Effectiveness of contingency management for smoking cessation in substance users: A systematic review and meta-analysis

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Abstract

Objective. We conducted a systematic review and meta-analysis (ID: CRD42019122315) to assess the evidence for the effectiveness of contingency management (CM) to promote smoking abstinence among individuals with substance use disorder or in recovery. **Method.** Databases were PubMed, PsycINFO, Cochrane, and EBSCO. The primary eligibility criteria for inclusion in our meta-analysis were as follows: any study examining the efficacy of CM for smoking cessation that reported smoking abstinence and/or cigarette reductions. The methodological quality of the included studies was assessed using the Effective Public Health Practice Project Quality assessment tool. Publication bias was examined using Egger's regression intercept, the Begg-Mazumdar test, and Tweedie's trim-and-fill approach. **Results.** A total of 22 articles were included, and 13 were included in three meta-analyses: abstinence at posttreatment (12 studies), abstinence at follow-up (8 studies), and reduction outcomes at posttreatment (6 studies). CM was superior to comparison arms in smoking abstinence (RR= 2.555; 95%CI: 1.730-3.775; $p < .001$) and reduction (*SMD*=.601; 95%CI: 0.372, 0.831; $p < .001$) at end-of-treatment. At long-term follow-ups, CM did not show enhanced effects over abstinence beyond those shown in comparison arms (RR=1.029; 95%CI: 0.577, 1.836; $p = .922$). Smoking-cessation treatment (all treatments included CM) and smoking abstinence increased the likelihood of abstinence from alcohol and/or illicit drugs. All studies were rated as being of strong or moderate quality and no marked presence of publication bias was found. **Conclusions.** CM for smoking cessation in individuals with substance use disorders performs significantly better than control conditions in reducing smoking at end-of-treatment.

*Keywords***:** Meta-analysis, contingency management, effectiveness, smoking cessation, substance use disorder.

Public Health Significance Statement

This study informs on the efficacy of contingency management for facilitating short-term smoking abstinence and cigarette reductions in substance users. Delivering contingency management solely or as an adjunctive smoking cessation intervention is advisable for a significant impact on public health.

Effectiveness of contingency management for smoking cessation in substance users: A systematic review and meta-analysis

Tobacco smoking is highly prevalent and is the leading behavioral risk factor causing a substantially large number of potentially preventable deaths worldwide (World Health Organization, 2012). Despite the significant decline in the prevalence of smoking in developed countries, rates of smoking among those with mental disorders remain elevated compared to the general population, with the highest rates among those with substance use disorders (SUD) (Kelly, Greene, Bergman, & Hoeppner, 2019; Smith et al., 2020; Weinberger, Funk, & Goodwin, 2016; Winhusen, 2017). Individuals with SUD are more likely to smoke, smoke more heavily, and are three times more likely to be dependent on nicotine than those without SUD (Compton, Thomas, Stinson, & Grant, 2007; Minami et al., 2018; Weinberger et al., 2019). Moreover, this population experiences increased substance-related disease and premature mortality, and is more likely to die from tobacco-related causes than those using alcohol/illicit substances alone (Das & Prochaska, 2017; Hurt et al., 1996; Kelly et al., 2019; Rogers, Boardman, Pendergast, & Lawrence, 2015). Furthermore, smoking rates in recovering SUD populations are more than double those of the general population (Kelly et al., 2019). Previous research has also shown that quitting smoking increases long-term abstinence from other substances among individuals with SUD, but smokers with SUD have less success in quitting than the general population (Campbell, Le, Tajima, & Guydish, 2017; Weinberger et al., 2016).

Because of the increased health risks associated with smoking among people with SUD, there is a need to focus greater scientific and public health efforts on developing innovative approaches to support smoking cessation and reduce the harmful consequences of smoking for these individuals (Campbell, Yip, Le, Gubner, & Guydish,

2019; Das & Prochaska, 2017; Lembke & Humphreys, 2016; McHugh et al., 2017). Despite this, little is known about smoking treatment options for this population and more research is needed to identify successful interventions.

Contingency management (CM) is a behavioral intervention in which patients receive reinforcement contingent upon biochemically verified abstinence. Two of the most widely implemented CM procedures are voucher-based reinforcement therapy (Higgins, Kurti, & Davis, 2019) and prize-based CM (Ledgerwood, Arfken, Petry, & Alessi, 2014). Whereas in voucher-based therapy, patients receive incentives exchangeable for retail items, environmental activities, or cash-equivalent checks, in the prize-based procedure, participants receive tickets that allow them to draw from a bowl for prizes of different magnitude.

The efficacy of CM has been demonstrated in a wide range of substance-using populations, including alcohol, cannabis, cocaine, and opiate patients (Ainscough, McNeill, Strang, Calder, & Brose, 2017; Benishek et al., 2014; Davis et al., 2016; Dutra et al., 2008; Getty, Morande, Lynskey, Weaver, & Metrebian, 2019; Lussier, Heil, Mongeon, Badger, & Higgins, 2006; McPherson et al., 2018; Prendergast, Podus, Finney, Greenwell, & Roll, 2006; Rash, Stitzer, & Weinstock, 2017; Schierenberg, van Amsterdam, van den Brink, & Goudriaan, 2012). There are also several reviews on cigarette smokers that have provided qualitative descriptions and analyses of the whole set of CM studies, showing that incentives are effective in reducing smoking (Cahill, Hartmann-Boyce, & Perera, 2015; Donatelle et al., 2004; Hand, Ellis, Carr, Abatemarco, & Ledgerwood, 2017; Higgins, Kurti, & Davis, 2019; Ledgerwood, 2008; Sigmon & Patrick, 2012).

Reviews and meta-analyses that specifically evaluate the effectiveness of smoking cessation interventions for patients with SUD are scarce. Some of these

studies focus on special populations, such as pregnant women (Akerman et al., 2015) or individuals with methadone maintenance (Okoli et al., 2010). Most of these reviews do not examine the differential effects by treatment condition (Das & Prochaska, 2017; Prochaska, Delucchi, & Hall, 2004; Thurgood, McNeill, Clark-Carter, & Brose, 2016), exclude studies assessing CM interventions (Apollonio, Philipps, & Bero, 2016) or focus only on the effect of smoking cessation treatments on the use of other drugs, but not on tobacco smoking (McKelvey, Thrul, & Ramo, 2017). To our knowledge, only two meta-analyses have examined the effects of smoking interventions on smoking and substance use. The first meta-analysis included only one study evaluating a CM condition (Prochaska et al., 2004). More recently, in a subgroup analysis, Notley et al. (2019) addressed the issue of whether incentives facilitate long-term smoking abstinence for SUD populations. However, given that they focused on mixed populations (including smokers who do not use other substances), conclusions on CM efficacy cannot be drawn. Additionally, this review only included trials with at least six months of follow-up, although post-treatment outcomes were not included, and it reported abstinence rates but not smoking reductions or other substance misuse outcomes.

