treatment for adults who are overweight or obese (20, 21).

Mindfulness involves cultivation of openness and awareness of the present moment and curiosity and acceptance of experiences, both internal (e.g., thoughts, reactions) and external (e.g., interpersonal and environmental events; 22, 23, 24). In practice, mindfulness interventions are broadly classified as a complementary medicine approach (25), and methods for teaching and exercising mindfulness skills can vary. Sessions may involve individual or group meditation, yoga, and awareness training. Among its many benefits, mindfulness practice improves self-awareness, self-regulation, and adaptive coping with negative emotions (22, 24, 26).

Formal mindfulness programs have been developed for therapeutic intervention (27), including Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT). Mindfulness can also serve as a component of other therapeutic approaches such as Acceptance and Commitment Therapy (ACT; 28). ACT emphasises non-judgemental acceptance of thoughts and feelings, whilst focusing on value- and goal-driven behaviour. Whilst ACT does not necessarily prescribe formal meditation practice, the approach does emphasise mindfulness as a strategy to foster defusion from self-criticism, acceptance of thoughts and feelings, and contact with the present moment (22, 24, 26).

Reviews of the Obesity and Mindfulness Link

Mindfulness-based interventions have increasingly been successfully applied to health-related conditions and behaviours (29, 30) and may have a particular relevance for obesity (21, 31). There are a number of mechanisms through which mindfulness may influence the management and treatment of obesity. These may include reduced emotional distress, increased motivation, enriched supportive relationships, or alterations in biological pathways affecting health, such as the immune or metabolic system (29). Mindfulness training also encourages healthier decisions through the heightening of a broader range of body experiences, including an awareness of hunger and satiety cues. These cues are fundamental to the self-regulation of innate drives to consume high-calorie foods that underlie chronic desires to eat unhealthy foods (21).

Three systematic reviews in recent years have investigated the efficacy of mindfulness-based therapies on obesity-related eating behaviours and weight loss. Results from 18 of the 21 studies examined by O'Reilly and colleagues indicated an improvement in binge-, emotional-, and external-eating (33). Body weight and mindfulness skills also consistently improved in those studies reporting on these outcomes, but associations between the two were not explicitly examined. Olson and colleagues (32) reported significant weight reduction across 13 of the 19 included studies included in their review. Changes in mindfulness were also examined, with evidence of a relationship between mindfulness and weight loss limited. Finally, Katterman and colleagues (34) reported binge- and emotional-eating decreased in 9 of 11 studies examining these domains. Results from the 10 included studies reporting on weight outcomes included both weight gain and weight loss. Mindfulness was not examined as an outcome.

Encouragingly, the three reviews suggest a positive effect for mindfulness-based interventions on problematic eating behaviours. However, none of the three reviews was

specific to individuals who were overweight or obese, rather including studies that frequently combined healthy weight, overweight, and obese participants into a single treatment group. Other studies included in these previous reviews utilised exclusively healthy weight individuals, or failed to report the BMI of participants. Such heterogeneous study populations may explain the variability reported across the three reviews regarding effects on weight outcomes. Furthermore, while reported in several of the examined studies, none of the reviews considered outcomes such as mood symptoms, eating attitudes, or quality of life in their analyses.

Objectives of the Current Meta-analysis

The current meta-analysis provides the first systematic evaluation of the effectiveness of mindfulness-based interventions specifically for adults who are overweight or obese. Critically, this analysis assesses the effectiveness of mindfulness-based interventions on psychological health, physical health, and eating-related constructs, progressing our understanding of an alternative treatment approach that offers a unique theoretical basis for addressing unmet needs of this pressing health issue.

Method

The current review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (35).

Search Strategy

Studies were identified through a literature search of the electronic AMED, CINAHL, Cochrane Library, EMBASE, MEDLINE/PubMed, Pre-Medline, PsycEXTRA, PsycINFO, Science Direct, Scopus, and Web of Science indexing databases. Combinations of the following key search terms were used across all databases: *body mass index, BMI, body weight, dietary restraint, eating behaviour, energy intake, feeding behaviour, food habit, food intake, obesity, overweight, waist circumference, waist hip ratio, weight management, weight maintenance, weight control, or weight loss, and acceptance-based, insight meditation, Mindfulness and Acceptance Based Interventions, Mindfulness Based Cognitive Therapies, mind body, mindful, mindfulness, mindful mediation, Mindfulness Based Stress Reduction, stress reduction, or Vipassana*. To illustrate, the full electronic search strategy for the EMBASE database is included in Appendix 1.

The eligibility assessment was performed independently in a standardized manner by two of the authors (JR and KM). After deleting duplicate papers, the title and abstract of all studies were screened by the authors to assess suitability for inclusion. Those considered potentially eligible were read in full. Papers meeting the specified inclusion criteria were included in the meta-analysis. Disagreements between reviewers were resolved by consensus.

The last database search was completed 9 June 2015. Hand searching the reference lists of relevant reviews, meta-analyses and included studies were also used to identify potentially relevant publications. The last hand search was performed 10 June 2015 yielding one additional relevant study (36).

Inclusion and Exclusion Criteria

This meta-analysis reviewed randomised control trials (RCTs), observational designs (ODs), and case studies examining the delivery of mindfulness-based interventions for

individuals who were overweight or obese, published in English, in peer-reviewed articles, prior to 1 June 2015. Observational and case studies were considered as we believed it would be informative to compare effect sizes between these non-experimental designs and RCT investigations. Adult participants (≥ 18 years old) who were overweight and obese, defined as $\geq 25 \text{ kg/m}^2$, were included. Studies reporting animal or child research (< 18 years old) were excluded. Acceptance/mindfulness (e.g. ACT) or meditation (e.g. MBSR; MBCT) -based treatments were included. There is currently limited consensus regarding recommendations for the frequency and intensity of mindfulness practice (37, 38) however common practice suggests that the adequate development of mindfulness requires regular and repeated practice (30). Thus for the current meta-analysis, studies where the intervention consisted of a single treatment session were excluded. Interventions that included mindfulness as a minor component of treatment rather than the focus were also excluded, due to the inability to isolate the specific outcome effects of mindfulness.

Data Extraction

Outcome measures of psychological health, physical health, and eating-related constructs were extracted independently by two authors (JR and MF) and entered independently by two authors (JR and MF) into Comprehensive Meta-Analysis (CMA; Biostat, Englewood, NJ) version 3.3.070. At both stages, differences between reviewers were resolved by consensus. The outcome measures across all included studies could be clustered into eight meaningful categories: Depression (i.e., as measured by the Beck Depression Inventory) and Anxiety (i.e., Beck Anxiety Inventory) symptoms; Stress (i.e., Perceived Stress Scale); Metacognition (referring to the acquisition of mindfulness skills, such as measured by Kentucky Inventory of

Mindfulness Skills); Quality of Life (QoL) outcomes (i.e., Quality of Life Inventory); Eating Behaviours (i.e., Binge Eating Scale); and, Eating Attitudes (i.e., Three Factor Eating Questionnaire). Only one physical health outcome was consistently reported across studies, body mass index (BMI). Follow-up data was also extracted when available (39-44).

Each study included in the current review could contribute to one or more outcome measures.

When a study reported on more than one instrument for an outcome measure (e.g. multiple measures of anxiety), all results were combined into a single measure of effect. This combined effect estimate was the mean effect of the related tests, based on an assumed inter-correlation between tests of 0.7 (45). All analyses were performed using CMA. ***Risk of Biases and Planned***

Methods of Analysis

Overall effect sizes were calculated by aggregating the mean effect sizes weighted by each study's sample size, calculation of 95% confidence intervals (CI), and computation of z scores based on the overall mean and standard error. Effect sizes were calculated so that outcomes favouring treatment had a positive value and effects favouring control or treatment as usual had a negative value. Publication bias was assessed using Egger's regression test, which is more objective and specific than funnel plots and more appropriate for small sample sizes than Begg's rank correlation test (46). All analyses were performed in CMA, computing the effect size estimate Hedge's g , a variation of Cohen's d that corrects for biases due to small sample sizes (47). Cohen has described effect sizes ≥ 0.2 , 0.5 and 0.8 as *small*, *medium* and *large*, respectively (48). As we expected considerable heterogeneity, we conducted all analyses using the more conservative random effects model. Heterogeneity was then assessed by calculating the I^2 statistic, where a value of 0% indicates no observed heterogeneity, 25% low, 50% moderate,

and 75% high heterogeneity (49). The Q statistic was also calculated to estimate the likelihood of one or more moderating variables operating on the observed effect size.

Subgroup analyses were performed by testing differences in Hedge's g between outcome variables (BMI, Anxiety and Depression symptoms, Stress, QoL, Eating Attitudes, Eating Behaviour and Metacognition) and time point (post intervention and follow-up). The type of intervention (ACT, meditation, or mindfulness) and the dose of the intervention (less than or equal to 12 hours, or more than 12 hours) were also included in our analysis plan. Dose was calculated by multiplying the duration of prescribed face to face sessions by the number of sessions. Due to a lack of reported compliance data, time spent in individual practice was not included in the calculation. Study dose was then applied as a dichotomous variable, using a median split criteria. Finally, it was hypothesised that effect sizes may vary according to the methodological quality of the studies. Effect sizes were therefore also calculated separately for RCTs and ODs. For RCTs, we compared post-test scores from the comparison group and the experimental group to calculate the effect size. For ODs, we compared the post intervention score with the pre intervention score. For any studies, if no means or standard deviations were reported, other test statistics (e.g. t , f or p) were converted into Hedge's g .

