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Contingency Management Interventions for Tobacco and other Substance Use Disorders in Pregnancy

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Abstract

Contingency management (CM) is an effective intervention for reducing use of licit and illicit substances in a variety of populations. Pregnant women are a vulnerable population with much to gain from effective interventions for substance use disorders, and for whom CM interventions may be especially well-suited. We reviewed the literature on CM interventions among pregnant women with tobacco and other substance use disorders with three aims: 1) describe the effectiveness of CM for reducing use of tobacco and other substances during pregnancy, 2) describe the effects of CM interventions on infant outcomes, and 3) identify needs for future research on CM in pregnancy. Our search strategy revealed 27 primary studies of CM in pregnancy. CM was effective in the majority of studies targeting nicotine abstinence, and results were mixed in studies targeting illicit substances. A variety of methodologies were used within the relatively small number of studies making it difficult to identify underlying mechanisms. Also, very few studies reported maternal and infant outcomes, and significant effects of CM were only apparent when secondary analyses pooled data from multiple studies. Furthermore, there is extremely limited data on the cost-effectiveness of CM interventions in pregnancy. Future research should address these three areas to better determine the ultimate value of CM as an efficacious treatment for pregnant women with substance use disorders.

Keywords

contingency management; pregnancy; tobacco; substance use disorder; incentives

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Substance use during pregnancy is the leading preventable cause of poor birth outcomes, maternal complications, and associated health care expenditures (Cnattingius, 2004; Patrick et al., 2012). Tobacco is the most commonly used substance during pregnancy, used by approximately 12% of all pregnant women (Tong et al., 2013) with substantially higher rates among socioeconomically disadvantaged women (Higgins & Chilcoat, 2009; Kandel, Griesler, & Schaffran, 2009). Smoking is associated with multiple adverse maternal and fetal/infant health outcomes including placental abruption, placenta previa and preeclampsia, low birth weight, preterm birth, neonatal mortality and sudden infant death syndrome (Cnattingius, 2004). Approximately 4.7% of pregnant women report prior-month use of illicit substances, with 3.4% reporting marijuana use followed by 0.8% misusing prescription pain relievers (Center for Behavioral Health Statistics and Quality, 2016). Prescription and non-prescription (i.e., heroin) use account for 41% of pregnant women's admissions to substance use disorder treatment programs (SAMHSA, 2015). Opioid-exposed births increase the risk of infants developing Neonatal Abstinence Syndrome (NAS), which is a temporary and treatable condition, but often requires lengthy, costly inpatient hospital stays (Kocherlakota, 2014). Annual healthcare costs associated with opioid-exposed births have topped $1.5 billion (Patrick et al., 2015).

Pregnancy is a time when many women are motivated to address substance use disorders (McBride, Emmons, & Lipkus, 2003; Daley, Argeriou, & McCarthy, 1998), but the vast majority of these women require interventions to reduce or cease substance use. For example, many women reduce the number of cigarettes they smoke upon learning of pregnancy (Heil et al., 2014), but fewer than 20% of women cease smoking completely by the time of their delivery without assistance (Solomon & Quinn, 2004; Ma, Goins, Pbert, & Ockene, 2005). Interventions ranging from brief counseling to intensive behavioral treatments and pharmacotherapies can double the likelihood of cessation (Chamberlain et al., 2013). For women with illicit substance use disorders, treatment tends to be more intense, ranging from counseling to medication assisted treatments to comprehensive inpatient hospital services. Pregnant women who enter treatment for illicit substance use disorders are very likely to be using additional substances, chiefly tobacco (Akerman et al., 2015), which necessitates comprehensive treatment.

There are few interventions that are as universally effective in reducing substance use as Contingency Management (CM; Lussier, Heil, Mongeon, Badger, & Higgins, 2006; Prendergast, Podus, Finney, Greenwell & Roll, 2006; Dutra et al., 2008). CM is based on the principles of operant conditioning and involves delivering reinforcers contingent upon a person exhibiting specific, objectively verifiable behaviors. In the realm of substance use disorders, the behavior to be reinforced is typically providing a biological specimen (e.g., urine) that is free of a particular substance. Among men and non-pregnant women, positively reinforcing biochemically-verified abstinence has been consistently shown to decrease use of alcohol (Petry, Martin, Cooney, & Kranzler, 2000), tobacco (Ledgerwood, Arfken, Petry, & Alessi, 2014; Ledgerwood, 2008), methamphetamine (Roll, 2007), benzodiazepines (Chutuape, Silverman, & Stitzer, 1999; Stitzer, Bigelow, & Liebson, 1979; Stitzer, Bigelow, Liebson, & Hawthorn, 1982), cocaine (Higgins et al., 1994; Higgins, Wong, Badger, Ogden, & Dantona, 2000; Petry, Martin, & Simcic, 2005; Silverman et al., 1996), and marijuana

(Budney, Moore, Rocha, & Higgins, 2006). CM interventions that reinforce attendance to substance use disorder treatment or medical care have been shown to increase attendance at group and individual substance use disorder treatment sessions as well as prenatal care (Elk et al., 1998; Jones et al., 2001; Ledgerwood, Alessi, Hanson, Godley, & Petry, 2008; Petry et al., 2005).