To fill this gap in knowledge, the primary aim of this review and meta-analysis is to evaluate the short- and long-term effectiveness of CM for smoking cessation among individuals with SUD. Moreover, with the aim of informing on CM parameters that affect treatment efficacy, we examine whether treatment setting, magnitude of incentives, or treatment length are associated with short- or long-term smoking outcomes. The secondary aim is to evaluate the impact of smoking cessation treatments on the use of substances other than tobacco. Finally, the presence of publication bias and the methodological quality of the included studies are also evaluated.

Method

A protocol was designed and registered in the International Prospective Register of Systematic Reviews, PROSPERO (ID: CRD42019122315). The systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews (PRISMA statement) (Moher et al., 2009). Both the Journal Article Reporting Standards (JARS) and Meta-Analysis Reporting Standards (MARS) were also conformed to, as detailed in Applebaum et al. (2018).

Eligibility and Inclusion Criteria

The primary eligibility criteria were peer-reviewed published studies examining the effect of CM for smoking cessation that met the following conditions: 1) the study involved adult smokers (i.e., aged ≥18) with current drug use and/or enrolled in treatment/recovery for SUD; and 2) it provided a measure of smoking abstinence or reduction in cigarette use. Both the use of biochemical verification (e.g., carbon monoxide or cotinine) and reports on reduction of or abstinence from drugs other than nicotine were recorded but not required. Studies were excluded if the results were overlapping (i.e., multiple publications on the same data set, sample size, and outcomes).

Literature Search Procedure

Studies were identified through a comprehensive literature search with no restriction on the year of publication using the PubMed, PsycINFO, Cochrane and EBSCO databases as of 31 January 2020 (see Figure 1). Search terms used pertained to CM (e.g., contingent reinforcement), smoking (e.g., cigarette), and substance use (e.g., marijuan*). The specific combinations of Boolean terms are provided under

Supplementary Material (see S1). Additionally, the authors conducted a manual search to identify systematic reviews and meta-analyses on the topic of the study.

[Figure 1 about here]

Data extraction

Two independent reviewers conducted the literature search and coded the studies independently. In cases where studies did not report the pertinent data, we requested the corresponding author to do so in order to permit inclusion in the analyses.

Narrative synthesis

A narrative synthesis on the primary and/or secondary outcomes was given for study designs (i.e., studies including a single group or multiple groups with different treatment components) that prevented us from determining the main effect of CM on the outcomes.

Meta-analytic approach

Analysis was conducted using the Comprehensive Meta-Analysis software v3.3.070. Meta-analyses were based only on randomized controlled trials that allowed us to ascertain the unique effect of CM on smoking outcomes. The effectiveness of CM was assessed using two outcomes: smoking abstinence and smoking reduction. At end-of-treatment (EOT), the primary outcome measure chosen was biochemically verified point-prevalence, or else continuous abstinence or the percentage of negative samples for smoking abstinence. Regarding the measure of smoking reduction, the primary outcome was a decrease in number of cigarettes, or instead a reduction in cotinine or in CO. In the long-term follow-ups, point-prevalence was the only measure considered. The different types of smoking abstinence and reduction measures at EOT were

combined in the meta-analysis given the high correlation between them (Hughes, Carpenter, & Naud, 2010). Due to the heterogeneity in the outcome variables, we computed effect sizes on the effects of the interventions on smoking abstinence and smoking reduction, separately.

In order to assess the effect sizes of smoking abstinence data, the risk ratio (RR) with a 95% confidence interval (CI) was calculated. In cells with zero events, we used the "adjusted Woolf" method to calculate the RR (Lawson, 2004). Effect sizes estimated from means and standard deviations of smoking reduction were calculated as follows (Kazis, Anderson, & Meenan, 1989): $d = (M_t - M_c)/SD_{pooled}$; where M_t refers to the mean of the treatment group, M_c to the comparison condition, and SD_{pooled} to the pooled standard deviation of the assessed arms. When abstinence or smoking reduction outcomes were not given, effect sizes were calculated from the reported values of *t*, *F*, or χ^2 statistics, as per prior recommendations (Cooper & Hedges, 2011). The meta-analysis was performed adopting a random effects approach. Cochran's *Q* test and I^2 were used to quantify heterogeneity of effect sizes. Cochran's *Q* tests the hypothesis that the studies are evaluating the same effect and indicates heterogeneity at a *p* value equal to .10. I^2 accounts for the variation that is explained by heterogeneity; $I^2 \leq 25\%$ indicates low heterogeneity, ~50% suggests moderate heterogeneity, and ≥75% is indicative of high heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003).

A mixed-effects analysis was conducted to examine whether smoking abstinence and reduction at EOT differed by type of CM combination (i.e., CM only, CM with psychological intervention, or with pharmacological intervention). As there were no studies reporting long-term outcomes using CM alone, mixed-effects analyses on long-term smoking abstinence and reduction were performed only with studies using psychological versus pharmacological CM combinations. The *Q* statistic associated

with the between-groups difference in the mixed effects analyses was calculated for this purpose.

A set of meta-regression analyses were carried out to examine whether treatment setting (i.e., outpatient versus residential) and comparison arm (i.e., treatment as usual or no treatment versus other active smoking cessation treatments), magnitude of incentives, and treatment length, predicted CM short- (i.e., at EOT) and long-term (i.e., at the longest follow-up) smoking outcomes.

Methodological quality assessment

Two independent reviewers assessed the methodological quality of the studies included in the meta-analysis using the Effective Public Health Practice Project Quality assessment tool (EPHPP) (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012). No discrepancies between reviewers were identified. This tool stands as appropriate for assessing the quality of a variety of study designs such as randomized controlled clinical studies and secondary ones. It comprises five domains: 1) selection bias, 2) study design, 3) confounders, 4) blinding, 5) data collection, and 6) withdrawals/dropouts. As per the EPHPP guidelines, each study domain is interpreted as weak, moderate, or strong and a global rating is calculated based on averaged scores: weak (1.00-1.50), moderate (1.51-2.50), or strong in quality (2.51-3.00).

Risk of bias assessment

The presence of publication bias was informed based on the interpretation of three different tests as a whole (Coburn & Vevea, 2015). Egger's regression intercept (Egger, Smith, Schneider, & Minder, 1997) shows the asymmetry of the funnel plot indicating the absence of publication bias when the regression intercept is close to zero. The Begg

and Mazumdar rank indicator (Begg & Mazumdar, 1994) correlates the standardized effect size and its variance, with deviations from zero suggesting the presence of publication bias. Duval and Tweedie's trim-and-fill approach (Duval & Tweedie, 2000) serves as an estimate of the unbiased effect size, as it corrects for the variance of the effects.