In one study, two comparison groups were reported (40), a waitlist group and a group that received psychoeducation and cognitive behavioural therapy. Effect sizes were calculated using the data from the psychoeducational and cognitive behavioural therapy group over the waitlist group, in keeping with the majority of RCTs reported in the current review that used an active control group (see Results below). Furthermore, one study (50) provided both intention to treat and treatment efficacy analyses; here effect sizes were calculated using the treatment efficacy data to again maximise comparability to other studies.

Results

Description of the Selected Studies

The selection process is illustrated in Figure 1. A total of 1994 studies were examined, from which 15 studies met inclusion criteria, including 355 participants completing treatment, and 205 control participants (see Table 1 for a summary of study characteristics). Seven studies used an RCT design (39-41, 50-53), one of these compared treatment with a waitlist control (50) and six studies included another active psychological intervention (40, 52) or behavioural treatment as usual (39, 41, 51, 53). Two papers reported on the same study, the first reported pre-post data (53), the second reported six-month follow-up data (41). Both sets of data were included in the current meta-analysis and treated as one study. Eight other studies used a non-randomised OD (36, 42-44, 54-57). No case studies were eligible for inclusion.

[Insert Figure 1 approximately here]

Of the included publications, seven studies utilised a mindfulness approach (36, 40, 42, 50, 51, 54, 57), six studies featured ACT (39, 41, 43, 44, 53, 55) and two primarily focused on meditation (52, 56). The intensity of the treatment intervention varied greatly from four to 40 sessions (median 9.5 sessions). The duration of each intervention session also varied, from 20-minute sessions to a full-day workshop. Excluding the single study that included a full-day workshop on top of the regular classes (50), the mean intervention session duration was one hour, 45 minutes. The calculated median dose of intervention was 12 hours; eight studies

prescribed 12 or less hours (36, 41-43, 52, 53, 55, 56), while seven studies (39, 40, 44, 50, 51, 54, 57) prescribed more than 12 hours.

The characteristics of each included study are presented in Table 1. In all but one study (52) the majority of participants were women. The mean age of participants across all studies was 45.79 years ($SD = 8.22$ years). The included studies recruited participants from a range of populations including community samples (36, 39, 40, 44, 50, 55), universities (43, 52), health-related organisations (42, 51) and hospitals (41, 53-55, 57). Attrition rates across studies averaged 15.99% ($SD = 11.97\%$, range 0 – 34%). One study did not report their attrition rate (39), while in three studies the attrition rate exceeded 25% (range 25% - 34%) (32, 41, 52).

[Insert Table 1 approximately here]

Risk of Bias in the Included Studies

Funnel plots (available on request) were constructed and asymmetry formally tested using Egger's regression test (46) to explore risk of publication bias across studies. The outcome measure Stress had insufficient data points to conduct a publication bias analysis. All other outcomes measures demonstrated a positive intercept, suggesting smaller studies tended to report larger than average effects (58). Although the 2-tailed p -value for all intercepts was non-significant ($p > 0.05$), all reported effect size outcomes were based on a random-effects model to give more weight to larger trials (46).

Pre-Post Effects of Mindfulness-based Interventions

Average weight loss across the 15 studies was 4.2 kg (range 0.0 – 12.0 kg). Hedge's g with 95% confidence intervals, significance testing, and forest plots for the psychological health, physical health, and eating-related constructs are presented in Table 2. Mindfulness-based interventions produced a *large* effect for improving Eating Behaviours ($g = 1.08$; 95% CI: 0.32-1.84), and *medium* effects for improving Depression ($g = 0.64$; 95% CI: 0.27-1.02) and Anxiety symptoms ($g = 0.61$; 95% CI: 0.38-0.85), Eating Attitudes ($g = 0.57$; 95% CI: 0.40-0.74), BMI ($g = 0.47$; 95% CI: 0.30-0.65), and Metacognition ($g = 0.38$; 95% CI: 0.08-0.69) from pre- to post-treatment in the overall sample. Effect sizes for Stress ($g = 0.39$; 95% CI: -0.04-0.82; $p = 0.07$) and QoL ($g = 0.66$; 95% CI: -0.01-1.34; $p = 0.06$) were approaching significance.. Within-group heterogeneity (I^2) across studies was *low* for BMI, Anxiety, Stress, and Eating Attitudes, *moderate* for Depression and Metacognition, and *high* for Eating Behaviours and QoL (See Table 2 for visual characterisation).

[Insert Table 2 approximately here]

Pre-Post Effects of Mindfulness-based Interventions Moderated by Study Quality

To assess the effect of study quality on the strength of the results, RCTs and ODs were analysed separately (see Supplementary Table 1). Not all outcomes of interest were measured by more than one study when sub-divided into RCT and OD categories and meta-analytic effects of a category were only interpreted for outcomes reported in two or more studies (59). RCT studies reported an average weight loss of 3.5 kg ($n = 4$, range 0.1 - 10.1 kg) and ODs reported an average weight loss of 4.6 kg ($n = 7$, range 0.0 - 12.0 kg). Based on all outcomes combined, RCTs produced *small* effects ($g = 0.41$; 95% CI: 0.21-0.61) and ODs ($g = 0.69$; 95% CI: 0.45-

0.93) produced *medium* effect size benefits, with between-group heterogeneity approaching significance ($Q = 2.98$, $df = 1$, $p = 0.09$).

Moderator analysis was also performed on individual outcomes (see Supplementary Table 1). Analyses of ODs showed *large* effects for Eating Behaviours ($g = 1.68$; 95% CI: 0.64-2.71), and Depression ($g = 0.77$; 95% CI: 0.37-1.17) and Anxiety symptoms ($g = 0.78$; 95% CI: 0.37-1.18). *Medium* effects were found for Eating Attitudes ($g = 0.62$; 95% CI: 0.41-0.82), BMI ($g = 0.56$; 95% CI: 0.24-0.88), and Metacognition ($g = 0.51$; 95% CI: 0.17-0.85). QoL and Stress were only examined by single OD studies. Within group heterogeneity (I^2) for ODs was *low* for BMI, Anxiety, and Eating Attitudes, *moderate* for Depression and Metacognition, and *high* for Eating Behaviours (See Supplementary Table 1 for visual characterisation).

RCTs showed *medium* effects for Anxiety ($g = 0.53$; 95% CI: 0.25-0.82) and Eating Behaviours ($g = 0.53$; 95% CI: 0.01-1.05), and *small* effects for Eating Attitudes ($g = 0.48$; 95% CI: 0.18-0.78), and BMI ($g = 0.43$; 95% CI: 0.21-0.65). Effects for Metacognition ($g = 0.25$; 95% CI: -0.29-0.79, $p = 0.36$) and QoL were not significant ($g = 0.33$; 95% CI: -0.12-0.79, $p = 0.15$). Depression and Stress were only examined by single RCT studies. Within-group heterogeneity (I^2) for RCTs was *low* for BMI, Anxiety, and Eating Attitudes, and *high* for Eating Behaviours (See Supplementary Table 1).

Pre-Post Effects of Mindfulness-based Interventions Moderated by Dose

To assess the effect of study dose on the strength of results, studies prescribing 12 or less hours were compared with studies prescribing more than 12 hours of face to face treatment (median split technique; see Supplementary Table 2). Again, meta-analytic effects of a category were only interpreted for outcomes reported in two or more studies (59). Based on all outcomes

combined, studies prescribing 12 or less hours ($g = 0.65$; 95% CI: 0.37-0.92) and studies prescribing more than 12 hours of face to face treatment ($g = 0.49$; 95% CI: 0.30-0.69), both produced *medium* effect size benefits, with between-group heterogeneity non-significant ($Q = 0.79$, $df = 1$, $p = 0.38$).

Moderator analysis was also performed on individual outcomes (see Supplementary Table 2). Studies prescribing 12 or less hours of face to face treatment showed *large* effects for Eating Behaviours ($g = 1.37$; 95% CI: 0.60-2.15), QoL ($g = 0.95$; 95% CI: 0.29-1.61), and Depression ($g = 0.81$; 95% CI: 0.323-0.1.39), *medium* effects for Eating Attitudes ($g = 0.69$ 95% CI: 0.38-0.99) and Anxiety ($g = 0.61$; 95% CI: 0.36-0.87), and *small* but significant effects for BMI ($g = 0.49$; 95% CI: 0.23-0.74) and Metacognition ($g = 0.35$; 95% CI: -0.01-0.71). Stress was only examined by a single study. Within-group heterogeneity (I^2) was *low* for BMI, Anxiety, and Eating Attitudes, and *moderate* for Depression, Eating Behaviours, Metacognition, and QoL (see Supplementary Table 2 for visual characterisation).

Analyses of studies prescribing more than 12 hours of face to face treatment showed *medium* effects for Eating Attitudes ($g = 0.52$; 95% CI: 0.32-0.73) and Depression ($g = 0.50$; 95% CI: -0.01-1.01), and *small* effects for BMI ($g = 0.46$; 95% CI: 0.61-0.75). Anxiety, Eating Behaviours, Metacognition, and Stress were only examined by single studies. Within-group heterogeneity for (I^2) high dose was *low* for BMI and Eating Attitudes, and *moderate* for Depression (see Supplementary Table 2).

