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Effectiveness of including weight management in smoking cessation treatments: A meta-analysis of behavioral interventions

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ABSTRACT

Introduction: The potential of weight gain after smoking cessation reduces the incentive to quit. This meta-analysis examines the efficacy of behavioral interventions for smoking cessation that also address post-cessation weight gain.

Methods: Medline, Web of Science, PsycINFO, and the Cochrane Central Register of Controlled Trials were searched for randomized controlled trials on behavioral treatments targeting both health outcomes. Six separate meta-analyses were undertaken to assess treatment efficacy on smoking abstinence and weight outcomes at end of treatment (EOT), short-term, and long-term follow-up. Individual and treatment moderators were examined as well as methodological quality and publication bias of studies.

Results: A total of 28 studies were included in the meta-analysis. There was a statistically significant positive impact of treatments addressing both targets on smoking outcomes at EOT (RR = 1.279, 95% CI: 1.096, 1.492, $p = .002$), but not at follow-ups. Age impacted on EOT abstinence rates Q (1) = 4.960, $p = .026$) while increasing the number of sessions significantly improved EOT abstinence rates ($p = .020$). There was no statistically significant impact of these treatments on weight at EOT (Hedges' $g = -0.015$, 95% CI: −.164, 0.135, $p = .849$) or follow-ups (short term: Hedges' $g = 0.055$, 95% CI: −0.060, 0.170, $p = .347$; long term: Hedges' $g = -0.320$, 95% CI: −.965, 0.325, $p = .331$). There were minimal impacts of publication bias, mostly related to sample size, meaning studies including small sample sizes revealed larger effect sizes on abstinence at EOT.

Discussion: Addressing post-cessation weight management in treatments for smoking cessation significantly enhances tobacco abstinence at EOT though it was not found to have a lasting impact after treatment.

1. Introduction

Tobacco is the most commonly used substance worldwide and one of the main risk factors for diseases (World Health Organization, 2020). Though there is variability, extant literature demonstrates that smoking cessation is associated with an average increase of 4–5 kilograms (kg) (Aubin et al., 2012; Tian et al., 2015), and that concerns about potential weight gain are a substantial obstacle to quit attempts that may trigger relapse (Germeroth & Levine, 2018; Salk et al., 2019). Post-cessation weight gain weakens the beneficial effect of giving up smoking by reducing the cardiovascular diseases benefits resulting from quitting within the first year after smoking cessation (Chen et al., 2021). Research also demonstrates that the co-occurrence of smoking and excess weight increases health risks such as the likelihood of developing a chronic health condition (e.g., diabetes or obesity) (Bush et al., 2016; Hasegawa et al., 2019; Kos, 2020; Zhou et al., 2021) or a disability (Townsend & Mehta, 2020).

Weight gain during smoking cessation is thought to be attributed to the elimination of nicotine's ability to decrease appetite and increase metabolic rate (Chiolero et al., 2008; Collins et al., 1996; Jessen et al., 2005; Schmidt et al., 2019). Research also suggests that smoking cessation is associated with increased caloric intake mediated by complex behavioral, hormonal and neural mechanisms, such as shared neurobiological pathways between highly palatable foods and nicotine. These have been shown to underlie the relationship between smoking, eating and weight regulation (Anker et al., 2021; Audrain-McGovern & Benowitz, 2011; Cepeda-Benito, 2020; Chao et al., 2019; Gottfredson & Sokol, 2019). Further studies are needed to examine these mechanisms responsible for smoking cessation-related weight gain. Given the risks associated with post-cessation weight gain, strategies to limit it should

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be considered as part of any smoking cessation intervention (Chao et al., 2019; Chen et al., 2021; Kos, 2020; Salman & Doherty, 2020).

Meta-analyses that evaluate the effectiveness of interventions for both smoking cessation and weight control are scarce. Two meta-analyses published in 2009 (Spring et al., 2009) and 2012 (Farley et al., 2012) found that treatments that address both health outcomes were promising, however, conclusions were limited by the restricted number of high-quality studies available, the lack of data on long-term efficacy, and mixed results that required further confirmation. Additionally, a meta-analysis of the effectiveness of multiple risk behavior interventions suggested that there is a concern that targeting both health outcomes may undermine quitting (Meader et al., 2017). An update of Farley et al. (2012) meta-analysis, current up to October 2020 (Hartmann-Boyce et al., 2021), concluded that it is not clear which treatments work best to avoid gaining weight when stopping smoking, or how they affect smoking abstinence outcomes. Implications for research of this meta-analysis stressed that behavioral programmes are the mainstay for weight management and further studies are needed to clarify the evidence on whether they limit weight gain and impact on smoking abstinence (e.g., it was found that a personalized weight-management programme may reduce weight gain but a weight-management programme without personalized assessment, planning and feedback may not reduce weight gain, and may reduce the number of people who stop smoking). These findings suggest that focusing on behavioral interventions may help clarify whether targeting both health outcomes increases or decreases treatment outcomes.

However, this recent meta-analysis is not specifically focused on behavioral interventions and does not examine individual and treatment moderators. Moderators of smoking cessation interventions have been examined but the same has not been done yet with the moderators of treatments addressing both tobacco abstinence and post-cessation weight control (Black, Eisma, et al., 2020; Black, Johnston, et al., 2020; Secades-Villa et al., 2020). Black, Eisma, et al. (2020) found that higher smoking cessation rates are predicted by the provision of smoking cessation medication and the delivery of a greater number of behavior change techniques (BCTs). In the same line, Black, Johnston, et al. (2020) found that smoking cessation interventions with more BCTs are more effective than those with fewer BCTs, and three individual BCTs might be particularly effective for person-delivered interventions across populations and settings (prompting commitment, social reward, identity associated with changed behavior). Finally, Secades-Villa et al. (2020) found that the treatment setting moderated post-treatment smoking reduction outcomes among smokers with substance use disorders (SUD). In particular, compared to smokers with SUD undergoing outpatient treatment, those in residential settings attained lower smoking reductions.

By learning more about the active characteristics and individual moderators of smoking cessation treatments, we can provide better guidance on which treatments will result in best outcomes for different individuals. For example, Cepeda-Benito (1993) found that treatment intensity moderated the effectiveness of nicotine gum, particularly at long-term follow-up, and Cepeda-Benito et al. (2004) extended their previous findings by noting that, whereas men and women benefited from nicotine replacement therapy (NRT) at short-term follow-up, only men benefited from NRT at long-term follow-up.

The primary aim of this meta-analysis was to determine the effectiveness of behavioral interventions for both smoking cessation and post-cessation weight control at EOT, short-term follow-up (i.e., from EOT to ≤ 6-month follow-up), and long-term follow-up (i.e., > 6 months). The secondary aim was to evaluate the influence of smoker characteristics and intervention-specific characteristics on treatment outcomes.

2. Material and methods

A systematic literature search of randomized controlled trials (RCTs), published before September 2021, was conducted according to PRISMA guidelines (Moher et al., 2009; Rethlefsen et al., 2021). The study was registered in PROSPERO (ref.: CRD42020144777).