Results

A total of 1,736 articles were identified through the literature search and individually examined, after removing duplicates (Figure 1). A full-text screening of 58 articles was performed. Of the reviewed articles, 22 studies published between 1995 and 2018 met the inclusion criteria and therefore were included in this review, and specifically 13 studies were included in the meta-analysis. Table 1 shows a summary of the characteristics of the reviewed studies.[Table 1 about here]

Participant and treatment characteristics

The 22 studies involved 2,186 participants. The sample sizes ranged from five to 538 participants per study. The mean age of the total sample was 36.63 (*SD*=8.45), and 58.01% were males. A total of 57.84% were Caucasian, 25.42% were African American, and the remaining races were Latino, Asian, and Hispanic, with minimal percentages (<20%). At baseline, the average number of cigarettes smoked per day was 17.78 (*SD*=7.32). All studies were conducted in the United States.

Six studies (27.27%) were conducted in residential treatment (Alessi & Petry, 2014; Alessi, Petry, & Urso, 2008; Hunt, Rash, Burke, & Parker, 2010; Robles et al., 2005; Rohsenow, Martin, Tidey, Colby, & Monti, 2017; Rohsenow et al., 2015), nine (40.9%) in outpatient treatment (Cooney et al., 2017, 2015; Mooney et al., 2008;

Shoptaw, Jarvik, Ling, & Rawson, 1996; Shoptaw et al., 2002; Sigmon & Patrick, 2012; Tuten, Fitzsimons, Chisolm, Nuzzo, & Jones, 2012; Winhusen et al., 2014; Wiseman, Williams, & McMillan, 2005), one (4.54%) via the Internet (Beckham et al., 2018), four (18.18%) in a research clinic (Drummond et al., 2014; Dunn et al., 2010; Orr et al., 2018; Schmitz, Rhoades, & Grabowski, 1995), and two (9.09%) in a mixture of the above (Campbell, Wander, Stark, & Holbert, 1995; Guydish et al., 2016).

In the 22 studies included, five trials (22.72%) evaluated the effect of CM only on smoking (Alessi et al., 2008; Orr et al., 2018; Schmitz et al., 1995; Shoptaw et al., 2002; Tuten et al., 2012), and the remaining studies combined CM with other psychological (4/18.18%) or pharmacological interventions (13/59.09%). CM was added to a cognitive-behavioral treatment (CBT) (Beckham et al., 2018; Campbell et al., 1995; Cooney et al., 2017, 2015; Guydish et al., 2016; Hunt et al., 2010), counseling or brief advice (Alessi & Petry, 2014; Dunn et al., 2010; Mooney et al., 2008; Robles et al., 2005; Rohsenow et al., 2017; Rohsenow et al., 2015; Winhusen et al., 2014), relapse prevention (Mooney et al., 2008; Shoptaw et al., 2002), and motivational interviewing (Rohsenow et al., 2015). Finally, nine studies combined CM with nicotine replacement therapy (NRT) (Campbell et al., 1995; Cooney et al., 2017, 2015; Guydish et al., 2016; Rohsenow et al., 2017, 2015; Shoptaw et al., 2002; Winhusen et al., 2014; Wiseman et al., 2005), and four with other pharmacotherapy (Dunn et al., 2010; Mooney, Babb, Jensen, & Hatsukami, 2005; Sigmon et al., 2016; Winhusen et al., 2014).

Of the 22 CM studies, a total of 19 used CM based on voucher-based reinforcement therapy, eight of which provided monetary incentives (Beckham et al., 2018; Campbell et al., 1995; Drummond et al., 2014; Hunt et al., 2010; Mooney et al., 2008; Orr et tal., 2018; Schmitz et al., 1995; Tuten et al., 2012). The remaining three

studies (Alessi et al., 2008; Alessi & Petry, 2014; Winhusen et al., 2014) used a prize-based procedure through a fish-bowl. Maximum earnings in vouchers within CM conditions ranged between US$10 and US$1,351, with an average of US$390.72.

All studies included biochemical validation (carbon monoxide or cotinine) as a measure of smoking abstinence. Moreover, the most common abstinence criterion was 7-day point-prevalence (13/59.09%), followed by continuous abstinence (6/27.27%), and percentage of negative CO samples (3/13.63%). The most utilized criterion for assessing smoking reduction was the number of cigarettes (14/63.63%) followed by a decrease in biochemical variables (carbon monoxide or cotinine) (3/13.63%).

Treatment length ranged from one single visit to sixteen weeks, with an average of 6.66 weeks. With regards to the follow-ups, seven studies (31.81%) had no follow-up beyond EOT, six (27.27%) had the furthest follow-up between two weeks and three months, and another six (27.27%) had the longest follow-up at six months. The remaining three (13.63%) reported smoking outcomes at 12-month.

Two meta-analyses were carried out, with a total of 12 studies being obtained that offered abstinence results at short-term and eight studies that offered abstinence results at time frames beyond treatment termination. Additionally, one meta-analysis was carried out including six studies that reported smoking reduction at short-term. Given that only four trials reported smoking reduction outcomes beyond EOT, a meta-analysis was not carried out and the results were narratively presented instead. Regarding the substance use outcomes, due to the fact that only 12 studies reported this information and the outcome measures were heterogeneous, these results were presented narratively as well.

Meta-analysis: Smoking outcomes

Forest plots of smoking cessation results at short-term and long-term are shown in Figure 2. For short-term abstinence, random effects produced a pooled risk ratio of 2.555 (95% CI: 1.730-3.775; $p \leq .001$), CM being significantly better than comparison arms. Heterogeneity was medium in magnitude (I^2=30.987%; Q=15.939; p =.143). In the longest follow-ups, CM interventions did not show enhanced effects on abstinence beyond those shown in comparison arms (RR=1.029; 95% CI: 0.577, 1.836; p = .922). Heterogeneity was low in magnitude (I^2<0.001%; Q=6.309; p =.504).

[Figure 2 about here]

A forest plot of smoking reduction results at short-term is shown in Figure 3. For short-term smoking reduction, random effects produced a pooled effect size estimate of .601 (95% CI: .372-.831; $p \leq .001$), CM being significantly better than comparison groups. Heterogeneity was medium in magnitude (I^2=34.12%; Q=7.589; p =.18).

[Figure 3 about here]

Moderation analyses

Treatment setting did not moderate smoking abstinence outcomes either at post-treatment (Q(1)= 0.22, p = .638) or in long-term time frames (Q(1)= 0.31, p = .576), but it did work as an effective moderator for post-treatment smoking reduction outcomes (Q(1)= 4.893, p = .027). In particular, compared to residential settings (*SMD* =.448, 95%CI .254-.643), being in an outpatient treatment (*SMD*=.836, 95%CI .553-1.119) significantly predicted higher effects.

An analysis of short-term smoking abstinence outcomes by CM combination did not yield statistical significance. Using CM only (Q(2) = 4.41, p = .11) did not differ

relative to its combination with either psychological or pharmacotherapy (RR = 10.735 vs. 1.543 and 2.415, respectively). Similarly, there were no differences in smoking reduction at short-term (Q(2) = 1.385, *p* = .50), showing an effect size of .627, .265, and .658 for CM only and in combination with psychological and pharmacological intervention, respectively. There were no significant differences in abstinence at long-term follow-up between the combination of CM with a psychological and a pharmacological intervention (Q(1) = .695 , p = .404, RR = .791 vs. 1.317, respectively)

The comparison group arm used to assess CM efficacy (i.e., treatment as usual or non-treatment versus other smoking cessation treatment) did not affect abstinence outcomes at short-term (Q(1) = 0.00, *p* = .99), or long-term (Q(1) = 0.02, *p* = .891). Similar results were observed for reduction at short-term (Q(1) = 0.32, *p* = .573).