Pre-Post Effects of Mindfulness-based Interventions Moderated by Treatment Approach

To assess the effect of intervention approach on the strength of results, studies utilising ACT, mindfulness, or meditation were examined separately (see Supplementary Table 3).

Again, meta-analytic effects were only interpreted for outcomes reported in two or more studies (59). Average weight loss was 7.6 kg ($n = 4$, range 2.2 - 12 kg) for ACT, 1.8 kg ($n = 1$) for meditation, and 1.9 kg ($n = 6$, range 0.0 – 6.7 kg) for studies using a mindfulness approach. Based on all outcomes combined, studies utilising ACT ($g = 0.66$; 95% CI: 0.42-0.90) and mindfulness ($g = 0.63$; 95% CI: 0.40-0.86) produced *medium* effect size benefits. While the effect size was *small* for studies utilising a meditation approach ($g = 0.33$; 95% CI: 0.07-0.60), the between-group heterogeneity was non-significant ($Q = 3.91$ df, = 2, $p = 0.14$).

Moderator analysis was also performed on individual outcomes (see Supplementary Table 3). Studies utilising ACT showed *medium* effects for Eating Attitudes ($g = 0.69$ 95% CI: 0.37-1.01) and BMI ($g = 0.66$; 95% CI: 0.36-0.96). Effects for QoL ($g = 0.66$; 95% CI: -0.01-1.34; $p = 0.06$) and Metacognition ($g = 0.45$; 95% CI: -0.12-1.02; $p = 0.12$) were not significant. Eating Behaviours were only examined by a single ACT study. Within-group heterogeneity (I^2) was *low* for both BMI and Eating Attitudes (see Supplementary Table 3).

Studies utilising a meditation approach had a non-significant effect for BMI ($g = 0.34$; 95% CI: -0.13-0.81, $p = 0.15$). Depression, Anxiety, Eating Behaviours, and Metacognition were only examined by single meditation studies.

Studies utilising mindfulness approaches showed *large* effects for Eating Behaviours ($g = 1.68$; 95% CI: 0.64-2.71), and *medium* effects for Depression ($g = 0.77$; 95% CI: 0.37-1.17), Anxiety ($g = 0.73$; 95% CI: 0.39-1.07), Metacognition ($g = 0.60$; 95% CI: 0.19-1.01), and Eating Attitudes ($g = 0.58$; 95% CI: 0.35-0.81). Effects for BMI ($g = 0.30$; 95% CI: -0.10-0.70, $p = 0.14$) and Stress were non-significant ($g = 0.39$; 95% CI: -0.04-0.82; $p = 0.07$). Within-group heterogeneity (I^2) for mindfulness approaches was *low* for Anxiety, Eating Attitudes, and

Metacognition, and *moderate* for Depression and Eating Behaviours (see Supplementary Table 3).

Follow-up Effects of Mindfulness-based Interventions

Six studies reported follow-up data beyond the intervention period, measuring BMI, QoL, Eating Attitudes, and Eating Behaviours (see Supplementary Table 4). One study provided a six-week follow-up (42), one a three-month follow-up (44), one a four-month follow-up (40), and three others a six-month follow-up (39, 41, 43). Studies that reported six-month follow-up data all featured ACT-based interventions. No identified studies reported on durability of treatment effects beyond six-months. Weight loss at post-intervention was consistently maintained at follow-up in the three studies reporting full data sets. Specifically, at four months participants had sustained 100% of their weight loss (post-intervention = -12.0 kg; follow-up = -12.1 kg) (44). Over six months participants continued to sustain (post-intervention = -10.1 kg; follow-up = -9.2 kg) (39), or even increase their weight loss (post-intervention = -6.2 kg; follow-up = -8.5 kg) (43).

Hedge's *g* calculations demonstrated a *medium* effect for BMI in all studies combined at follow up ($g = 0.57$; 95% CI: 0.07-1.06). However, when separated by study design, for the two RCTs there was a non-significant effect for BMI ($g = 0.30$; 95% CI: -0.54-1.13, $p = 0.49$), while for the two ODs there was a *large* effect ($g = 0.85$; 95% CI: 0.46-1.25) at six week and three month follow-ups. At follow up, a combined analysis found a *large* effect for Eating Attitudes ($g = 0.85$; 95% CI: 0.30-1.40), Again, for the two RCTs there was a non-significant effect for Eating Attitudes ($g = 1.11$; 95% CI: -0.58-2.80, $p = 0.20$), whereas for the two ODs there was a *large* effect ($g = 0.75$; 95% CI: 0.39-1.10) at six week and three month follow-ups. A *medium*

sized effect was found at follow-up in all studies combined for Eating Behaviours ($g = 0.66$; 95% CI: 0.06-1.26). These results were non-significant when examined separately for the two RCTs ($g = 0.36$; 95% CI: -0.04-0.77, $p = 0.08$), and there was insufficient data to examine the effect in ODs. Finally, combined analysis of follow-up QoL data found a *large* effect ($g = 1.84$; 95% CI: 0.39-3.23); however there was insufficient data to examine the effect separately by study quality.

Discussion

Main Findings of the Current Study

The National Institutes of Health's Third Strategic Plan for Exploring the Science of Complementary and Alternate Medicine (25) notes that "mindfulness meditation practices may be associated with greater psychological well-being, less disordered eating, greater weight loss, and improved metabolic function." However, to our knowledge the current study is the first meta-analysis to systematically examine the impact of mindfulness-based interventions exclusively for adults who are overweight or obese on variables beyond BMI or eating behaviour. Our review of 15 studies involving 560 participants measured BMI and eating behaviours, as well as a range of psychological outcomes including mood symptoms, eating attitudes, quality of life, and the acquisition of mindfulness skills.

When examined *en masse*, mindfulness-based interventions were significantly effective for improving BMI ($g = 0.47$) from baseline to post-test, with an average weight loss of 4.2 kg. The overall effect of mindfulness-based interventions on weight management in the current meta-analysis generally exceeded the results of previous systematic reviews of mindfulness, which utilised mixed populations of healthy, overweight, and obese individuals, and found the

effects on weight loss at post-intervention were mainly *small* (32, 33) or nonsignificant (34). The weight outcomes for mindfulness-based interventions in the current review also compared favourably to recent meta-analyses of other established behavioural and cognitive behavioural approaches (60, 61) for overweight and obesity. For instance, psychological services to post-operative bariatric surgery patients produced a *small* effect on weight loss (62), while motivational interviewing to overweight or obese adults was associated with a *medium* effect for weight management (63). Relatedly, a Cochrane review reported an average weight loss of 4.8 kg following CBT interventions coupled with dietary and physical activity for overweight or obese adults (19), however this was based on only two studies.

Furthermore, weight loss following mindfulness-based interventions was sustained or increased over four to six month follow-up periods, with an average weight loss at follow-up of 9.9 kg (range 9.2 - 12.1 kg). Comparatively, a recent meta-analysis of behavioural interventions focusing on both food intake and physical activity reported weight loss at 12 month follow up of 1.6 kg (64). However, while the durability of weight change following mindfulness-based interventions appears encouraging, it must be considered that the current findings are based on the results of only three studies, over much shorter follow-up periods.

In addition to improving weight control efforts for individuals who are overweight or obese, the mindfulness-based interventions reviewed in the current study facilitated holistic health gains. Specifically, Depression ($g = 0.64$) and Anxiety symptoms ($g = 0.61$), problematic Eating Attitudes ($g = 0.57$) and Eating Behaviours ($g = 1.08$), and Metacognition ($g = 0.38$) also significantly improved from pre to post-treatment. Improvements in Stress ($g = 0.39$) and QoL ($g = 0.66$) approached significance.

The acquisition of mindfulness skills has been examined in previous systematic reviews, primarily with an aim to elucidating the mechanism(s) effecting weight loss. To this end Olson and colleagues (32) described a lack of evidence of a relationship between mindfulness and weight loss in the studies reviewed, but did not report either overall or study specific effects. The reported effects for mindfulness ranged widely from *small* to *large* in studies included in the review by O'Reilly and colleagues (33), and of the 21 studies included, only two (42, 50) reported positive changes in both weight and mindfulness. When submitted to meta-analyses in the current evaluation, none of these effects were significant. In the current meta-analysis, post-intervention effects for weight change were reported in only eight of the 15 studies (36, 39, 40, 44, 50-52, 55), and effects for metacognition were reported in only five of the 15 studies (42, 43, 50, 52, 55). *Both* weight change and metacognition were reported in only three (50, 52, 55) of the 15 studies. In none of these studies was the effect for *both* weight change and metacognition significant. One study in the current analysis explicitly examined mindfulness as a mechanism of change (43), finding it mediated weight loss, but only at six-month follow-up. Overall, while the current meta-analysis found significant changes in BMI and metacognition separately, the extent to which increased mindfulness is an active component of treatment remains unclear (32).

The improvement in problematic eating behaviours reported in previous systematic reviews of mindfulness-based interventions has typically been *medium* to *large* (33, 34), consistent with the findings of the current meta-analysis. Other approaches for treating eating behaviours have found mixed effects. Compared to the current findings, *small* but significant effects were reported for behavioural treatment programs that targeted eating behaviours (65). Comparatively a meta-analysis of motivational interviewing for adults who are obese (66) reported 10 of the 13 studies that examined eating behaviours, such as decreasing salt intake and

increasing vegetable consumption, found no effect; for the three studies in which an effect was present, it was not maintained at follow-up.