2.1. Eligibility criteria and data sources

Multiple inclusion criteria were applied to the systematic search. Firstly, only RCTs on behavioral treatments targeting both smoking cessation and weight management in comparison to control or comparison conditions without weight management tested at both pre- and post-treatment were included. Studies involving behavioral treatments combined with pharmacotherapies (i.e., behavioral and pharmacological) were included only if identical pharmacotherapy was incorporated in both the experimental condition and control/comparison conditions. Secondly, participants had to be daily smokers and neither pregnant nor in the post-partum period. Thirdly, the studies were required to report data on both smoking cessation and weight change outcomes. Finally, English and Spanish language restrictions were used, date limit was not restricted and only studies published in peer review journals were included.

Studies were retrieved using Medical Subject Headings (MeSH) terms [(tobacco OR smok* cessation) AND (obesity OR weight OR overweight OR body mass index OR Quetelet OR waist-hip ratio) AND (management OR training OR treatment OR intervention OR therapy OR prevention)] in Medline, Web of Science, PsycINFO and the Cochrane Central Register of Controlled Trials (CENTRAL). Two authors independently (GGF and AK) conducted the screening of potentially eligible studies by verifying eligibility criteria and screening the title and abstract before completing a full text screen. Discrepancies were discussed with a third reviewer (AGR).

2.2. Meta-analytic approach

2.2.1. Treatment effectiveness

Comprehensive meta-Analysis (v 3.3.070) was used to meta-analyze smoking cessation and weight change. A total of six separate meta-analyses were performed. Three assessed treatment efficacy on smoking abstinence at end of treatment (EOT, $n = 25$), at short-term (i.e., from EOT to ≤ 6-month follow-up, $n = 20$; specifically, one at 4-week follow-up, four at 12 weeks, one at 13 weeks, three at 14 weeks, one at 20 weeks, one at 24 weeks, and nine at 26 weeks), and long-term follow-ups (i.e., > 6 months, $n = 17$; two at 39-week follow-up, 13 at 52 weeks, and two at 60 weeks). The remaining three assessed treatment efficacy on weight changes: EOT ($n = 12$), at short ($n = 5$; specifically, one at 14 weeks follow-up, one at 20 weeks, and three at 26 weeks), and long term ($n = 5$; one at 39 weeks, three at 52 weeks, and another one at 60 weeks). Smoking abstinence was measured as either point-prevalence and/or continuous abstinence. Whenever studies provided both measures, continuous abstinence was used. Weight changes were defined as changes in weight at each of the assessed follow-up time points and converted into kg. Studies providing weight in abstinent-only participants were excluded from the meta-analyses to avoid potential bias (Chao et al., 2019).

Effectiveness of interventions on smoking abstinence was examined using the risk ratio (*RR*) with a 95% confidence interval (CI). In circumstances of zero-outcome events in one treatment condition, one unit was added to the corresponding event-count cell only to permit RR calculation in Stata (v14). The non-event-count cell was decreased by one to preserve the total sample size in each arm and avoid distorting results (Möller & Ahrenfeldt, 2021). Treatment effectiveness on weight management was estimated using Hedges' g values of 0.20, 0.50, and 0.80 and interpreted as small, medium, and large (Ellis, 2010).

Given the marked heterogeneity in smoking abstinence outcomes and interventions, a random effects model was adopted to meta-analyze outcomes. Cochran's Q and I^2 were calculated to characterize heterogeneity (i.e., $p = .10$) and interpreted as per Higgins et al. (2003)

guidelines: $I^2 \leq 25\%$ low heterogeneity, ∼50% moderate heterogeneity and ≥ 75% high heterogeneity across studies.

2.2.2. Moderator analyses

Whenever main significant effects emerged, we examined potential moderators at individual (i.e., sex coded as percentage of females; age; BMI; and nicotine dependence coded as continuous variables) and treatment level (i.e., treatment length: number of smoking cessation therapy sessions and total number of both tobacco + weight management sessions; treatment type coded binary: behavioral or cognitive-behavioral treatments [CBT] vs non-CBTs; weight management treatment type defined as categorical: exercise treatment vs those including counseling on diet only vs interventions focused on weight concerns only or addressing both exercise and diet). The *Q* statistic associated with the differences between groups in mixed effects analyses was used to examine systematic differences based on categorical variables. The mixed effects approach is akin to ANOVA and here was used to compare the group mean effects for two or more subgroups (i.e., independent variables). The mixed effects test estimates a mean effect size and standard error for each group. Thus, with k studies grouped into × mutually exclusive categories of the moderator variable, we can estimate the (average) effect size for each level of the moderator - and test for between-group differences. Meta-regressions were implemented for continuous moderators using a two-sided 95% confidence level ($p < .05$). Meta-regression is a statistical technique to examine how characteristics of studies are related to variation in effect sizes across studies. Meta-regression is analogous to regression analysis and, in our study, we used effect sizes (abstinence rates) as our outcomes, and information extracted from studies regarding sex, age, BMI, and nicotine dependence as moderators/predictors.

2.2.3. Methodological quality assessment and publication bias

Two independent reviewers (AK and AGP) assessed the methodological quality of the studies included using the Cochrane risk-of-bias tool RoB 2 (Sterne et al., 2019). Impact of publication bias was evaluated using the interpretation of the following tests as a whole (Begg & Mazumdar, 1994; Duval & Tweedie, 2000; Egger et al., 1997): 1) Egger's test evaluates the asymmetry of the funnel plot and suggests the absence of publication bias when the regression intercept is close to zero; 2) The Begg and Mazumdar rank indicator correlates the standardized effect size and its variance, with deviations from zero suggesting the presence of publication bias; 3) Duval and Tweedie's trim-and-fill aims to trim studies in the opposite direction of missing studies so that the trimmed meta-analysis is less affected by publication bias. For follow-up, we conducted a jackknife analysis by systematically leaving out each observation at a time so as to estimate bias from any particular study (Greenhouse & Iyengar, 1994). We also conducted a series of two-sided 95% confidence level meta-regressions to examine the effects of year of publication and sample size as potential sources of bias.

3. Results

A total of 18,775 articles were examined (see Fig. 1) and a full-text screening of 145 articles was performed. Although a total of 30 studies were initially selected, two of them (Prod'hom et al., 2013; Ussher et al., 2003) involved the same RCT as another two (Bize et al., 2010; Ussher et al., 2007) and, for this reason, were collapsed into two unique studies. Finally, 28 studies were included in the meta-analysis. Table 1 summarizes the studies included.

3.1. Participants' characteristics

The 28 studies involved 8,942 participants and the sample sizes ranged from 20 to 2,540 subjects. Participants were adults (76.54% females) with a mean age of 44.62 (*SD* = 10.28). The average number of cigarettes smoked per day was 21.17 (*SD* = 8.67), mean nicotine dependence was 5.43 (*SD* = 2.37), and mean body mass index (BMI) was 27.71 (*SD* = 5.93). Most of the studies (71.43 %) were aimed at specific populations, such as females (17/28; Albrecht et al., 1998; Bloom, Ramsey et al., 2020; Danielsson et al., 1999; Dunsiger et al., 2021; Kinnunen et al., 2008; Levine et al., 2010; Marcus et al., 1999; Marcus et al., 1991; Marcus et al., 1995; Marcus et al., 2005; Oncken et al., 2020; Perkins et al., 2001; Pirie et al., 1992; Spring et al., 2004; Vickers et al., 2009; Whiteley et al., 2012; Williams et al., 2010), sedentary individuals (10/28; Albrecht et al., 1998; Bize et al., 2010; Kinnunen et al., 2008; Marcus et al., 1991, 1995, 1999, 2005; Vickers et al., 2009; Whiteley et al., 2012; Williams et al., 2010), participants concerned with their weight (6/28; Bloom, Ramsey et al., 2020; Danielsson et al., 1999; Levine et al., 2010; Perkins et al., 2001; Pirie et al., 1992; Spring et al., 2004), participants with excess weight (1/28; White et al., 2019), participants that gained weight in previous quit attempts (1/28; Danielsson et al., 1999), smokers with cardiovascular risk (1/28; Jennings et al., 2014), and individuals with depression (1/28; Vickers et al., 2009).