Magnitude of incentives did not impact short- (*p* = .788) or long-term smoking abstinence (*p* = .199) or reduction outcomes (*p* = .945). Smoking abstinence rates at short-term (*p* = .602), long-term abstinence (*p* = .175), and reductions at post-treatment (*p* = .496), were not affected by treatment length.

Systematic review: smoking outcomes

Most of the studies included abstinence rates (19/22, 86.36%), although not all studies offered abstinence rates by group or used 7-day point prevalence. The use of substantially different smoking abstinence measures (percentage, number or average of negative CO tests, days of consecutive negative CO tests, number or average of negative cotinine samples, etc.) precluded the comparison of the results on smoking abstinence among the different measures.

Overall, considering all smoking cessation treatments regardless of whether they included CM, mean abstinence rates were 20.25% at EOT (Beckham et al., 2018; Campbell, et al., 1995; Cooney et al., 2017, 2015; Dunn et al., 2010; Guydish et al., 2016; Hunt et al., 2010; Mooney et al., 2008; Robles et al., 2005; Shoptaw et al., 1996, 2002; Sigmon et al., 2016; Tuten et al., 2012; Winhusen et al., 2014), 7.83% at three-month follow-up (Alessi et al., 2008; Cooney et al., 2015; Dunn et al., 2010, Hunt et al., 2010; Rohsenow et al., 2017, 2015; Winhusen et al., 2014), and 5.85% at six-month follow-up (Alessi & Petry, 2014; Alessi et al., 2008; Cooney et al., 2017; Drummond et al., 2014; Rohsenow et al., 2017, 2015; Shoptaw et al., 2002; Winhusen et al., 2014), respectively.

Taking into account only those studies that included CM in the experimental group compared to a control group, in which participants received the same treatment without the CM component, mean abstinence rates at EOT were 36.03% vs 7.84% (Cooney et al., 2017, 2015; Dunn et al., 2010; Hunt et al., 2010; Shoptaw et al., 2002; Sigmon et al., 2016; Tuten et al., 2012; Winhusen et al., 2014), 12.86% vs 2.53% at three-month follow-up (Cooney et al., 2015; Dunn et al., 2010; Rohsenow et al., 2017, 2015; Winhusen et al., 2014), and 7.80% vs 1.71% at six-month follow-up (Cooney et al., 2017; Drummond et al., 2014; Rohsenow et al., 2017, 2015; Shoptaw et al., 2002; Winhusen et al., 2014).

Of the nine studies that were excluded from the meta-analysis, either because they were not a RCT, or because both groups included CM, six (66.67%) used pharmacological and psychological interventions in addition to CM. Beckham et al. (2018) and Campbell et al. (1995) used CBT+NRT+CM, and informed of abstinence rates of 40.0% and 11.0% at EOT, respectively. On the other hand, Cooney et al. (2015) and Winhusen et al. (2014) explored whether adding a smoking cessation treatment

(CBT+NRT+CM, and bupropion+counselling+NRT+CM, respectively) to one that addressed other drugs helped to increase abstinence rates. Both found higher smoking cessation rates in treatments that included tobacco use cessation ($p < .05$). Specifically, abstinence rates at posttreatment were 50.5% vs 2.2% (Cooney et al., 2015) and 25.5% vs 2.2% (Winhusen et al., 2014). At three-month follow-up, statistical differences remained, with abstinence rates of 19.0% vs 0.0% (Cooney et al., 2015) and 19.0% vs 3.0% (Winhusen et al., 2014). The other two studies (Mooney et al., 2008; Robles et al., 2005), used both bupropion and CM for smoking cessation and found abstinences rates of 12.82% and 43.75% at EOT, respectively.

Only three studies (33.33%) not included in the meta-analysis did not incorporate any pharmacological strategy and delivered CM on its own. Guydish et al. (2016) showed a decrease in the number of cigarettes from the start to EOT ($p <.01$). In addition, four participants (5.33%) abstained from smoking at EOT. In a within-subjects study design (A-B-A-B), Schmitz et al. (1995) treated five smokers with methadone maintenance and found no effects of this intervention on smoking rates ($p = .14$). Finally, in the study of Shoptaw et al. (1996), none of the smokers achieved abstinence at EOT, however, 76.5% of smokers with methadone maintenance decreased their CO levels compared to the initial value.

Systematic review: substance use outcomes

Twelve studies out of twenty-two (54.54%) included some type of information about participants' drug use after treatment (Alessi & Petry, 2014; Beckham, et al., 2018; Campbell et al., 1995; Cooney et al., 2017, 2015; Mooney et al., 2008; Orr et al., 2018; Rohsenow et al., 2017, 2015; Shoptaw et al., 1996, 2002; Winhusen et al., 2014). Except for Cooney et al. (2015), all studies included a biochemical verification of

substance use. A total of 9/22 (40.9%) (Cooney et al., 2017, 2015; Mooney et al., 2008; Orr et al., 2018; Rohsenow et al., 2017, 2015; Shoptaw et al., 1996, 2002; Winhusen et al., 2014) had an adequate design to explore the effect of the smoking treatment and/or smoking abstinence on non-nicotine substance use. Six of the twelve studies identified the unique effect of CM on substance use outcomes (Alessi & Petry, 2014; Cooney 2017; Orr et al., 2018; Rohsenow et al., 2017, 2015; Shoptaw et al., 2002).

Regarding the impact of smoking treatments, which included CM combined with other smoking cessation treatments, on drug use, a total of 3/4 (75%) found significant reductions in drug use. Specifically, Winhusen et al. (2014) found that adding a smoking cessation treatment (which included bupropion, NRT, counselling, and CM) to treatment as usual for SUD, increased drug-free days at six-month follow-up. Similarly, both studies by Rohsenow et al. (2017, 2015) showed decreased drug use across time in all treatment conditions. On the other hand, Cooney et al. (2015) found no differences in rates of heavy drinking between intensive alcohol treatment plus smoking cessation intervention (CBT + NRT + CM) and intensive alcohol treatment only. However, both increased the frequency of alcohol abstinent days from 40% of days at baseline to 95% of days at the three-month follow-up ($p < .001$).

Smoking abstinence had a positive impact on the use of other drugs. Shoptaw et al. (1996, 2002) reported that patients that attained longer periods of smoking abstinence were significantly less likely to use cocaine and more likely to provide negative opiate or cocaine urine tests ($p < .001$). Lastly, Cooney et al. (2017) found that tobacco abstinence mediated the relationship between alcohol and other drug abstinence at one-month follow-up.