Nevertheless, CM has been criticized for providing only short-term changes in substance use at a high cost, and is less preferred by clinicians as a result (Benishek, Kirby, Dugosh, & Padovano, 2010; Kirby, Benishek, Dugosh, & Kerwin, 2006). These perceived shortcomings of CM are directly countered when CM is applied during pregnancy. Pregnancy is a brief period of time when temporary changes in substance use can benefit both maternal and infant health, in turn reducing the human and financial costs associated with substance use during pregnancy. In this review, we discuss how CM has been used among pregnant women with substance use disorders, including its effectiveness in reducing maternal substance use, increasing treatment attendance, and improving maternal and child health. We also discuss opportunities for future research into CM during pregnancy.

Method

Studies that examined the use of incentives in treatment for substance use disorders among pregnant women were collected. PsycINFO, Web of Science, and PubMed were queried using the following terms: contingency management or token economy or voucher or prize or incentive and pregnant or perinatal or postnatal or postnatal. There were no restrictions with regard to publication date, except that the articles had to have been indexed in one of the three databases by the time of the search (October 1, 2016). In the interest of only including peer-reviewed studies, dissertation abstracts were not searched. PsycINFO, Web of Science, and PubMed returned 255, 487, and 2,722 results, respectively. Given the high number of studies returned in the PubMed search, the search query was narrowed to only include those studies that contained the search terms in the abstract or title, with 170 studies meeting these criteria. In total, 912 study titles and abstracts (170 from Pubmed, 255 from PsycINFO and 487 from Web of Science) were reviewed by two authors (J.D.E. and M.M.C). Peer-reviewed studies that were published in English, mentioned pregnancy, the perinatal period, and/or contingency management, and empirical and/or review papers advanced to full text review. This strategy identified 214 articles, 62 of which were duplicates. Therefore, the full texts of 152 articles were extracted by two of the authors (J.D.E. and M.M.C.) and reviewed by two other authors (D.J.H. and D.L.W.).

During full text review, studies were included if: 1) the target population was pregnant or perinatal women with current substance use disorders; 2) the study included or reported contingency management outcomes; 3) the study included an independent sample for whom results were not previously published elsewhere; and 4) reinforcers were provided for abstinence or treatment attendance. Disagreements on these criteria were settled by consensus between these four reviewing authors. All available reviews and cited references were examined to ensure that all relevant studies were extracted based on the search strategies described above. Finally, all authors reviewed their personal collections and found

one article not identified by the search strategy. In total, 27 studies met the above inclusion criteria and are presented below.

Results

Studies Targeting Nicotine

Details of the studies that targeted nicotine abstinence are displayed in Table 1. Of the 14 studies targeting nicotine abstinence, nine were RCTs (Donatelle, Prows, Champeau, & Hudson, 2000; Glover, Kira, Walker, & Bauld, 2015; Harris & Reynolds, 2015; Heil et al., 2008; Higgins et al., 2014; Ondersma et al., 2012; Tappin et al., 2015; Tuten, Fitzsimons, Chisolm, Nuzzo, & Jones, 2012a; Walsh, Redman, Brinsmead, Byrne, & Melmeth, 1997), three were non-randomized studies (Gadomsky, Adams, Tallman, Krupa, & Jenkins, 2011; Higgins et al., 2004; Ker, Leischow, Markowitz, & Merikle, 1996), and two were single-arm prospective cohort studies (Ierfino et al., 2015; Radley et al., 2013). All studies employed some form of biochemical verification including expired carbon monoxide (CO), urinary cotinine, salivary cotinine, or salivary thiocyanate. Twelve studies employed voucher-based reinforcement where all participants who met the biochemical verification criteria received reinforcement, and two used prize-based reinforcement where participants who met criteria received a chance to win some cash-valued prize. Six studies noted that nicotine replacement therapy was offered to participants, but was not a requirement in any study. One study collected data on additional substance use, specifically alcohol and marijuana (Harris & Reynolds, 2015), and one study was conducted among methadone-maintained women (Tuten et al., 2012a), but neither study statistically controlled for illicit substance use. One study explicitly excluded women who used opioids, stimulants, or antipsychotics (Higgins et al., 2014). Several secondary analyses of data from these studies have been published and are not included in Table 1.