3.2. Study and treatment characteristics

The majority of studies (75%, 21/28) were conducted in the USA and the remaining in Europe (Bize et al., 2010; Danielsson et al., 1999; Durmaz et al., 2019; Jennings et al., 2014; Leslie et al., 2012; Lycett et al., 2020; Ussher et al., 2007). Most of the studies implemented face-to-face treatments but four studies were conducted either via telephone calls (Bush et al., 2012, 2018), internet (i.e., web-based cognitive behavioral treatment) (White et al., 2019) or WhatsApp® (Durmaz et al., 2019).

Seven studies (25%) exclusively assessed the effect of behavioral interventions on smoking cessation (Albrecht et al., 1998; Hall et al., 1992; Marcus et al., 1991, 1995, 1999; Perkins et al., 2001; Spring et al., 2004) while the remaining 21 studies (75%) combined behavioral interventions with pharmacotherapy.

Strategies for post-cessation weight gain focused on four types of targets. While the majority incorporated physical activity or exercise (75%, 21/28; Albrecht et al., 1998; Bize et al., 2010; Bush et al., 2018; Ciccolo et al., 2011; Dunsiger et al., 2021; Durmaz et al., 2019; Hall et al., 1992; Jennings et al., 2014; Kinnunen et al., 2008; Leslie et al., 2012; Marcus et al., 1991; Marcus et al., 1995; Marcus et al., 1999; Marcus et al., 2005; Oncken et al., 2020; Pirie et al., 1992; Spring et al., 2004; Ussher et al., 2003; Vickers et al., 2009; Whiteley et al., 2012; Williams et al., 2010), some studies provided advice and reduced-fat meal plans meant to foster portion control and healthy eating (39.29%, 11/28; Albrecht et al., 1998; Bush et al., 2018; Danielsson et al., 1999; Durmaz et al., 2019; Hall et al., 1992; Jennings et al., 2014; Leslie et al., 2012; Lycett et al., 2020; Perkins et al., 2001; Pirie et al., 1992; Spring et al., 2004) and others targeted post-cessation weight concerns using CBT to minimize these concerns, encourage acceptance of moderate weight gain, and improve body dissatisfaction (14.29%, 4/28; Bush et al., 2012; Levine et al., 2010; Perkins et al., 2001; White et al., 2019). Finally, one study (3.57%) targeted distress tolerance, appetite awareness and mindful eating to manage weight concerns and emotional eating (Bloom, Ramsey et al., 2020).

Treatment length ranged from one to 53 sessions, with an average of 19.88 sessions in experimental conditions and 17.38 sessions in control or comparison conditions. With regard to follow-ups, three studies had no follow-up beyond EOT (Albrecht et al., 1998; Jennings et al., 2014; Leslie et al., 2012), eight studies had their follow-up sessions the furthest apart, between 4 and 26 weeks (Bloom, Ramsey et al., 2020; Bush et al., 2012; Ciccolo et al., 2011; Durmaz et al., 2019; Lycett et al., 2020; Vickers et al., 2009; White et al., 2019; Williams et al., 2010), while 17 studies had the biggest gap between EOT and follow-up, which took

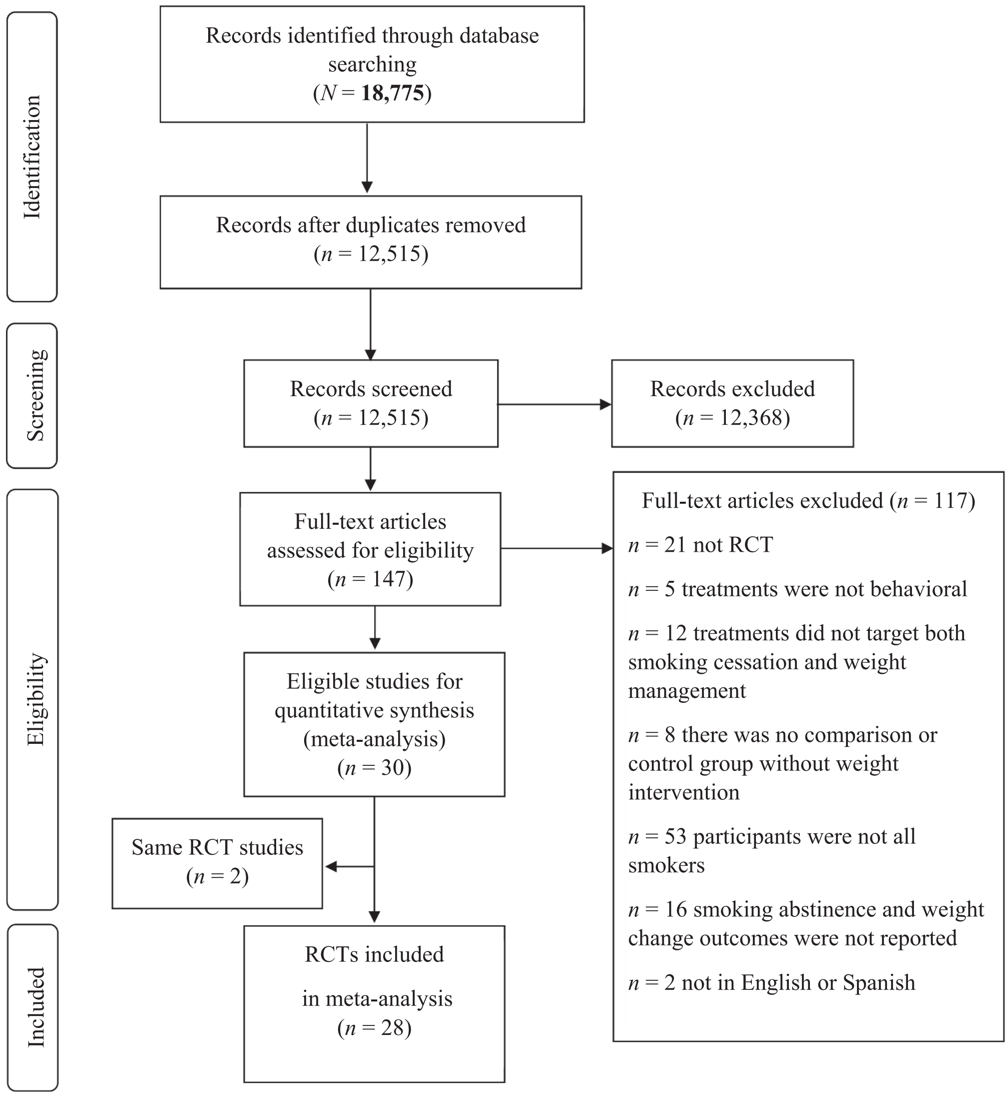

Fig. 1. Literature search procedure. *Note*. RCT = randomized controlled trial.

place between weeks 39 and 60 (Bize et al., 2010; Bush et al., 2018; Danielsson et al., 1999; Dunsiger et al., 2021; Hall et al., 1992; Kinnunen et al., 2008; Levine et al., 2010; Marcus et al., 1991, 1995, 1999, 2005; Oncken et al., 2020; Perkins et al., 2001; Pirie et al., 1992; Spring et al., 2004; Ussher et al., 2007; Whiteley et al., 2012).