Concerning the impact of CM on substances other than nicotine, only one study found a positive effect ($p < .05$) on alcohol abstinence compared with the control

condition at EOT (Orr et al., 2018). The other five studies found no differences between CM and comparison groups. Alessi et al. (2014) found no differences between CM and standard care in days of substance use at follow-ups ($p > .45$). Similarly, Cooney et al. (2017) found no differences in abstinence rates between CBT + NRT vs CBT + NRT + CM ($p > .05$). Moreover, both studies of Rohsenow et al. (2017, 2015) found no effect of CM on substances other than nicotine in any of the follow-ups. Lastly, Shoptaw et al. (2002) found that relapse prevention led to lower rates of opiate use in comparison with CM and other interventions ($p < .001$).

Methodological quality ratings

Individual and global scores for each study included in the meta-analysis are in Table 2. Overall, seven trials (53.84%) were rated as strong, six (46.15%) were given a moderate quality score, and none of them were deemed to be weak. The main component that decreased the overall quality was the high drop-out rate of the interventions.

[Table 2 about here]

Publication bias

There was no marked presence of publication bias, as evinced by non-significant results on the purported publication bias analyses. Egger's test was significant for the post-treatment smoking abstinence outcomes (p=.019). No publication bias was obtained for either the long-term abstinence (p=.333) or short-term reduction outcomes (p=.338). Kendall's test yielded no significant results (cigarette reduction: $\tau_{\text{post-treatment}} = .133$, $p = .71$; smoking abstinence: $\tau_{\text{post-treatment}} = .287$, $p = .19$; $\tau_{\text{follow-ups}} = .178$, $p = 54$), thus indicating absence of asymmetry. Although Tweedie's trim-and-fill analysis suggested the presence of four unpublished studies for the post-treatment results and

one for those pertaining to subsequent follow-ups, the imputation of the data from these studies did not significantly alter the observed estimates [$RR_{post\text{-}treatment}$ before trimming: 2.307, 95%CI: 1.746-3.047; $RR_{post\text{-}treatment}$ after trimming: 2.091, 95%CI: 1.595, 2.741; $RR_{follow\text{-}ups}$ before trimming: 1.029, 95%CI: 0.577-1.835; $RR_{follow\text{-}ups}$ after trimming: 0.991, 95%CI: 0.561, 1.751).

Discussion

This systematic review and meta-analysis examined the effectiveness of CM on smoking cessation for patients with SUD. This study is relevant due to the high smoking-related burden and low smoking-abstinence rates observed in this population.

The meta-analysis revealed increased short-term smoking abstinence and reduction with CM relative to a set of pharmacological and behavioral treatments. In the studies included in the meta-analysis, patients treated with CM were more likely to successfully quit or reduce tobacco than the comparison groups at short-term. Of the studies that reported point-prevalence or continuous abstinence at short-term, patients in the groups that included CM were 4.59 times more likely to achieve smoking abstinence than comparison groups at that point. This aligns with the literature documenting the efficacy of CM in promoting smoking abstinence in the general population (Cahill et al., 2015; Sigmon & Patrick, 2012) and stresses the necessity to provide SUD smokers with CM, as it represents a clinically meaningful therapy option that facilitates initial smoking abstinence. Nevertheless, consistent with findings from a previous study (Notley et al., 2019), CM treatment effects were no longer significant at long-term follow-ups, showing similar abstinence rates between CM and comparison groups.

The deterioration of CM effects beyond treatment termination has been noted previously (Prendergast et al., 2006) and is consistent with other studies in SUD

smokers where improved smoking abstinence within treatment did not result in meaningful smoking abstinence rates in the longer term (Notley et al., 2019; Thurgood et al., 2016). The maintenance of CM effects following the discontinuation of incentives is an important challenge in clinical research and thus a research priority. As per the CM literature (see e.g., Secades-Villa et al., 2019; Vlad, Arnsten, & Nahvi, 2020), there is promising evidence that extended incentives during follow-ups promote sustained abstinence, both in tobacco and substance use. Combining CM with other interventions that provide skills for sustaining abstinence (e.g., CBT or relapse prevention treatment) (Carroll et al., 2012) and the use of incentive programs in workplaces requiring the provision of negative tests for extended periods (Chudzynski, Roll, McPherson, Cameron, & Howell, 2015; Silverman, DeFulio, & Sigurdsson, 2012) have also been shown as effective vehicles to facilitate long-term abstinence. More recently, the use of technology platforms for CM delivery has gained interest as it represents a low-cost procedure that might facilitate continuing reinforcement over longer periods (Getty et al., 2019).

It is worth mentioning that CM combination (i.e.., CM alone versus added to pharmacotherapy or psychological treatment) did not impact abstinence outcomes. This suggests that providing CM alone for SUD smokers would be a more cost-efficient approach than using a combination protocol, particularly in view of the absence of additive effects of the latter. This, however, should be interpreted in the context of the limited number of studies, and warrants further investigation.

On another note, we found that treatment setting moderated CM effectiveness. Compared to SUD smokers undergoing outpatient treatment, those in residential settings attained lower smoking reductions. Quitting smoking is notoriously difficult in

residential settings because tobacco use is a widespread coping strategy for dealing with anxious situations as well as being a form of socialization (Fallin-Bennett, Parker, Miller, Ashford, & Hahn, 2018). Given that cigarette smoking is commonly unrestricted in treatment facilities (e.g., it is permitted indoors or in outdoor spaces, such as the courtyard) (González-Roz et al., 2019; Hahn, Warnick, & Plemmons, 1999), quitting attempts may be hampered by the lack of non-smoking organizational cultures (Guydish, Wahleithner, Williams, & Yip, 2020; Ingram et al., 2017).

It is also worth mentioning that, contrary to prior research (Sigmon & Patrick, 2012), using higher magnitudes of reinforcement did not predict enhanced smoking reductions or abstinence. Nonetheless, given the low variability in the magnitude of incentives used in the reviewed studies, no definitive conclusions can be drawn on this issue, and further research is needed to determine the optimal magnitude of incentives that should be used in this population.

Results also showed that individuals in SUD treatment or recovery receiving smoking-cessation treatments that include a CM component might evidence not only improvements in smoking outcomes, but also in substance-use outcomes as well. This same patterning of results has also been more broadly reported (Baca & Yahne, 2009; Friend & Pagano, 2005; McKelvey et al., 2017; Piper, Kenford, Fiore, & Baker, 2012), and suggests that smoking cessation and even reductions in tobacco use may be associated with enhanced drug treatment outcomes. This is an important finding since integration of smoking cessation care in drug treatment settings is low (Skelton et al., 2019), and patients' and treatment providers' concerns about sobriety may still serve as substantial barriers to smoking cessation efforts during addiction treatment (Fine, Bearnot, Rigotti, & Baggett, 2019; González-Roz et al., 2019).