Level 1 studies (67) of evidence for effectiveness of alternate psychological approaches for mood management, including depression, anxiety, and stress in adults who are overweight or obese are sparse, and generally inferior to the benefits identified in the current review. A meta-analysis examining outcomes of behavioural and very-low-energy diets for adults with obesity found no effect on depression symptoms for either intervention (68). Similarly, interventions that sought to develop realistic goal setting with adults who were obese had no impact on depression symptoms, or related psychological constructs such as self-esteem (69).

In the first moderator analysis, the effects for BMI, Anxiety, Eating Attitudes, and Eating Behaviours remained when RCTs were examined separately from ODs. Unfortunately, the measurement of psychological variables such as depression, stress, and quality of life were generally lacking in the RCT studies identified in the current review, limiting the analyses that could be completed on these outcomes. Improvements in BMI and Eating Attitudes remained at follow-up, but were only significant in lower quality OD studies (40-44).

The second moderator analysis was unable to detect a linear dose-response relationship. Utilising a median split criterion, all significant therapeutic effects of mindfulness-based interventions were detectable in studies prescribing 12 or less hours of face to face treatment, with no clear further benefit to studies prescribing more than 12 hours of intervention. For future studies seeking to maximise both the efficacy and the efficiency of treatment, there may be a limit to any presumed positive correlation between the extent of a mindfulness-based intervention and the degree of derived therapeutic benefits (38, 70).

The third moderator analysis examined the impact of different mindfulness-based intervention approaches, exploring the effects separately for primarily ACT, meditation, or mindfulness. ACT was the only intervention approach to produce a significant effect ($g = 0.66$) for BMI. Mindfulness was effective for psychological health outcomes Depression ($g = 0.77$), Anxiety ($g = 0.73$), and Metacognition ($g = 0.60$), and the constructs of Eating Behaviours ($g = 1.68$) and Eating Attitudes ($g = 0.58$). Only two studies utilised meditation, limiting the detection of any significant benefits for this intervention approach.

In sum, mindfulness has been argued to cultivate distress tolerance and adaptive coping mechanisms, leading to greater success dealing with cravings, a more active, flexible and committed style of adjustment, and ultimately greater long-term weight control (20). Results of the current study are consistent with previous systematic reviews demonstrating a positive association between mindfulness-based interventions and physical outcomes, such as BMI (32, 33) and problematic eating behaviours (33, 34). This review extends existing knowledge by highlighting the impact of mindfulness-based interventions on psychological health, including eating attitudes and perceived symptoms of depression and anxiety. Interventions targeting mindfulness skills such as awareness, openness, and distress tolerance can be beneficial in reducing these negative emotions, which are associated with attrition from weight loss programs, poorer weight loss, and greater weight re-gain (71). Reciprocally, mindfulness treatments of psychological health may further positively impact efforts to control weight, by addressing common triggers for unhealthy eating habits (20, 21, 31).

Limitations of the Current Study

The current review has several limitations. As this is a newly emerging area of research, study sample sizes tended to be small and often lacked a comparison control group. In addition, there was considerable variability in terms of the therapeutic components and duration, even within studies utilising a formal approach. For example, one ACT-based intervention included general mindfulness exercises seeking to increase bodily awareness (41, 53), whereas three other ACT-based interventions targeted mindful eating and self-regulation of hunger and satiety cues (39, 44, 55). In addition, these interventions included the use of mindfulness exercises both during sessions and for homework (41, 44, 53), however exact doses of each were not reported, further obscuring analysis of the incremental and independent benefits of alternate mindfulness-based practices.

The effectiveness of mindfulness-based interventions for a range of different outcomes, despite the diversity of methodologies, suggests that mindfulness training can be effective in many forms (33). However, despite a mindfulness-based approach to intervention, only two of the six RCTs (50, 52) and three of the eight ODs (42, 43, 55) measured mindfulness as an outcome variable. This methodological limitation makes it difficult to determine how mindfulness was functioning on the other observed outcomes in most studies (32). Also, while positive trends for BMI and Eating Attitudes were found up to six-months after intervention, the durability of these effects beyond this timeframe has not been established. This is particularly important given the significant risk for relapse in this population (72-74).

Across all studies, there was also variability in the outcomes measured. Although the aim of this review was to evaluate both physical and psychological outcomes, no more than one of any of the identified RCTs reported on depression or stress, restricting the current analysis of these outcomes to ODs. As noted above, only five of 14 studies reported on mindfulness. In

addition, while instruments applied for the assessment of outcomes such as Depression and Eating Behaviours were highly consistent across studies, significant variability was observed in the instruments utilised for other outcomes such as Eating Attitudes. Comparisons between studies in regard to this outcome may need to be interpreted with more caution.

Furthermore, in all but one study (52), the majority of participants were female, although men experience overweight and obesity at similar rates as women (75, 76). Notably, the one study (52) in the current analysis to include a predominately male participant group reported *medium* effects in improving BMI ($g = 0.55$) and anxiety ($g = 0.51$); encouraging results for a population known to be less likely to seek treatment (77). Finally, as is common with most review papers (32, 33) the current meta-analysis cannot disregard possible publication bias effects. The current meta-analysis was limited to analysing peer-reviewed papers, thus we are uncertain of how many studies with non-significant findings in this area may exist but were not accepted for publication.

Implications for Practice

Although incidence of harm was not formally reported in any of the reviewed studies, drop-out rates were low ($M = 16\%$, $SD = 12\%$), and it is generally accepted in the mindfulness literature that contra-indications to this approach are uncommon (29, 78), particularly compared with pharmacological and surgical treatments (79-82). Furthermore, the generally strong participant retention reported in the included studies is promising, as drop-out rates of CBT approaches can be problematic (83). Taken as a whole, further exploration of mindfulness-based interventions as either a component of existing weight loss interventions or as a stand-alone

approach for individuals who are overweight or obese is encouraged to help improve and extend health outcomes for this population.

Conclusion and Directions for Future Research

Despite the aforementioned limitations, the current review adds to a growing body of evidence that mindfulness-based interventions can be beneficial to both the psychological and physical health of adults who are overweight or obese. These positive changes may persist for upwards of 6-months, but further high-quality research needs to be conducted examining both psychological and physical health outcomes over longer follow-up time periods, in both men and women, comparing the efficacy of mindfulness-based approaches with other evidence-based psychologically-minded techniques, accompanied by explicit reporting of intervention details. Clear theoretical frameworks for mindfulness, and empirical examination of the strength of association between mindfulness variables and other observed outcomes are also needed, as the underlying mechanism(s) through which mindfulness-based interventions improve psychological and physical health outcomes for adults who are overweight or obese remains unclear. Potential mechanisms could include increased motivation to implement lifestyle changes, an enhanced ability to be self-reflective in relation to lifestyle choices, reduced emotional distress, enriched social support, or heightened awareness and self-regulation of body experiences. Such mechanisms require further research to disentangle and optimise the effects by which the promising outcomes reported in this review occurred for people who are overweight or obese.

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Conflicts of interest statement

The authors have no conflicts of interest to disclose.

Authors' contributions

JR and LB conceived and designed the study. JR and KM conducted the study search and identification. JR, MF, and CL conducted data extraction and analysis. JR, MF, KM, LB, and CL contributed to manuscript preparation.

References

List of Figures

Figure 1. Process for identification of the included studies

Table 1. Characteristics of Included Studies

Author ¹	Study Design ²	Mean BMI (SD or range) at baseline	Mean Age (SD or range) (total or t, c)	Male %	Intervention	Intervention Group N ³	Session number, duration (m or h) ⁴	Comparison Group ⁵	Comparison Group N ⁶	Attrition in Tx group; Tx Adherence (attendance or mindful practice) ⁷	Pre, post & follow up ⁸	Outcome Measures ⁹	Average Weight Change (kg)
Alberts, Mulkens & Smeets (2010; 51)	RCT	31.3 (4.1)	51.9 (12.8)	10%	Weekly dietician education & physical exercise, + 7wk Mindfulness based training programme	10	10, 1.5 h (Dose >12)	TAU: Weekly dietician education & physical exercise	9	0 lost; mindfulness 7.6 min/day	Pre & Post	BMI Attitudes: G-FCQ-T	Pre-post: -1.9
Daubenmier, Kristeller & Hecht (2011; 50)	RCT	31.40 (4.7)	t 40.42 (8.0); c 41.39 (6.7)	0%	Novel Mindfulness program + one 2 h nutrition and exercise session	19	9, 2.5 h + 1 day guided meditation class (Dose >12)	W/L: One 2 h nutrition and exercise session	21	5 lost; meditation 98±79 min & eating 5.9±4.4 mindfully/wk	Pre & Post	BMI Anxiety: STAI Stress: PSS, WCSI Metacognition: KIMS Attitudes: DEBQ	Pre-post: -0.6
Forman, Butryn & Juarascio (2013; 39)	RCT	34.10 (3.6)	45.67 (12.8)	NR	Acceptance-Based Behavioural Treatment	28	40, 75 m (Dose >12)	TAU: Standard Behavioural Treatment	29	NR; intervention attended M= 21.08±5.47 sessions	Pre, Post & 6m	BMI QoL: QOLI	Pre-post: -10.1 F/U: -9.2
Kristeller, Wolever & Sheets (2013; 40)	RCT	40.26 (26-78)	46.55 (20-74)	12%	Mindfulness-Based Eating Awareness Training	40	12, 1.5 h (Dose >12)	TAU: Psychoed & cognitive-behavioural training	33	13 lost post & 1 lost 4m follow-up; meditation 2 h/wk	Pre, Post & 4m	BMI Depression: BDI Behaviour: BES Attitudes: ESES, PFS, TFEQ	Pre-post: NR
Mantzios & Giannou (2014; 52)	RCT	28.74 (1.6)	22.9 (4.5)	57%	Group Mindfulness Practice	76	Daily for 6 weeks, 20 m + 1 day guided mindfulness class (Dose ≤12)	TAU: Individual Mindfulness Practice	76	7 lost; NR	Pre & Post	BMI Anxiety: CBAS Metacognition: MAAS	Pre-post: -1.8
Weineland, Arvidsson & Kakoulidis	RCT	37.13 (30.70 – 47.50)	43.08 (25-59)	11%	Acceptance & Commitment Therapy (internet & phone)	15 @F/U ¹⁰ 12	6 wk, self-paced + 30 m weekly phone	TAU: individual surgery team	18 @F/U 17	4 lost; NR @F/U 3 lost; NR	Pre & Post @F/U	QoL: WHOQOL Behaviour: SBEQ Attitudes: AAQW,	Pre-post: NR F/U: NR