3.3. Meta-analysis

3.3.1. Smoking abstinence outcomes

Figs. 2–3 display the forest plots on the treatment efficacy on abstinence outcomes at EOT and follow-ups. The meta-analysis at EOT evidenced a moderate magnitude heterogeneity (I^2 = 66.958%; Q = 72.634; p < .001) and the RR was estimated in 1.279 (range: 0.731–7.142) (95% CI: 1.096, 1.492, p = .002). This indicates that treatments that target both smoking cessation and weight management significantly increase the odds of abstinence at EOT (averaged % of abstinence: 33.85) relative to control or comparison conditions (averaged % of abstinence: 28.36).

An analysis by treatment type (n CBT = 14; n non-CBT interventions = 11) revealed no significant differences in the estimated effects (Q [1] = 0.691, p = .406). Interventions based on exercise (n = 12, RR = 1.171, 95% CI: 0.985–1.392, p = .073), weight concerns (n = 2, RR = 1.413, 95% CI: 0.681–2.935, p = .353) or both exercise plus diet (n = 7, RR = 1.250, 95% CI: 0.886–1.764, p = .204) did not reveal a significant impact on smoking abstinence, but those focused on dieting did (n = 2, RR = 1.423, 95% CI: 1.099–1.844, p = .007). Nonetheless, the total between effect was not statistically significant (Q [3] = 1.630, p = .653), which suggests no particular weight-management intervention had a better effect on post-treatment abstinence. Except for age (n = 24; Q [1] = 4.96, p = .026), none of the individual moderators (n female sex = 25, n nicotine dependence = 16, and n BMI = 18) had a statistically significant influence on EOT abstinence rates (all p values > 0.321). Of note is that the number of tobacco sessions did not significantly affect the abstinence rates (p = .547), but the total number of both tobacco and weight management sessions did (p = .021), thus demonstrating that more weight management sessions resulted in higher post-cessation smoking abstinence outcomes.

Meta-analyses at both short- and long-term follow-ups (see Fig. 3) showed no evidence of heterogeneity (short term: I^2 = 34.787%; Q = 29.135; p = .064, long term: I^2 = 26.636%; Q = 21.809, p = .149). Results revealed non-significant effects over time (short term: RR = 1.154, 95% CI: 0.979, 1.360, p = .088; long term: RR = 1.050, 95% CI: 0.899, 1.227, p = .539). Averaged percentage of abstinence in intervention arms was 19.87 at short and 16.89 at long term, respectively. Comparison conditions evidenced 14.80% and 14.72% of abstinence at each time-frame assessment.

Table 1
Study characteristics.

Author (year)	Sample size (% female)	Age Mean ± *SD*	CPD Mean ± *SD*	FTND Mean ± *SD*	BMI Mean ± *SD*	Setting (Country)	Conditions (experimental vs control)	Treatment length (*n* sessions)	Longest follow-up
Albrecht et al. (1998)	109 (100)	41±9	22±9	6±2	26±5	Hospital (USA)	SE + DC vs CC (both with CBTSC)	48	EOT
Bize et al. (2010)	481 (43)	42.2 ±10.1	27±10.2	5.4±2.2	24.49 ±3.98	University (Switzerland)	SE vs HE (both with CBTSC[a])	1	52 weeks
Bloom, Ramsey et al. (2020)	69 (100)	49.6 ±12.4	16.1±6.8	4.81±2.29	31.41 ±6.8	USA	Distress Tolerance + Appetite Awareness + Mindful Eating Skills vs HE (both with CBTSC[a])	9	26 weeks
Bush et al. (2012)	2000 (77)	41.3	At least 5 cigarettes	–	30.4 ±7.2	Helpline (USA)	CBTWC + SCC[a] vs SCC[a]	8 vs 5	26 weeks
Bush et al. (2018)	2540 (65.8)	43.2 ±12.2	20±8.3	–	30 ±7.11	Quit line (USA)	Sequential Weight Talk® (PAC + DC) vs Simultaneous Weight Talk® (PAC + DC) vs CC (all three with SCC[a])	10	52 weeks
Ciccolo et al. (2011)	25 (52)	36.5±12	18±10.1	4 ± 2.6	–	USA	Resistance Training (SE) vs HE (both with SCC[a])	25	26 weeks
Danielsson et al. (1999)	287 (100)	46.8 ±6.9	19.5±7.5	5.8 ± 1.9	26.8 ±2.2	Hospital (Sweden)	Very Low Energy Diet + SCC[a] vs SCC[a]	13 vs 11	52 weeks
Dunsiger et al. (2021)	105 (100)	42.5 ±11.2	17±7.7	–	27.65 ±5.2	USA	SE + SCC vs HE + SCC	36	52 weeks
Durmaz et al. (2019)	132 (39.4)	18–24: 13 25–34: 41 35–44: 32 45–54: 30 +55: 16	<10: 14; 11–20: 64; 11–30: 32; > 30: 22	Low: 14 Medium: 89 High: 29	–	University Clinic and WhatsApp Messenger (Turkey)	WhatsApp Messages (DC + PAC + SC) + SCC vs SCC (both with Motivational Interview[a, b, or c])	1	13 weeks
Hall et al. (1992)	158 (73)	40.3 ±8.8	27.4±11.7	–	–	USA	DC and Diet Plan + EC and Exercise Plan + Eating Self-Management vs Nonspecific Control vs Standard Control (all three with Aversive Therapy + Relapse Prevention)	–	52 weeks
Jennings et al. (2014)	696 (40)	59.9 ±6.7	19.6±8.9	–	–	Hospitals (Italy, Spain, UK, and Netherlands)	Euroaction Plus (DC + PAC + SCC[a or b]) vs Advice and Referral to Local Service	–	EOT
Kinnunen et al. (2008)	182 (100)	38.4 ±9.6	18.5±8.5	4.86±2.33	26.0 ±5.5	Hospital (USA)	SE vs Standard Care Control vs CC (all three with SCC[a])	24	52 weeks
Leslie et al. (2012)	138 (74.5)	50	25.2±11.4	–	28.2 (5.3)	Community-Based Services (UK)	DC + PAC vs Usual Care (both with SCC[a or b])	10 vs 7	EOT
Levine et al. (2010)	349 (100)	42±10.1	20.7±8.4	5.2±2.2	27.3 ±5.5	USA	CBTWC [b] vs CBTWC + Placebo vs CC [b] vs CC + Placebo (all with SCC)	12	39 weeks
Lycett et al. (2020)	76 (60.50)	46.7 ±13.5	–	5.7±2.1	30.4 ±5.3	Primary Care Services (UK)	Slimming World Program (DC) + BSC[a or c] vs BSC[a or c])	18 vs 6	14 weeks
Marcus et al. (1991)	20 (100)	39±8.5	23±9	–	–	USA	SE + BSC vs BSC	53 vs 8	52 weeks
Marcus et al. (1995)	20 (100)	37.5±9	23±9	–	–	USA	SE vs. HE (both with BSC)	53	52 weeks
Marcus et al. (1999)	281 (100)	40.1 ±8.92	22.1±9.3	6.2±1.9	25.4 ±4.9	USA	Supervised Vigorous Exercise vs HE (both with CBTSC)	48	60 weeks
Marcus et al. (2005)	217 (100)	42.7 ±10.3	20.6±9.3	4.8±2.3	26.2 ±5.5	Hospital (USA)	Supervised and Home-Based Moderate-Intensity Exercise Training vs HE (both with CBTSC[a])	16	52 weeks
Oncken et al. (2020)	301 (100)	55.8 ±6.2	18.9±7.5	5.3±1.9	28.5 ±6.4	Universities (USA)	SE vs Relaxation (both with SCC [c])	30	60 weeks
Perkins et al. (2001)	219 (100)	44.5 ±9.9	21.7±9.4	5.0±2.1	25.6 ±4.9	USA	CBTWC vs DC vs CC (all three with CBTSC)	10	52 weeks
Pirie et al. (1992)	417 (100)	43.15	26.2	–	24.1	Clinic (USA)	PAC + DA vs. PAC + DA[a] (both with CBTSC) vs. CBTSC[a] vs. CBTSC	7	52 weeks
Spring et al. (2004)	315 (100)	42.6 ±10.3	20.3±9.4	5.9±1.9	27.4 ±5.4	Universities, Medical School, and Medical Center (USA)	Early Diet (DC + Meal Plan) + PAC vs Late Diet (DC + Meal Plan) + PAC vs CC (all three with CBTSC)	16	39 weeks
Ussher et al. (2007)	299 (62.9)	42.9 ±11.1	21.9±8.9	5.5±2.0	25.5 ±3.6	Clinic (UK)	EC vs HE (both with CBTSC[a])	6	52 weeks
Vickers et al. (2009)	60 (100)	41.3 ±11.9	20.8±7.5	5.9±2.3	–	USA	EC vs HE (both with SCC[a])	10	14 weeks
White et al. (2019)	54 (72.2)	45.9 ±10.5	19.7±8.5	–	33.2 ±6.3	Website (USA)	Online CBTWC vs Online HE (both with Online CBTSC[a])	12	12 weeks
Whiteley et al. (2012)	330 (100)	43.5 ±9.9	17.4±7.1	5.1±2.1	28.2 ±5.8	YMCAs (USA)	SE vs CC (both with CBTSC[a])	16	52 weeks
Williams et al. (2010)	60 (100)	42.3 ±11.5	<10: 14; 11-20: 31; 21-30: 11; > 31: 4	4.8±2.2	–	Research Center (USA)	SE vs HE (both with SCC[a])	25	4 weeks