No superior effects of CM were obtained on substance use other than nicotine when compared to other effective smoking-cessation interventions. As it was evidenced by several studies (Cooney et al., 2015; Rohsenow et al., 2017, 2015; Winhusen et al., 2014), smoking cessation treatment appears to be related to higher substance use abstinence rates; whereas among the six CM studies, only one found statistically significant differences between groups in substance use abstinence. That is, although positive effects are shown when CM is delivered, its effect seems not to be enough to facilitate abstinence rates from substances other than nicotine beyond the effects of other efficacious approaches. Of note is that studies that assessed the sole effect of CM, used excessively low magnitude reinforcers (i.e., US$10-US$73). Nevertheless, the evidence to date is insufficient, since only five studies analyzed the differential effects of CM over other effective treatments.

Results from this study are of major clinical importance; however, there are several limitations intrinsic to the reviewed studies that should be addressed. These limitations primarily pertain to the lack of consistency in CM procedures across studies [i.e., different reinforcement magnitudes not based on gold standard guidelines; see Petry (2000)], and small study sample sizes, probably due to high attrition rates, especially after treatment termination. Also, the use of different measurements (i.e., smoking abstinence and reduction) precluded direct comparisons across studies and thus limited us in identifying effective interventions. Following the recommendations by the Society for Research on Nicotine and Tobacco (Benowitz et al., 2019), smoking abstinence must be biochemically verified considering the same cut-off points according to the guidelines. This study is another example that shows that adopting one or more empirically validated and clinically relevant outcome measures is essential to advance research on smoking treatment. It is concerning that most of the studies that could not

be meta-analyzed and were narratively reviewed merely placed attention on reporting statistically significant results instead of providing smoking or other substance use abstinence outcomes in terms of 7-day point-prevalence or continuous abstinence, the gold standard in tobacco research (Hughes et al., 2010). In the same vein, authors should be encouraged to provide abstinence rates using these aforementioned measures at least. Finally, close to 50% of the reviewed studies did not evaluate the effects of smoking cessation treatments on other substance use outcomes, thereby limiting the study's power to conclude any particular effect of either CM or smoking cessation on non-nicotine SUDs.

Strengths of this review include the fact that it concentrated mostly on randomized controlled trials, the large sample in terms of the number of studies and participants included (n = 2,186), and the comparability of trials in terms of participant characteristics. Also, all studies included in the meta-analysis were rated as strong or moderate in terms of methodological quality and no significant impact of publication bias was found.

Implications and conclusion

In conclusion, CM for smoking cessation increases short-term abstinence in SUD patients undergoing treatment or in recovery, although long-term effects were not found. There have been concerns about the feasibility of providing CM and, more broadly, smoking cessation quitting aids to SUD patients in real-world contexts (i.e., substance abuse treatment facilities). This clearly demonstrates the feasibility of integrating smoking cessation interventions, and specifically CM, into existing SUD infrastructures. Individuals with SUD can successfully quit smoking and should be offered evidence-based smoking cessation treatments, including CM, especially given

the positive effects of smoking abstinence on improvements in other substance outcomes.

Data transparency statement

The authors claim that this represents an original paper. The data have not been previously published.

Table 1.
Study characteristics

Author (year)	Sample size (% male)	Age Mean±*SD*	Cigarettes Mean±*SD*	Substance type (%)	Conditions	Maximum incentives value	Treatment length	Longest follow-up	Primary outcome measures included in meta-analysis
Alessi et al. (2008)	24 (100%)	36.6±7.8	18.8±7.0	ALC (96%), COC (58%), OPI (33%)	NC vs CM[b]	$910	12 weeks	6 months	EOT abstinence: % CO negatives Follow-up abstinence: NA EOT reduction: Number of cigarettes
Alessi et al. (2014)	45 (100%)	37.9±9.9	18.7±6.3	POLY (65%), OPI (18%), other drugs (18%)	Monitoring (brief behavioral support) vs Monitoring + CM[b]	$473	4 weeks	6 months	EOT abstinence: PP Follow-up abstinence: PP EOT reduction: Number of cigarettes
Beckham et al. (2018)	5 (20.0%)	43.6±8.9	10.6±11.2	THC (100%)	CBT + NRT + mobile CM for smoking and cannabis	$1351[a]	7 weeks	6 months	
Campbell et al. (1995)	90	-	23	OPI (50%), STI (28%), other drugs (21%)	CBT + NRT + CM vs Control (waiting-list)	$105	16 weeks	EOT	
Cooney et al. (2015)	151 (86.1%)	49.1±9.0	16.2±8.7	ALC (100%), COC (33%), THC (17%), other drugs (7%)	Intensive alcohol treatment (CBT+MI+12 step) + CBT + NRT + CM for smoking vs Intensive alcohol treatment	$140	3 weeks	3 months	
Cooney et al. (2017)	83 (96.4%)	49.8±9.9	20.3±9.7	ALC (100%), COC (30%), other drugs (9%)	CBT + NRT vs CBT + NRT + CM	$140	3 weeks	6 months	EOT abstinence: PP Follow-up abstinence: PP EOT reduction: NA

Drummond et al. (2014)	100 (53.0%)	49.8±9.9	> 1 in the last month	ALC (51%), NON-IDU (32%), IDU (21%)	Usual Care vs Usual Care + CM	$225	1 day	6 months	EOT abstinence: NA Follow-up abstinence: PP EOT reduction: NA
Dunn et al. (2010)	40 (33.0%)	31.0±1.8	18.5±1.8	MTD (100%)	NC vs CM (both with counseling + bupropion under request)	$362.5	2 weeks	3 months	EOT abstinence: PP Follow-up abstinence: PP EOT reduction: Number of cigarettes
Guydish et al. (2016)	75 (0.0%)	39.7±10.3	12.3±5.6	STI (58%), ALC (25%), OPI (16%), other drugs (1%)	RG vs RG + CM	$10	3 weeks	1 months	
Hunt et al. (2010)	39 (100%)	-	14.5±9.6	SUD	CBT vs CBT + CM	$90	4 weeks	3 months	EOT abstinence: PP Follow-up abstinence: PP EOT reduction: NA
Mooney et al. (2008)	40 (85.0%)	34.2±11.2	23.8±10.7	OPI, COC	Buprenorphine + bupropion vs Buprenorphine + placebo (both with counseling + RP + CM for cocaine, opiates and smoking)	$150[a]	10 weeks	EOT	
Orr et al. (2018)	34 (64.7%)	35.0±10.5	17.6±7.2	ALC (100%), THC (50%), other drugs (18%)	NC ALC and TOB vs CM ALC + NC TOB vs NC ALC + CM TOB vs CM ALC and TOB	$120	4 weeks	EOT	EOT abstinence: % CO negatives Follow-up abstinence: NA EOT reduction: NA
Robles et al. (2005)	16 (100%)	32.6±1.3	15.3±3.7	STI (63%), ALC (19%), OPI (13%), other drugs (6%)	CM + counseling + Bupropion	$823	4 weeks	2 weeks	