¹ First three authors., year of publication and citation

² RCT, randomized controlled trial; OD, observational design

³ Group sizes reflect the total number of participants included in reported analyses at post treatment

⁴ h, hour; m, minute

⁵ TAU, treatment as usual; W/L, wait list control

⁶ NR, not reported; NA, not applicable

⁷ Attrition rate as reported by the study (either % or number of participants)

⁸ Follow up time period reported in m, months; wks, weeks

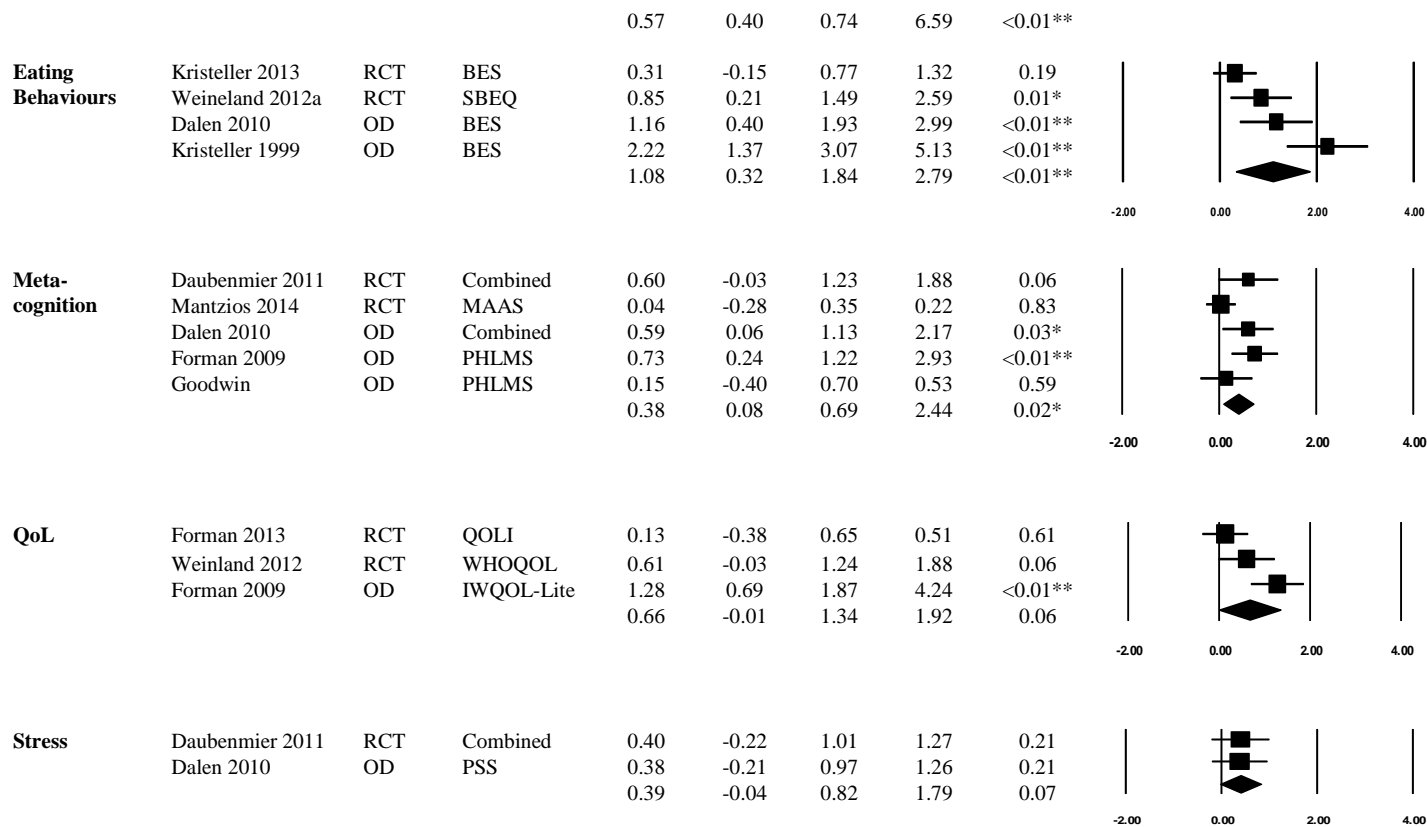
⁹ **Depression outcomes:** BDI, Beck Depression Inventory; CES-D, Centre for Epidemiological Studies- Depression Scale; **Anxiety outcomes:** BAI, Beck Anxiety Inventory; CBAS, Cognitive-Behavioural Avoidance Scale; STAI, State Trait Anxiety Inventory; **Stress outcomes:** PSS, Perceived Stress Scale; Wheaton Chronic Stress Inventory; **QoL outcomes:** IWQOL-Lite, Impact of Weight on Quality of Life; QOLI, Quality of Life Inventory; WHOQOL, World Health Organisation Quality of Life; **Metacognition outcomes:** KIMS, Kentucky Inventory of Mindfulness Skills; MAAS, Mindful Attention and Awareness Scale; PHLMS, Philadelphia Mindfulness Scale; **Eating Attitudes outcomes:** AAQW, Acceptance and Action Questionnaire for Weight Related Difficulties; DEBQ, Dutch Eating Behaviour Questionnaire; EDEQ, Eating Disordered Examination Questionnaire; EES, Emotional Eating Scale; EI, Eating Inventory; ESES, Eating Self-Efficacy Scale; FAAQ, Food Acceptance and Action Questionnaire; G-FCQ-T, General Food Craving Questionnaire Trait; PFS, Power of Food Scale; TFEQ, Three Factor Eating Questionnaire; WELQ, Weight Efficacy Lifestyle Questionnaire; **Eating Behaviour outcomes:** BES, Binge Eating Scale; SBEQ, Subjective Binge Eating Questionnaire

¹⁰ @F/U = data reported at follow-up (in the Weineland et al. (2012) study).

							support (Dose ≤12)	support			6m	EDEQ	
(2012; 53); Weineland, Hayes & Dahl (41)													
Courbasson, Nishikawa & Shapria (2011; 54)	OD	Eligibility criteria = ≥ 30 or ≥ 28 + medical problems	42 (11.0)	21%	Group Mindfulness- Action Based Cognitive Behavioural Therapy	29	16, 2 h (Dose >12)	NA	NA	9 lost; NR	Pre & Post	Depression: BDI Attitudes: EDE-Q	Pre-post: NR
Dalen, Smith & Shelley (2010; 42)	OD	36.9 (6.2)	44 (8.7)	30%	Mindful Eating & Living	10	6, 2 h (Dose ≤12)	NA	NA	0 lost at post & 1 lost at 6wk follow-up, 1 participant missed 1 session	Pre, Post & 3m	BMI: follow-up only Depression: BDI Anxiety: BAI Stress: PSS Metacognition: KIMS Behaviour: BES Attitudes: TFEQ	Pre-post: NR F/U: -4.0
Forman, Butryn & Hoffman (2009; 43)	OD	35.77 (5.4)	43.66 (9.8)	0%	Acceptance-Based Behavioural Intervention	19	12, 1 h (Dose ≤12)	NA	NA	10 lost at post & 5 lost at 6m follow-up, 9.62±2.06 sessions attended	Pre, Post & 6m	Metacognition: PHLMS QoL: IWQOL-Lite	Pre- post:-6.2 F/U: -8.5
Goodwin, Forman & Herbert (2012; 55)	OD	35.61 (7.8)	56.42 (12.7)	31%	Brief Acceptance- Based Behaviour Therapy	12	4, 1.5 h (Dose ≤12)	NA	NA	4 lost, NR	Pre & Post	BMI Metacognition: PHLMS Attitudes: FAAQ	Pre-post: -2.2
Kidd, Graor & Murrock (2013; 36)	OD	44.7 (6.9)	51.8 (9.1)	0%	Mindful Eating Group Intervention	8	8, 1-1.5 h (Dose ≤12)	NA	NA	4 lost, NR	Pre & Post	BMI Depression: CES-D Attitudes: WELQ	Pre-post: -0.7
Kristeller & Hallett (1999; 56)	OD	40.33 (28-52)	46.5 (10.5)	0%	Meditation-Based Intervention for Binge- Eating	18	6, NR (Dose ≤12)	NA	NA	3 lost, 2 missed 2+ sessions, 15.82± 3.15 h Meditation	Pre & Post	Depression: BDI Anxiety: BAI Behaviour: BES	Pre-post: 0.0
Leahey, Crowther & Irwin (2008; 57)	OD	40.83 (5.9)	54 (49-64)	14%	CBT Mindfulness- Based Group Intervention	7	10, 75 m (Dose >12)	NA	NA	0 lost, 100% compliance & attendance	Pre & Post	Depression: BDI Attitudes: EES, EDEQ, ESES	Pre-post: -6.7
Niemeier, Leahey & Reed (2012; 44)	OD	32.8 (3.4)	52.2 (7.6)	9%	Acceptance-Based Behavioural Intervention	18	24, 1 h + 10- 40m daily exercise (Dose >12)	NA	NA	3 lost at post & 0 lost at 3m follow-up, 20.5 ±4.8 sessions attended	Pre, Post & 3m	BMI Attitudes: AAQW, EI	Pre-post: -12.0 F/U: -12.1