Note. SD = standard deviation; CPD = cigarettes per day; FTND = Fagerström Test for Nicotine Dependence; BMI = body mass index; USA = United States of America; SE = supervised exercise; DC = diet counseling; CC = contact control; CBTSC = cognitive-behavioral therapy for smoking cessation; EOT = end of treatment; HE = health education; CBTWC = cognitive-behavioral therapy for weight concerns; SCC = smoking cessation counseling; PAC = physical activity counseling; EC = exercise counseling; BSC = behavioral smoking cessation treatment; UK = United Kingdom; YMCAs = Young Men's Christian Association.
[a] nicotine replacement therapy, [b] bupropion, [c] varenicline.

3.3.2. Weight change outcomes

There were no statistically significant impacts of smoking cessation treatments plus weight management on weight changes at EOT (Hedges' $g = -0.015$, 95% CI: $-.164$, 0.135, $p = .849$, see Fig. 4) or follow-ups (short term: Hedges' $g = 0.055$, 95% CI: $-.060$, 0.170, $p = .347$; long term: Hedges' $g = -0.320$, 95% CI: $-.965$, 0.325, $p = .331$, see Fig. 5).

Minimal and no heterogeneity was evinced at EOT and short term, respectively (EOT: $I^2 = 33.161\%$; $Q = 16.457$; $p = .125$; short term: $I^2 < 0.001$; $Q = 1.545$; $p = .819$). These latter results contrasted with the markedly high heterogeneity at long term: $I^2 = 96.564\%$; $Q = 116.424$, $p < .001$).

3.3.3. Assessment of methodological quality and publication bias

Nineteen of the 28 studies presented some concerns about the risk of bias and the remaining studies (9/28) presented a high risk of bias (see Table 2).

Table 3 informs on publication bias on the estimated effect sizes by study outcome and time-frame assessment. Overall, there was moderate publication bias for smoking abstinence outcomes and minimal evidence of it for the effect sizes on weight outcomes. In regard to smoking abstinence, none, except for Egger's test for short- and long-term abstinence, were significant. This suggests potentiality of larger effect sizes in smaller studies, which was further confirmed by the significant moderating effects of sample size on short-term abstinence outcomes. As per Tweedie's trim and fill approach, it suggested two potentially missing studies for EOT abstinence effect sizes. However, trimmed estimates did not show any variation in the estimated effects. Year of publication did not impact on smoking abstinence and weight outcomes at any follow-up assessment. A follow-up jackknife analysis revealed the substantial impact of several studies on estimated effect sizes (see Table 4). Jackknife analyses suggested some influential cases for smoking cessation outcomes and lower influence of bias on weight outcomes. For EOT smoking abstinence, changes in estimates between the overall analyses and the jackknife approach were substantial for Jennings et al. (2014) (ES difference = 1.230), Marcus et al. (1991) (ES difference = 5.884), Marcuset al. (1995) (ES difference = 1.727), and White et al. (2019) (ES difference = 1.401). For short-term abstinence, variations in estimates were higher for Marcus et al. (1991) (ES difference = 3.150), Marcus et al. (1995) (ES difference = 1.853), and White et al. (2019) (ES difference = 1.196). At long term, the greatest deviations were observed in Dunsiger et al. (2021) (ES difference = 2.013), Marcus et al. (1991) (ES difference = 1.812), Marcus et al. (1995) (ES difference = 1.957), and Marcus et al. (1999) (ES difference = 1.186). Minimal impacts were detected for weight outcomes, with the only exception being observed in the Marcus et al. (1991) study (ES difference = −1.281).

4. Discussion

Including weight management in smoking cessation treatments did not have an impact on weight change but revealed a more favorable smoking abstinence response at EOT (33.85%) than treatments for quitting smoking without weight management (28.36%). Nonetheless, positive effects reduced over time, revealing an average decrease of 16% in smoking abstinence effects. Despite the short-term effectiveness of smoking cessation treatments with weight management for improving smoking abstinence rates at EOT, results were no longer significant at follow-ups, suggesting no additive effects on smoking abstinence rates after treatment termination.