Rohsenow et al. (2015)	184 (44.6%)	34.5±8.4	22.3±9.4	COC (74%), ALC (71%), OPI (53%), THC (37%)	MI + CM vs MI + NC vs BA + CM vs BA + NC	$433	19 days	12 months	EOT abstinence: CA Follow-up abstinence: PP EOT reduction: NA
Rohsenow et al. (2017)	340 (67.0%)	37.6±10.0	19.5±7.4	ALC (76%), COC (60%), OPI (49%), THC (36%)	NC vs CM (both with BA + NRT)	$433	19 days	12 months	EOT abstinence: CA Follow-up abstinence: PP EOT reduction: Number of cigarettes
Schmitz et al. (1995)	5 (80.0%)	38.4±5.5	-	MTD (100%)	CM	$40	10 weeks	EOT	
Shoptaw et al. (1996)	17 (76.5%)	43.8	30.0	MTD (100%), OPI (41%), COC (24%)	CM	$73	4 weeks	EOT	
Shoptaw et al. (2002)	175 (60.6%)	44.0±7.8	22.1±9.7	MTD (100%), ALC (17%), other drugs (43%)	NRT vs RP vs CM vs RP + CM (all with NRT)	$447.5	12 weeks	12 months	EOT abstinence: PP Follow-up abstinence: PP EOT reduction: NA
Sigmon et al. (2016)	63 (41.0%)	34.4±10.3	18.2±9.5	MTD (71%), BUP (29%)	NC vs CM (2 week after, all CM + bupropion under request)	$932.5	12 weeks	EOT	EOT abstinence: PP Follow-up abstinence: NA EOT reduction: Cotinine
Tuten et al. (2012)	102 (0.0%)	30.8±6.0	18.0±8.6	MTD (100%)	NC vs CM vs TAU	$857.5	12 weeks	6 weeks	EOT abstinence: PP Follow-up abstinence: NA EOT reduction: CO
Winhusen et al. (2014)	538 (52.0%)	36.4±10.0	16.3±7.9	STI (100%), ALC (27%), THC (14%), other drugs (5%)	SUD TAU vs SUD TAU + Bupropion + NRT + CM[b]	$380	10 weeks	6 months	
Wiseman et al. (2005)	20 (100%)	40.1±7.5	22.4±6.3	COC (100%), ALC (30%), other drugs (5%)	NC + Placebo vs NC + NRT vs CM + Placebo vs CM + NRT	$100	2 weeks	EOT	EOT abstinence: CO negative Follow-up abstinence: NA EOT reduction: NA

Note. ALC = Alcohol; COC = Cocaine; OPI = Opiates; NC = Non-Contingent; CM = Contingency Management; NA = Not applicable; POLY = Polydrugs; PP = Point-prevalence; THC = Cannabis; CBT = Cognitive Behavioral Therapy; NRT = Nicotine Replacement Therapy; STI = Stimulants; MI = Motivational interviewing; IDU = Injection Drug Users; MTD = Methadone; RG = Smoking Cessation Readiness Group; SUD = Substance Use Disorder; RP = Relapse Prevention; EOT = End-of-treatment; TOB = Tobacco; BA = Brief Advice; CA = continuous abstinence; BUP = Buprenorphine; TAU = Treatment As Usual.

[a]CM was used to reinforce abstinence from both smoking and other drugs
[b]CM was prize-based

Table 2. *Methodological quality assessment*

	Selection bias	Study design	Confounders	Blinding	Data collection	Withdrawals	Global ratings
Alessi et al. (2008)	Weak	Strong	Strong	Moderate	Strong	Weak	Moderate
Alessi & Petry (2014)	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Cooney et al. (2017)	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Drummond et al. (2014)	Weak	Strong	Weak	Moderate	Strong	Weak	Moderate
Dunn et al. (2010)	Strong	Strong	Strong	Moderate	Strong	Moderate	Strong
Hunt et al. (2010)	Moderate	Strong	Strong	Moderate	Strong	Weak	Moderate
Orr et al. (2018)	Moderate	Strong	Strong	Moderate	Strong	Weak	Moderate
Rohsenow et al. (2015)	Strong	Strong	Strong	Moderate	Strong	Moderate	Strong
Rohsenow et al. (2017)	Strong	Strong	Strong	Moderate	Strong	Strong	Strong
Shoptaw et al. (2002)	Strong	Strong	Strong	Moderate	Strong	Moderate	Strong
Sigmon et al. (2016)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Moderate
Tuten et al. (2012)	Moderate	Strong	Strong	Moderate	Strong	Moderate	Moderate
Wiseman et al. (2005)	Strong	Strong	Weak	Strong	Strong	Strong	Strong