Randomized controlled trials—Of the nine RCTs, seven found that CM produced significantly greater nicotine abstinence than control conditions. The percentage of participants in CM conditions who achieved abstinence in these studies ranged from 13% to 45%, while 0% to 18% of control participants met abstinence criteria. In the seminal RCT reported in Donatelle et al. (2000), pregnant women were enrolled and received the intervention at area Women, Infants, and Children (WIC) sites. Biochemical verification (salivary thiocyanate) of nicotine abstinence was triggered monthly when participants self-reported abstinence. Verified abstinence earned the participant a $50 voucher and a non-smoking social support person also received a voucher. Significantly more women in the incentives condition were nicotine abstinent at 8 months gestation and 2 months postpartum than women in the control condition who did not receive vouchers.

Tappin et al. (2015) was the largest single RCT of a CM intervention targeting nicotine abstinence in pregnancy with 612 total participants. Participants in the incentives group received three opportunities across at least 12 weeks of pregnancy to earn vouchers for verified abstinence, while controls received counseling. Significantly more women in the incentives group were biochemically verified as abstinent at the final assessment during pregnancy, and self-reported continued abstinence 6 months after the incentives phase

ended. A secondary cost-effectiveness analysis of Tappin et al. (2015) revealed their intervention was at least as cost effective as other smoking cessation interventions (Boyd, Briggs, Bauld, Sinclair, & Tappin, 2016). Although these results are impressive, both studies used an infrequent abstinence monitoring scheme leaving large periods of time when there are no data on smoking behavior.

A more frequent abstinence monitoring schedule was used in several other RCTs, which increases the likelihood of identifying periods of continuous abstinence. In the studies by Heil et al. (2008) and Higgins et al. (2014), participants provided expired CO for the first five days of the study. In subsequent weeks, abstinence was verified by urinary cotinine. The schedule of samples, and thus opportunities to earn reinforcers, decreased to twice per week in weeks 2–7, weekly from weeks 7–12, and then every other week until delivery. In Higgins et al. (2014), participants could start the 12-week pattern over again once in the study, and slightly less than half of each group did so. Both studies employed an escalating, resetting schedule of reinforcement, meaning voucher values increased each consecutive time the participant met abstinence criteria and reset to a baseline when smoking was verified. In both studies, 36–46% of participants who received abstinence-contingent reinforcers met abstinence criteria by the end of pregnancy compared to 10–18% of participants who received fixed-value vouchers regardless of their expired CO or urinary cotinine. Higgins et al. (2014) included a group that received a greater proportion of their total potential voucher value early in their participation in hopes of quickening cessation of smoking, but found no benefit of this schedule over the other contingent-vouchers group. Both studies included 12 weeks of intervention in the postpartum period with a similar abstinence monitoring schedule producing similar results as the prenatal period. There were no significant differences in nicotine abstinence between contingent and non-contingent voucher groups in either study at 24 weeks postpartum, 12 weeks after incentives were discontinued.

The study by Tuten et al. (2012a) also used an escalating, resetting schedule of reinforcement, but differs from the others in several ways. First, participants were pregnant women receiving methadone-assisted treatment for opioid use disorder, a population with a high rate of smoking and for whom many interventions are ineffective (Akerman et al., 2015). Second, participants provided breath and urine samples three times per week throughout the study. Finally, the criterion for earning reinforcers became more strict across the study in an attempt to reinforce successive decreases in smoking until abstinence was achieved. For those earning reinforcers contingent upon smoking reductions, almost half achieved a 75% reduction and one third achieved abstinence by 12 weeks. Virtually none of the participants who received non-contingent reinforcers or treatment as usual met the 75% reduction or complete abstinence criteria.

The two RCTs that found no difference between CM and their respective control conditions involved significant methodological departures from the other RCTs. Ondersma et al. (2012) compared low-intensity CM to a computer-provided brief intervention based on the 5As designed in accordance with consensus guidance (Fiore et al., 2008) and found that the computerized brief intervention was superior to CM, even when combined with CM. The CM methodology in this study departs from most of the other studies as participants decided when they would request biochemical verification instead of a more frequent and consistent

schedule. Additionally, participants in the Ondersma et al. (2012) study could only earn a maximum of five reinforcers, each worth $50, over the 10 week study period.

The other RCT that found no significant benefit of CM was a pilot study comparing an established internet-based CM delivery system, Motiv8 (Meredith, Grabinski, & Dallery 2011), compared to a telephone-based counseling among pregnant smokers in Appalachia, a rural area with high rates of substance use disorders and low socioeconomic status (Harris & Reynolds, 2015). Participants in the CM condition submitted videos twice daily of themselves completing expired CO measurements, earning credits that could be exchanged for gift cards to a variety of vendors. Two additional follow-up measurements randomly occurred before delivery which resulted in $100 cash if the participant tested negative for having smoked. The CM intervention resulted in faster reductions in smoking, but did not differ from telephone counseling in overall nicotine abstinence. Telephone counseling also appeared to foster longer-lasting nicotine abstinence. Given the study's small sample size (N = 17) and lack of additional CM studies that target pregnant smokers in this unique, remote area, further research is needed to determine how best to serve this particularly high-risk population.