Table 2. Pre-post effects of mindfulness-based interventions

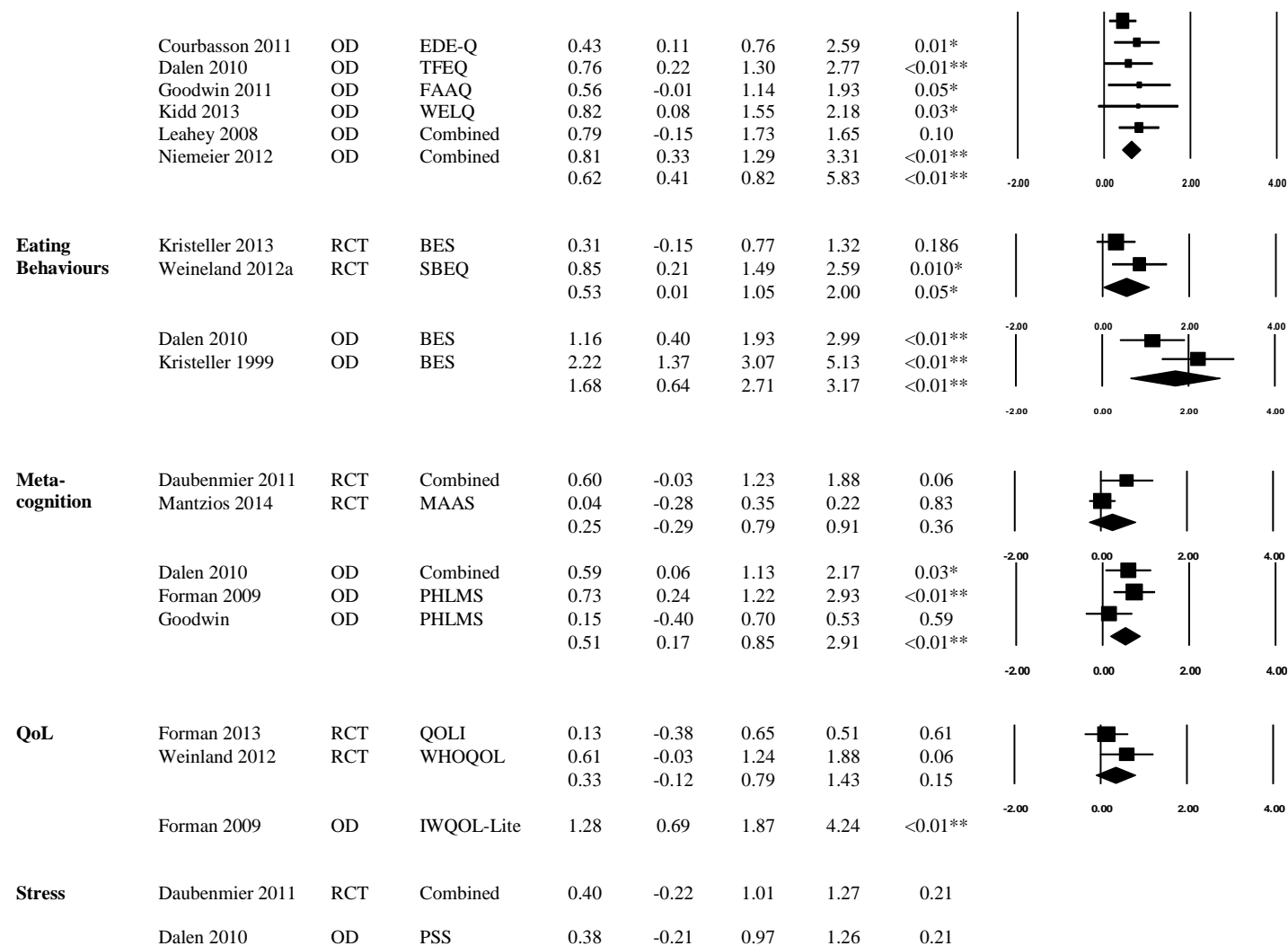
Variable	Study	Design	Statistics for each study					Hedges's g and 95% CI	
			Measure Used	Hedges's g	Lower limit	Upper limit	Z-Value		p-Value
BMI	Alberts 2010	RCT		0.49	-0.38	1.37	1.10	0.27	
	Daubenmier 2011	RCT		0.26	-0.37	0.88	0.80	0.43	
	Forman 2013	RCT		0.64	0.12	1.17	2.39	0.02*	
	Kristeller 2013	RCT		0.07	-0.42	0.55	0.27	0.78	
	Mantzios 2014	RCT		0.55	0.23	0.87	3.35	<0.01**	
	Goodwin 2011	OD		0.48	-0.08	1.04	1.69	0.09	
	Kidd 2013	OD		0.25	-0.38	0.87	0.77	0.44	
	Niemeier 2012	OD		0.81	0.33	1.29	3.31	<0.01**	
			0.47	0.30	0.65	5.20	<0.01**		
Anxiety	Daubenmier 2011	RCT	STAI	0.63	0.01	1.25	1.97	0.05*	
	Mantzios 2014	RCT	CBAS	0.51	0.19	0.83	3.11	<0.01**	
	Dalen 2010	OD	BAI	0.94	0.24	1.64	2.63	<0.01**	
	Kristeller 1999	OD	BAI	0.70	0.20	1.20	2.75	<0.01**	
				0.62	0.38	0.85	5.17	<0.01**	
Depression	Kristeller 2013	RCT	BDI	0.10	-0.36	0.56	0.42	0.67	
	Courbasson 2011	OD	BDI	0.43	0.11	0.76	2.59	0.01*	
	Dalen 2010	OD	BDI	1.24	0.46	2.03	3.10	<0.01**	
	Kidd 2013	OD	CES-D	0.24	-0.39	0.87	0.76	0.45	
	Kristeller 1999	OD	BDI	1.01	0.46	1.56	3.59	<0.01**	
	Leahey 2008	OD	BDI	1.30	0.48	2.12	3.12	<0.01**	
				0.64	0.27	1.02	3.33	<0.01**	
Eating Attitudes	Alberts 2010	RCT	G-FCQ-T	0.88	-0.03	1.78	1.90	0.06	
	Daubenmier 2011	RCT	Combined	0.48	-0.14	1.10	1.51	0.13	
	Kristeller 2013	RCT	Combined	0.31	-0.15	0.77	1.30	0.19	
	Weineland 2012a	RCT	Combined	0.63	0.01	1.26	1.97	0.05*	
	Courbasson 2011	OD	EDE-Q	0.43	0.11	0.76	2.59	0.01*	
	Dalen 2010	OD	TFEQ	0.76	0.22	1.30	2.77	<0.01**	
	Goodwin 2011	OD	FAAQ	0.56	-0.01	1.14	1.93	0.05*	
	Kidd 2013	OD	WELQ	0.82	0.08	1.55	2.18	0.03*	
	Leahey 2008	OD	Combined	0.79	-0.15	1.73	1.65	0.10	
	Niemeier 2012	OD	Combined	0.81	0.33	1.29	3.31	<0.01**	



* Significant at $P < 0.05$, ** Significant at $P < 0.01$

Supplementary Table 1. Pre-post effects of mindfulness-based interventions moderated by study design