Figure 1. Flow diagram of the literature search procedure

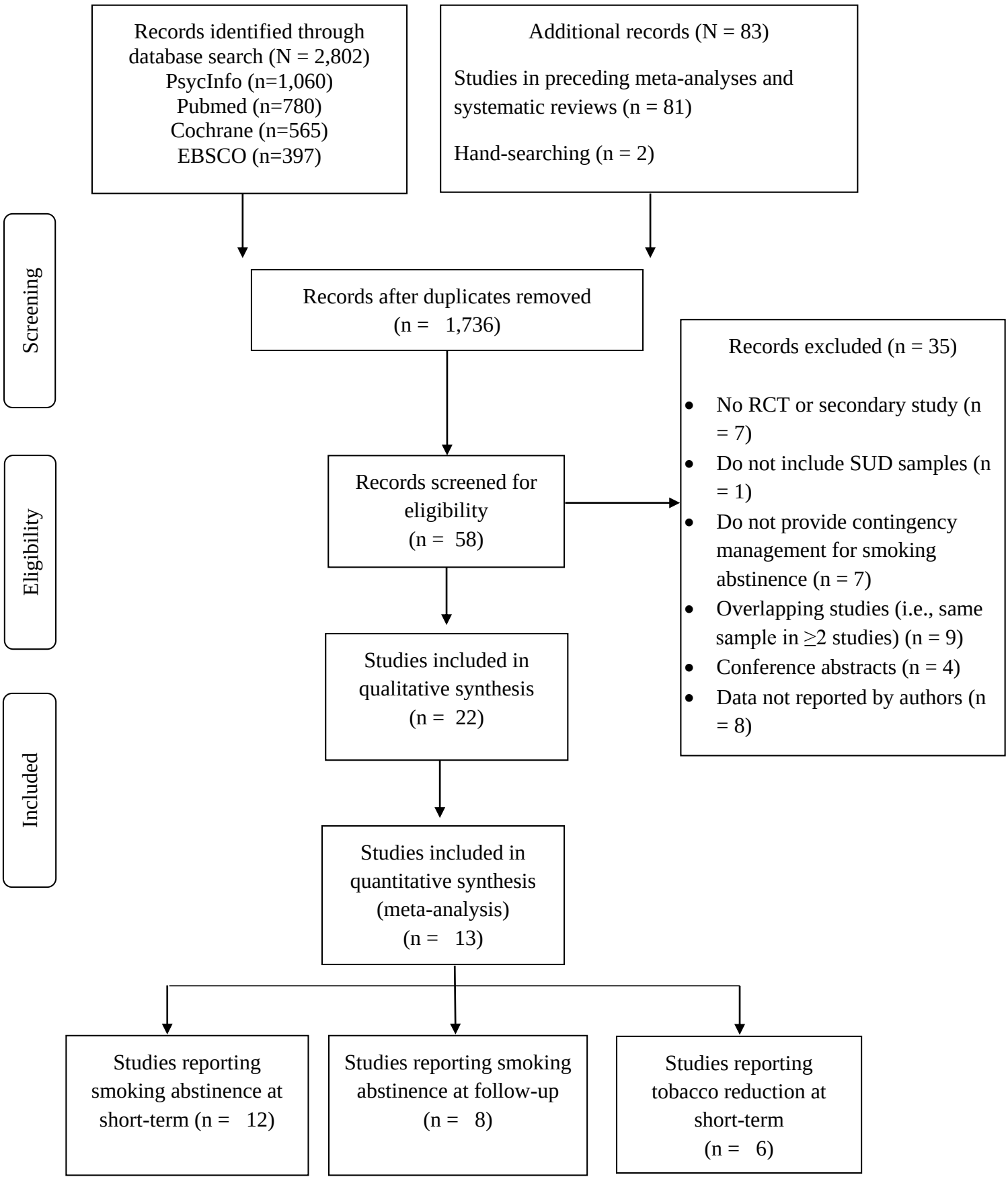


Figure 2. Forest plots of the meta-analytic findings of smoking abstinence results at end-of-treatment and follow-ups

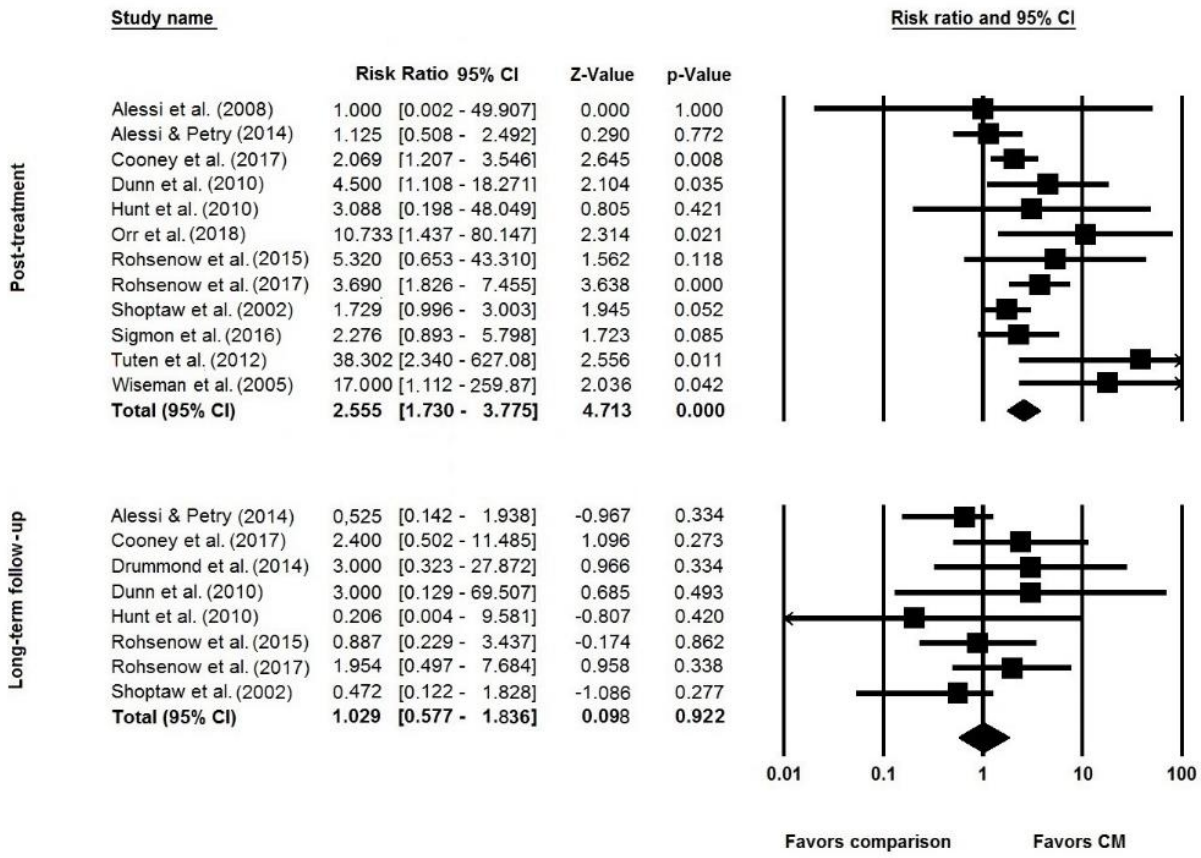
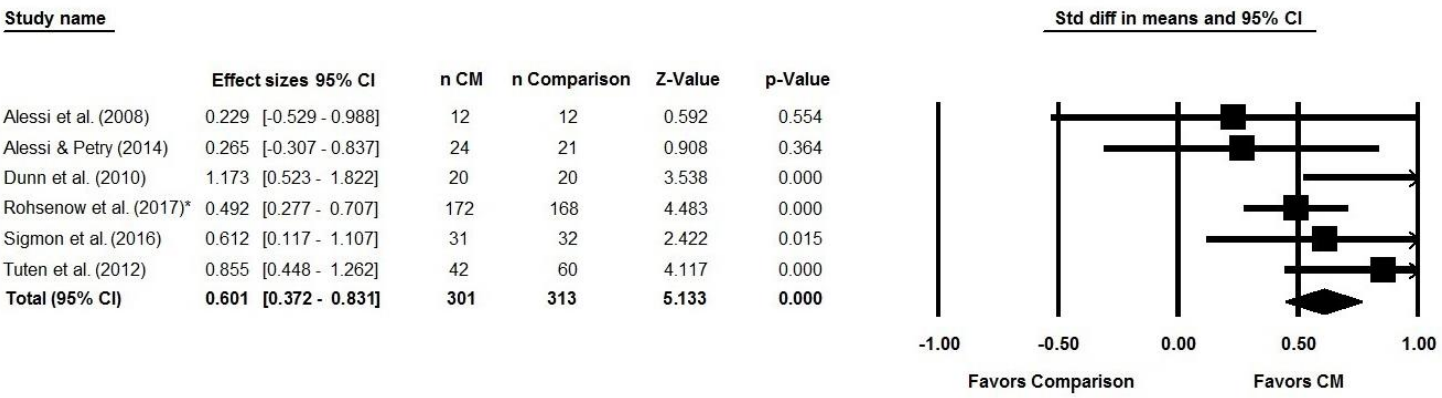


Figure 3. Forest plot of smoking reduction results at end-of-treatmen



*Data for one month-follow up is included

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