In line with previous meta-analysis (Farley et al., 2012; Hartmann-Boyce et al., 2021; Spring et al., 2009) but in contrast with others (Meader et al., 2017) concluding that it may not be optimal to target smoking simultaneously with other risk behaviors, the present study found that there was no evidence to suggest that adding a weight management component worsened smoking cessation outcomes. In fact, it seems that adding a weight component to a smoking cessation intervention improves smoking cessation outcomes at EOT, but that such effect is short lived, and likely an artifact of increasing the intensity or attention provided to the individuals in treatment. The maintenance of outcomes following the discontinuation of treatment in tobacco and

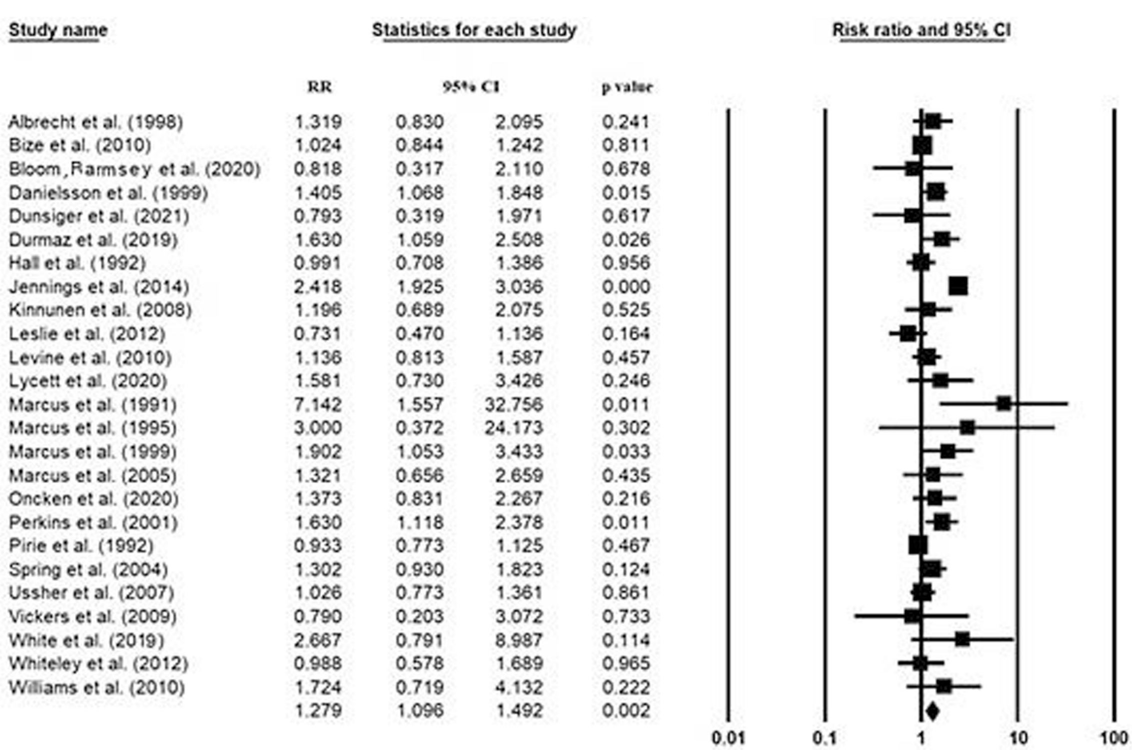

Fig. 2. Forest plots on the efficacy of smoking cessation treatments over smoking abstinence at the end of treatment (EOT). *Note.* RR = Risk ratio.

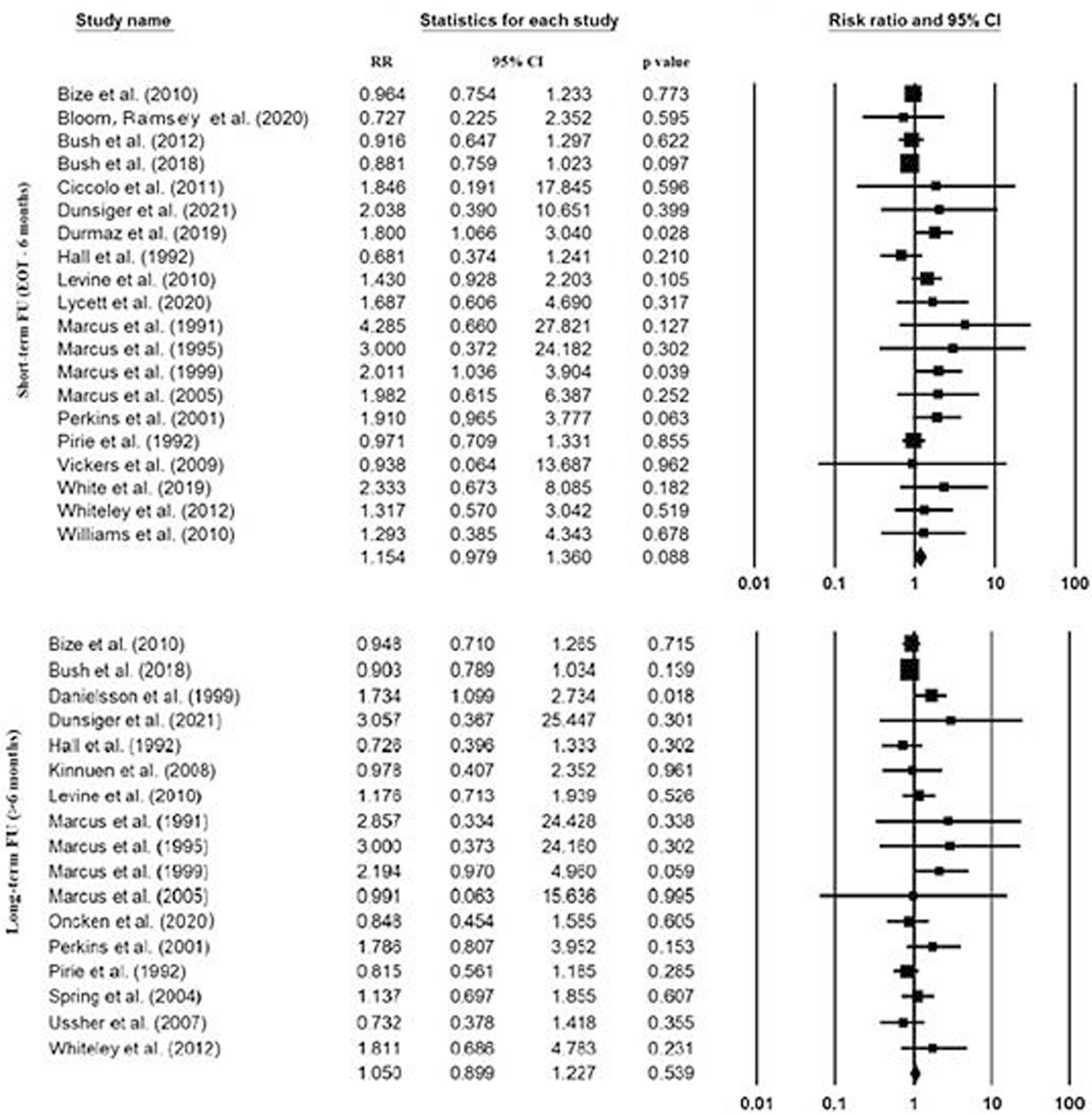

Fig. 3. Forest plots on the efficacy of smoking cessation treatments over smoking abstinence at short- (i.e., from end of treatment to 6 months) and long-term (i.e., from 6 months) follow-ups. *Note.* RR = Risk ratio; FU = follow-up; EOT = end of treatment.

obesity fields is a challenging priority (Paixao et al., 2020). Research highlights the importance of investigating which combinations of techniques lead to higher rates of smoking cessation (Black, Johnston, et al., 2020) and successful weight management (Nordmo et al., 2020; Samdal et al., 2017).