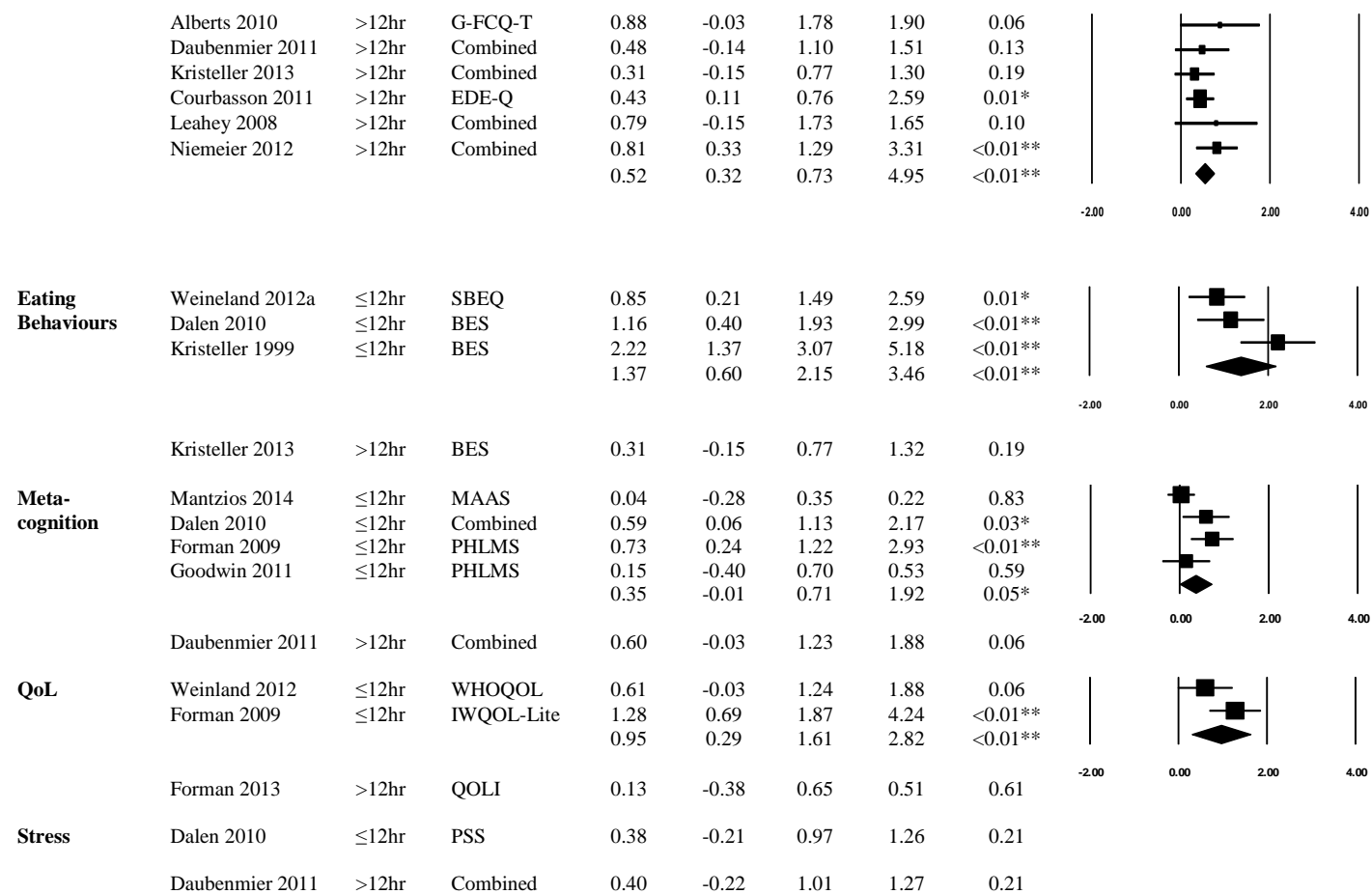
Variable	Study	Design	Statistics for each study					Hedges's g and 95% CI	
			Measure Used	Hedges's g	Lower limit	Upper limit	Z-Value		p-Value
BMI	Alberts 2010	RCT		0.49	-0.38	1.37	1.10	0.27	
	Daubenmier 2011	RCT		0.26	-0.37	0.88	0.80	0.43	
	Forman 2013	RCT		0.64	0.12	1.17	2.39	0.02*	
	Kristeller 2013	RCT		0.07	-0.42	0.55	0.27	0.78	
	Mantzios 2014	RCT		0.55	0.23	0.87	3.35	<0.01**	
				0.43	0.21	0.65	3.90	<0.01**	
	Goodwin 2011	OD		0.48	-0.08	1.04	1.69	0.09	
	Kidd 2013	OD		0.25	-0.38	0.87	0.77	0.44	
	Niemeier 2012	OD		0.81	0.33	1.29	3.31	<0.01**	
				0.56	0.24	0.88	3.43	<0.01**	
Anxiety	Daubenmier 2011	RCT	STAI	0.63	0.01	1.25	1.97	0.05*	
	Mantzios 2014	RCT	CBAS	0.51	0.19	0.83	3.11	<0.01**	
				0.53	0.25	0.82	3.66	<0.01**	
	Dalen 2010	OD	BAI	0.94	0.24	1.64	2.63	<0.01**	
	Kristeller 1999	OD	BAI	0.70	0.20	1.20	2.75	<0.01**	
				0.78	0.37	1.18	3.77	<0.01**	
Depression	Kristeller 2013	RCT	BDI	0.10	-0.36	0.56	0.42	0.67	
	Courbasson 2011	OD	BDI	0.43	0.11	0.76	2.59	0.01*	
	Dalen 2010	OD	BDI	1.24	0.46	2.03	3.10	<0.01**	
	Kidd 2013	OD	CES-D	0.24	-0.39	0.87	0.76	0.45	
	Kristeller 1999	OD	BDI	1.01	0.46	1.56	3.59	<0.01**	
	Leahey 2008	OD	BDI	1.30	0.48	2.12	3.12	<0.01**	
				0.77	0.37	1.17	3.73	<0.01**	
Eating Attitudes	Alberts 2010	RCT	G-FCQ-T	0.88	-0.03	1.78	1.90	0.06	
	Daubenmier 2011	RCT	Combined	0.48	-0.14	1.10	1.51	0.13	
	Kristeller 2013	RCT	Combined	0.31	-0.15	0.77	1.30	0.19	
	Weineland 2012a	RCT	Combined	0.63	0.01	1.26	1.97	0.05*	
				0.48	0.18	0.78	3.15	<0.01**	



* Significant at $P < 0.05$, ** Significant at $P < 0.01$. Note: Forest plots are only presented for outcomes reported in two or more studies.

Supplementary Table 2. Pre-post effects of mindfulness-based interventions moderated by study dose

Variable	Study	Dose	Measure Used	Statistics for each study					Hedges's g and 95% CI
				Hedges's g	Lower limit	Upper limit	Z-Value	p-Value	
BMI	Mantzios 2014	≤12hr		0.55	0.23	0.87	3.35	<0.01**	
	Goodwin 2011	≤12hr		0.48	-0.08	1.04	1.69	0.09	
	Kidd 2013	≤12hr		0.25	-0.38	0.87	0.77	0.44	
				0.49	0.23	0.74	3.73	<0.01**	
	Alberts 2010	>12hr		0.42	-0.38	1.37	1.10	0.27	
	Daubenmier 2011	>12hr		0.26	-0.37	0.88	0.80	0.43	
	Forman 2013	>12hr		0.64	0.12	1.17	2.39	0.02*	
	Kristeller 2013	>12hr		0.07	-0.42	0.55	0.27	0.78	
	Niemeier 2012	>12hr		0.81	0.33	1.29	3.31	<0.01**	
				0.46	0.16	0.75	3.03	<0.01**	
Anxiety	Mantzios 2014	≤12hr	CBAS	0.51	0.19	0.83	3.11	<0.01**	
	Dalen 2010	≤12hr	BAI	0.94	0.24	1.64	2.63	<0.01**	
	Kristeller 1999	≤12hr	BAI	0.70	0.20	1.20	2.75	<0.01**	
				0.61	0.36	0.87	4.78	<0.01**	
	Daubenmier 2011	>12hr	STAI	0.63	0.01	1.25	1.97	0.05*	
Depression	Dalen 2010	≤12hr	BDI	1.24	0.46	2.03	3.10	<0.01**	
	Kidd 2013	≤12hr	CES-D	0.24	-0.39	0.87	0.76	0.45	
	Kristeller 1999	≤12hr	BDI	1.01	0.46	1.56	3.59	<0.01**	
				0.81	0.23	1.39	2.74	<0.01**	
	Kristeller 2013	>12hr	BDI	0.10	-0.36	0.56	0.42	0.67	
	Courbasson 2011	>12hr	BDI	0.43	0.11	0.76	2.59	0.01*	
	Leahey 2008	>12hr	BDI	1.30	0.48	2.12	3.12	<0.01**	
				0.50	-0.01	1.01	1.93	0.05*	
Eating Attitudes	Weineland 2012a	≤12hr	Combined	0.63	0.01	1.26	1.97	0.05*	
	Dalen 2010	≤12hr	TFEQ	0.76	0.22	1.30	2.77	<0.01**	
	Goodwin 2011	≤12hr	FAAQ	0.56	-0.01	1.14	1.93	0.05*	
	Kidd 2013	≤12hr	WELQ	0.82	0.08	1.55	2.18	0.03*	
				0.69	0.38	0.99	4.43	<0.01**	



* Significant at $P < 0.05$, ** Significant at $P < 0.01$. Note: Forest plots are only presented for outcomes reported in two or more studies.