Age was the only individual moderator tested that significantly affected smoking abstinence at EOT, indicating better abstinence outcomes for older individuals. Therefore, the use of treatments targeting both health outcomes seems generalizable among individuals of both sexes, different BMI or nicotine dependence; however, youth-friendly treatments are required to improve quitting among young adults (Dono et al., 2020; Fanshawe et al., 2017; Orsal & Ergun, 2021; Villanti et al., 2020). Further, treatment length was the only moderator tested that significantly impacted smoking abstinence at EOT, showing that an increasing number of treatment sessions led to improved post-treatment smoking abstinence outcomes. It is worth noting that average treatment length was high, with an average of 19.88 sessions in treatments for smoking cessation with weight management and 17.38 sessions in treatments without weight management (de Bruin et al., 2021).

Regarding weight change outcomes, meta-analysis revealed that adding weight management into smoking cessation treatments did not show statistically significant effects. Nevertheless, these results should

Study name	Hedges's g	95% CI		p value
Albrecht et al. (1998)	0.155	-0.219	0.529	0.416
Bloom, Ramsey et al.(2020)	0.194	-0.338	0.726	0.475
Hall et al. (1992)	-0.393	-0.733	-0.054	0.023
Leslie et al. (2012)	-0.086	-0.513	0.341	0.693
Marcus et al. (1991)	-1.280	-2.293	-0.267	0.013
Marcus et al. (1995)	-0.191	-1.127	0.745	0.689
Marcus et al. (1999)	0.022	-0.283	0.327	0.888
Marcus et al. (2005)	0.014	-0.251	0.279	0.919
Spring et al. (2004)	-0.017	-0.265	0.231	0.892
Vickers et al. (2009)	0.490	-0.143	1.122	0.129
White et al. (2019)	-0.085	-0.676	0.505	0.778
Williams et al. (2010)	0.298	-0.209	0.804	0.249
	-0.015	-0.164	0.135	0.849

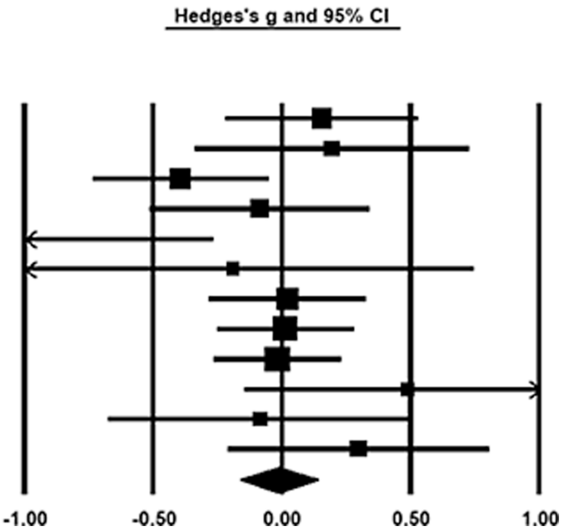

Fig. 4. Forest plots on the efficacy of smoking cessation treatments on weight gain at the end of treatment (EOT).

	Study name	Hedges's g	95% CI		p value
Short-term FU (EOT- 6 months)	Bloom, Ramsey et al. (2020)	0.183	-0.344	0.710	0.497
	Bush et al. (2018)	0.052	-0.076	0.179	0.429
	Ciccolo et al. (2011)	-0.418	-1.445	0.609	0.425
	Marcus et al. (1999)	0.016	-0.337	0.368	0.931
	Vickers et al. (2009)	0.283	-0.381	0.948	0.403
		0.055	-0.060	0.170	0.347
Long-term FU (>6 months)	Bize et al. (2010)	-1.487	-1.751	-1.223	0.000
	Bush et al. (2018)	0.061	-0.067	0.189	0.349
	Hall et al. (1992)	-0.423	-0.796	-0.050	0.026
	Marcus et al. (1999)	0.256	-0.087	0.600	0.144
	Spring et al. (2004)	0.003	-0.367	0.373	0.987
		-0.320	-0.965	0.325	0.331

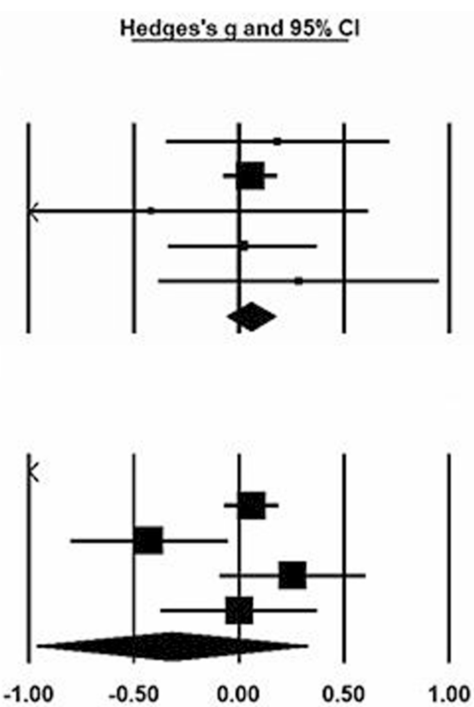

Fig. 5. Forest plots on the efficacy of smoking cessation treatments on weight gain at short- (i.e., from end of treatment to 6 months) and long-term (i.e., from 6 months) follow-ups. *Note.* FU = follow-up; EOT = end of treatment.

Table 2
Methodological quality summary (Cochrane risk-of-bias tool RoB 2).

Author (year)	Randomization process	Deviations from the intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall risk-of-bias judgement
Albrecht et al. (1998)	Some concerns	High	High	Low	Low	High
Bize et al. (2010)	Low	High	Low	Low	Low	High
Bloom, Ramsey et al. (2020)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Bush et al. (2012)	Low	Low	Some concerns	Low	Low	Some concerns
Bush et al. (2018)	Low	Some concerns	Low	Low	Low	Some concerns
Ciccolo et al. (2011)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Danielsson et al. (1999)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Dunsiger et al. (2021)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Durmaz et al. (2019)	Low	Some concerns	Low	High	Low	High
Hall et al. (1992)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Jennings et al. (2014)	Low	Some concerns	Low	High	Low	High
Kinnunen et al. (2008)	Some concerns	High	Low	Low	Some concerns	High
Leslie et al. (2012)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
Levine et al. (2010)	Low	Low	High	Low	Low	High
Lycett et al. (2020)	Low	Some concerns	Some concerns	Low	Low	Some concerns
Marcus et al. (1991)	Some concerns	High	Low	Low	Some concerns	High
Marcus et al. (1995)	Some concerns	Some concerns	Some concerns	Low	Some concerns	Some concerns
Marcus et al. (1999)	Low	Some concerns	Some concerns	Low	Low	Some concerns
Marcus et al. (2005)	Low	Some concerns	Low	Low	Low	Some concerns
Oncken et al. (2020)	Low	Some concerns	Low	Low	Low	Some concerns
Perkins et al. (2001)	Some concerns	Some concerns	High	Low	Some concerns	High
Pirie et al. (1992)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Spring et al. (2004)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Ussher et al. (2007)	Low	Some concerns	High	Low	Some concerns	High
Vickers et al. (2009)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns
White et al. (2019)	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Whiteley et al. (2012)	Low	Some concerns	Low	Low	Low	Some concerns
Williams et al. (2010)	Low	Some concerns	Some concerns	Low	Some concerns	Some concerns

Note. Cochrane risk-of-bias tool RoB 2 comprises five domains and yields an overall risk of bias judgement (low/high/some concerns) regarding reviewers' scores on: 1) the randomization process, 2) deviations from intended interventions, 3) missing outcome data, 4) bias in outcome measurement, and 5) bias in selection of the reported result. Low bias is considered when no bias exists for all of the domains, some concerns are deemed if concerns are raised on at least one domain, but there is no high risk of bias for any domain. High risk of bias is considered when concerns are raised for at least one domain, or if the study is judged to have some concerns for multiple domains.