Supplementary Table 3. Pre-post effects of mindfulness-based interventions moderated by intervention type

Variable	Study	Type	Statistics for each study					Hedges's <i>g</i> and 95% CI	
			Measure Used	Hedges's <i>g</i>	Lower limit	Upper limit	Z-Value		<i>p</i> -Value
BMI	Forman 2013	ACT		0.64	0.12	1.17	2.39	0.02*	
	Goodwin 2011	ACT		0.48	-0.08	1.04	1.69	0.09	
	Niemeier 2012	ACT		0.81	0.33	1.29	3.31	<0.01**	
				0.66	0.36	0.96	4.33	<0.01**	
	Kristeller 2013	Med		0.07	-0.42	0.55	0.27	0.78	
	Mantzios 2014	Med		0.55	0.23	0.87	3.35	<0.01**	
				0.34	-0.13	0.81	1.44	0.15	
	Alberts 2010	Mind		0.49	-0.38	1.37	1.10	0.27	
	Daubenmier 2011	Mind		0.26	-0.37	0.88	0.80	0.43	
	Kidd 2013	Mind		0.25	-0.38	0.87	0.77	0.44	
			0.30	-0.10	0.70	1.48	0.14		
Anxiety	Mantzios 2014	Med	CBAS	0.51	0.19	0.83	3.11	<0.01**	
	Daubenmier 2011	Mind	STAI	0.63	0.01	1.25	1.97	0.05*	
	Dalen 2010	Mind	BAI	0.49	0.24	1.64	2.63	<0.01**	
	Kristeller 1999	Mind	BAI	0.70	0.20	1.20	2.75	<0.01**	
				0.73	0.39	1.07	4.23	<0.01**	
Depression	Kristeller 1999	Med	BDI	0.10	-0.36	0.56	0.42	0.67	
	Courbasson 2011	Mind	BDI	0.43	0.11	0.76	2.59	<0.01**	
	Dalen 2010	Mind	BDI	1.24	0.46	2.03	3.10	<0.01**	
	Kidd 2013	Mind	CES-D	0.24	-0.39	0.87	0.76	0.45	
	Kristeller 2013	Mind	BDI	1.01	0.46	1.56	3.59	<0.01**	
	Leahy 2008	Mind	BDI	1.30	0.48	2.12	3.12	<0.01**	
	Mind TOTAL			0.77	0.37	1.17	3.73	<0.01**	
Eating	Weinland 2012a	ACT	Combined	0.63	0.01	1.26	1.97	0.05*	

Outcome	Study	Group	Measure	Mean	SE	CI Lower	CI Upper	p-value	Forest Plot
Attitudes	Goodwin 2011	ACT	FAAQ	0.56	-0.01	1.14	1.94	0.05*	
	Niemeier 2012	ACT	Combined	0.81	0.33	1.29	3.31	<0.01**	
				0.69	0.37	1.01	4.25	<0.01**	
	Kristeller 2013	Med	Combined	0.31	-0.15	0.77	1.30	0.19	
	Alberts 2010	Mind	G-FCQ-T	0.88	-0.03	1.78	1.90	0.06	
	Daubenmier 2011	Mind	Combined	0.48	-0.14	1.10	1.51	0.13	
	Courbasson 2011	Mind	EDE-Q	0.43	0.11	0.76	2.59	0.01*	
	Dalen 2010	Mind	TFEQ	0.76	0.22	1.30	2.77	<0.01**	
	Kidd 2013	Mind	WELQ	0.82	0.08	1.55	2.18	0.03*	
	Leahy 2008	Mind	Combined	0.79	-0.15	1.73	1.65	0.10	
			0.58	0.35	0.81	5.04	<0.01**		
Eating Behaviours	Weinland 2012a	ACT	SBEQ	0.85	0.21	1.49	2.59	0.01*	
	Kristeller 2013	Med	BES	0.31	-0.15	0.77	1.32	0.19	
	Dalen 2010	Mind	BES	1.16	0.40	1.93	2.99	<0.01**	
	Kristeller 1999	Mind	BES	2.22	1.37	3.07	5.13	<0.01**	
				1.68	0.64	2.71	3.17	<0.01**	
Meta-cognition	Forman 2009	ACT	PHLMS	0.73	0.24	1.22	2.93	<0.01**	
	Goodwin 2011	ACT	PHLMS	0.15	-0.40	0.70	0.53	0.59	
				0.45	-0.12	1.02	1.56	0.12	
	Mantzios 2014	Med	MAAS	0.04	-0.28	0.35	0.22	0.83	
	Daubenmier 2011	Mind	Combined	0.60	-0.03	1.23	1.88	0.06	
	Dalen 2010	Mind	Combined	0.59	0.06	1.13	2.17	0.03*	
				0.60	0.19	1.01	2.87	<0.01**	
QoL	Forman 2013	ACT	QOLI	0.13	-0.38	0.65	0.51	0.61	
	Weinland 2012	ACT	WHOQOL	0.61	-0.03	1.24	1.88	0.06	
	Forman 2009	ACT	IWQOL-Lite	1.28	0.69	1.87	4.24	<0.01**	
				0.66	-0.01	1.34	1.92	0.06	
Stress	Daubenmier 2011	Mind	Combined	0.40	-0.22	1.01	1.27	0.21	

Dalen 2010	Mind	PSS	0.38	-0.21	0.97	1.26	0.21
			0.39	-0.04	0.82	1.79	0.07

*Significant at $P < 0.05$, ** Significant at $P < 0.01$. Note: ACT = Acceptance and Commitment therapy; Med = Meditation therapy; Mind = Mindfulness therapy. Forest plots are only presented for outcomes reported in two or more studies.

Supplementary Table 4. Follow-up effects of mindfulness-based interventions by study design

Variable	Study	Design	Measure Used	Statistics for each study					Hedges's g and 95% CI
				Hedges's g	Lower limit	Upper limit	Z-Value	p-Value	
BMI	Forman 2013	RCT 6/12		0.73	0.20	1.26	2.69	<0.01**	
	Kristeller 2013	RCT 4/12		-0.12	-0.61	0.36	-0.49	0.62	
				0.30	-0.54	1.13	0.70	0.49	
	Dalen 2010	OD 6/52		0.94	0.24	1.64	2.63	<0.01**	
	Niemeier 2012	OD 3/12		0.81	0.33	1.29	3.31	<0.01**	
			0.85	0.46	1.25	4.22	<0.01**		
		TOTAL		0.57	0.07	1.06	2.25	0.03*	
Eating Attitudes	Kristeller 2013	RCT 4/12	Combined	0.29	-0.20	0.77	1.15	0.25	
	Weinland 2012b	RCT 6/12	Combined	2.01	1.13	2.90	4.45	<0.01**	
				1.11	-0.58	2.80	1.28	0.20	
	Dalen 2010	OD 6/52	TFEQ	0.67	0.13	1.21	2.43	0.02*	
	Niemeier 2012	OD 3/12	Combined	0.81	0.33	1.29	3.31	<0.01**	
			0.75	0.39	1.10	4.09	<0.01**		
		TOTAL		0.85	0.30	1.40	3.00	<0.01**	
Eating Behaviours	Kristeller 2013	RCT 4/12	BES	0.32	-0.17	0.81	1.27	0.20	
	Weinland 2012b	RCT 6/12	SBEQ	0.47	-0.26	1.20	1.26	0.21	
				0.36	-0.04	0.77	1.76	0.08	
	Dalen 2010	OD 6/52	BES	1.38	0.55	2.21	3.27	<0.01**	
		TOTAL		0.66	0.06	1.26	2.14	0.03*	
QoL	Weinland 2012b	RCT 6/12	WHOQOL	2.63	1.64	3.61	5.22	<0.01**	
	Forman 2009	OD 6/12	IWQOL-Lite	1.14	0.49	1.79	3.45	<0.01**	
			TOTAL		1.84	0.39	3.23	2.48	

Note: 6/52 = six-week follow-up; 3/12 = three-month follow-up; 4/12 = four-month follow-up; 6/12 = six-month follow-up; * Significant at $P < 0.05$, ** Significant at $P < 0.01$

Appendix 1. Sample search strategy for the EMBASE database

Set #	Search String	Results
1	mindfulness.mp	2487
2	mbsr.mp	326
3	insight meditation*.mp	8
4	vipassana.mp	36
5	stress reduction.mp	1835
6	(stress adj3 reduction).mp	4537
7	mbct.mp	222
8	mindful meditation.mp	11
9	(mindful* adj3 meditation).mp	580
10	(mindful based adj3 (treat* or therap* or intervention*)).mp	1
11	mabis.mp	8
12	(mind body adj3 (treat* or intervention* or therap*)).mp	534
13	mindfullnes*.mp	17
14	(mind fullnes* or mind fulnes*).mp	11
15	(acceptance based adj3 (intervention* or therap* or treat*)).mp	108
16	(acceptance adj3 (treat* or therap* or intervention*)).mp	2465
17	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16	9300
18	exp obesity/	254605
19	weight maintenance.mp	1730
20	weight control/	3266
21	weight loss.mp. or weight reduction/	111309
22	dietary restraint.mp	958
23	food intake/	70439
24	Overweight.mp	49092
25	Body Mass Index.mp. or body mass/	198721
26	bmi.mp	123864
27	Food Habits.mp	1745
28	Body Weight Changes.mp. or weight change/	6091
29	caloric restriction/	8579
30	waist circumference/	21117
31	waist hip ratio/	6555
32	feeding behavior/ or feeding behaviour*.mp	45045
33	Energy Intake.mp	15605
34	weight height ratio/	26
35	weight gain/	60556
36	diet restriction/	53202
37	18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36	641227
38	17 and 37	583

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