Table 3
Publication bias outcomes.

Follow-up assessment	Begg-Mazumdar test		Egger's regression analysis			Tweedie's trim and fill approach			Year of publication				Sample size			
	Kendall's τ	*p*	Intercept	95% CI	*p*	$N_{trimmed}$	ES	95% CI	Coefficient	SE	95 % CI	*p*	Coefficient	SE	95 % CI	*p*
Smoking abstinence																
EOT	0.196	0.168	0.624	-0.798, 2.047	0.373	2	1.253	1.071, 1.465	0.002	0.008	-0.015, 0.019	0.803	0.0003	0.0005	-0.0006, 0.0012	0.512
Short term	0.110	0.495	0.198	0.530, 1.866	**0.001**	NA	NA	NA	0.001	0.009	-0.016, 0.019	0.887	-0.0002	0.0001	-0.0003, <-0.001	**0.010**
Long term	0.272	0.127	0.947	0.164, 1.729	**0.020**	NA	NA	NA	-0.005	0.008	-0.023, 0.011	0.527	-0.001	0.0001	-0.0004, 0.0001	0.228
Weight gain																
EOT	-0.045	0.837	-0.361	-0.253, 1.807	0.718	NA	NA	NA	0.016	0.008	-0.0005, 0.034	0.057	-0.0001	0.0009	-0.0018, 0.0016	0.902
Short term	<0.001	1.00	-0.012	−1.615, 1.590	0.982	NA	NA	NA	0.002	0.009	-0.017, 0.021	0.839	<0.001	0.0001	-0.0001, 0.0001	0.878
Long term	-0.300	0.462	−3.625	−22.508, 15.256	0.584	NA	NA	NA	-0.008	0.046	-0.098, 0.082	0.861	0.0002	0.0006	-0.001, 0.001	0.740

Note. NA = Not applicable. Note that Tweedie's trim and fill approach was only computed for significant effect sizes as this procedure estimates the number of potentially missing studies that would bring *p* values to non-significant. EOT = end of treatment; Short term = from EOT to 6-month follow up (FU); Long term = > 6-month FU

be interpreted with caution because there is a great heterogeneity in weight interventions and only half of the studies objectively weighed participants. Furthermore, only five studies were included in short- and long-term weight change meta-analyses, and involved follow-ups with heterogeneous temporal points (specifically, one study at 14 weeks, another at 20 weeks, and three studies at 26 weeks at short-term; and one study at 39 weeks, three at 52 weeks, and one at 60 weeks at long-term). Another important limitation is that most of the studies focused on women.

It is worth mentioning that none of the studies in the meta-analysis addressed diet, physical activity, and weight concerns simultaneously, and only one addressed emotional eating (Bloom et al., 2017). Moreover, while one recent study explored dual contingency management (CM) in which both smoking cessation and weight maintenance were incentivized(Bloom, Hunt et al., 2020), no study included in our meta-analysis explored the effect of CM. As CM is a well-established treatment for smoking (Cahill et al., 2015) and a promising approach for weight control (Ellis et al., 2021), the lack of inclusion of studies that used CM leaves out an important part of the picture when looking at treatments for smoking cessation.

Taken together, these results suggest that clinicians should assess and provide weight management strategies regularly while undergoing smoking cessation. Routine assessment of weight (Corbaton Anchuelo et al., 2019), weight concerns (Germeroth & Levine, 2018), diet, physical activity and disordered eating (Durrer Schutz et al., 2019; Paixao et al., 2020; Zhu et al., 2022) before, during and after quitting could be useful. This is especially important for participants who are at risk of health problems if they suffer weight gain (Chen et al., 2021). Just one of the studies included was aimed at participants with excess weight (White et al., 2019) and one focused on those with cardiovascular risk (Jennings et al., 2014). Some recent studies assessing smokers with specific risk profiles include those with diabetes (Martinez et al., 2020) or those attending cardiac rehabilitation (Salman & Doherty, 2020).

Despite this meta-analysis providing a comprehensive assessment of the effectiveness and moderators of behavioral treatments for smoking cessation and post-cessation weight management, the findings should be considered within the context of their limitations. Although 28 studies were included in the meta-analysis, no study was classified as low risk of bias. Further, most of the studies included females (76.8%) and the nature of the smoking cessation and weight management interventions, the time frames of assessments, and the metrics for abstinence and weight were heterogeneous and thus limited the interpretation of the intervention effects (Black, Johnston, et al., 2020). Additionally, several of the moderation analyses comprised a limited set of studies (e.g., two), although the use of large sample sizes across studies warrants sufficient power to detect meaningful effects.

4.1. Conclusions

The results of this study provide evidence on the effectiveness of addressing post-cessation weight gain in smoking cessation treatments for facilitating tobacco abstinence at EOT. However, it is not certain which behavioral interventions specifically work best to achieve smoking abstinence and prevent post-cessation weight gain. Future studies should aim to improve efficacy to stop smoking and limit weight gain for younger individuals and for populations at risk if they gain weight.

5. Author agreement statement

The submitted manuscript contains no data or other material or results that have been published or are in press or submitted elsewhere. All authors have been actively involved in substantive work leading to the report and have approved the final manuscript. No conflicts of interest are declared.

Table 4
Jackknife analyses outcomes.

Follow-up assessment	Range of estimated RR effects (random effects model)	Range of CI 95%		Range of estimated RR effects (jackknife analyses)	Range of CI 95%	
		Lower limit	Upper limit		Lower limit	Upper limit
Smoking abstinence						
EOT	0.731, 7.142	0.203, 1.925	1.125, 32.756	1.188, 1.313	1.060, 1.125	1.331, 1.534
Short term	0.068, 4.285	0.064, 1.066	1.023, 27.821	1.094, 1.214	0.937, 1.018	1.277, 1.471
Long term	0.726, 3.057	0.063, 1.099	1.034, 25.447	0.957, 1.103	0.856, 0.919	1.070, 1.323
Weight gain						
EOT	−1.280, 0.490	−2.293, −0.143	−0.267, 1.122	−0.038, 0.033	−0.195, −0.099	0.107, 164
Short term	−0.418, 0.283	−1.445, −0.076	0.179, 0.948	0.048, 0.069	−0.190, −0.054	0.164, 0.329
Long term	−1.487, 0.256	−1.751, −0.067	−1.223, 0.600	−0.462, −0.005	−1.269, −0.234	0.224, 0.493

Note. RR = risk ratio; EOT = end of treatment; Short term = from EOT to 6 month follow-up (FU) ; Long term = > 6-month FU.

6. Role of funding source

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CRediT authorship contribution statement

Gloria García-Fernández: Conceptualization, Funding acquisition, Project administration, Investigation, Methodology, Resources, Writing – original draft. **Andrea Krotter:** Investigation, Methodology, Writing – original draft. **Alba González-Roz:** Formal analysis, Methodology, Writing – original draft. **Ángel García-Pérez:** Investigation, Formal analysis. **Roberto Secades-Villa:** Funding acquisition, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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