Non-randomized studies—Of the five studies that were not RCTs, one was a pilot study for a future RCT (Higgins et al., 2004), and four were implementation studies where CM was incorporated into substance use disorder treatment or general maternal-infant health programs (Gadomsky et al., 2011; Ierfino et al., 2015; Ker et al., 1996; Radley et al., 2013). Ker et al. (1996) described the implementation of CM to achieve nicotine abstinence in a residential substance use disorder treatment program. In one program, smoking was technically not allowed by rules, but smoking resulted in no negative consequences unless it was a danger to the residence (i.e., covert smoking inside). Instead, residents earned credits exchangeable for prizes based on randomly sampled expired CO levels. Participants at a separate program received random expired CO tests but received no reinforcement for meeting a threshold. Participants in the program who received the CM intervention averaged the same expired CO levels as non-smokers pooled across both programs, suggesting that CM aided in maintaining cessation in an environment where abstaining from smoking was not voluntary.

Gadomski et al. (2011) aimed to maintain cessation through the postpartum period by providing vouchers for diapers contingent upon monthly expired CO or salivary cotinine levels indicating abstinence. CM was added to several models of counseling support and compared to a usual care condition that did not involve CM. The effectiveness of CM varied between models and is difficult to distinguish from the other elements of the intervention, but resulted in over half of women making a quit attempt during pregnancy, with anywhere from 0–44% remaining abstinent from smoking 12 months postpartum. This study is unique in that the incentives were only available to be earned during the postpartum period, but abstinence monitoring began during pregnancy.

Radley et al. (2013) described an innovative approach where CM was applied in a broad public health intervention. The program's availability was advertised in medical clinics, newspapers, libraries, and community centers, and pregnant smokers enrolled themselves in

the program at community pharmacies. The pharmacists then monitored participants' expired CO at weekly check-ins for 12 weeks, then every four weeks until 12 weeks postpartum. Fifty four percent of participants were abstinent 4 weeks into their participation, 32% at 12 weeks, and 17% 3 months postpartum. Although those who chose to engage in this program tended to be successful, only 20% of eligible pregnant women during the program's tenure engaged in the program. Ierfino et al. (2015) described a similar program where pregnant smokers opted to enroll in a CM program that was administered either via home visit or in community clinics. A greater percentage of eligible pregnant women (39%) enrolled in this program compared to that described in Radley et al. (2013). As a more robust check for abstinence from smoking, salivary cotinine or anabasine (for women receiving nicotine replacement therapy) was measured at 28 and 36 weeks gestation, and 2 days and 6 months postpartum. Using these more stringent criteria, 20% of participants had quit smoking at delivery, and 10% were abstinent at 6 months postpartum.

Studies Targeting Illicit Substances

Details of the 11 studies that targeted abstinence from illicit substances are displayed in Table 2. For two of these studies, only one arm involved CM targeting abstinence from illicit substances (Jones et al., 2000), or abstinence was a target for only a portion of the study (Jones et al., 2001). Of the 11 studies that targeted abstinence from illicit substances, seven were RCTs (Carroll, Chang, Behr, Clinton, & Kosten, 1995; Elk, Magnus, Rhoades, Andres, & Grabowski, 1998; Jones, Haug, Stitzer, & Svikis, 2000; Jones, Haug, Silverman, Stitzer, & Svikis, 2001; Silverman, Svikis, Robles, Stitzer, & Bigelow, 2001; Schottenfeld, Moore, & Pantalon 2011; Tuten, Svikis, Keyser-Marcus, O'Grady, & Jones, 2012b), one was a prospective multiple baseline study (Elk et al., 1995), and three were quasi experimental (Chang, Carroll, Behr, & Kosten, 1995; Jones, Svikis, & Tran, 2002; Jones, Svikis, Rosado, Tuten, & Kulstad, 2004). Some additional articles describe secondary or follow-up data analysis on original RCTs (e.g., Aklin et al., 2014 not in table). Biochemical verification of abstinence involved urinalysis testing which was conducted between twice and seven times per week. All studies used voucher- or monetary-based reinforcement. Nine studies examined CM within the context of methadone-assisted treatment. Cocaine-negative urine was the target in four studies, opioid and cocaine in three studies, and multiple substances (opioids, cocaine, marijuana, amphetamine) in four studies.

Randomized controlled trials—Three of the RCTs revealed significantly greater abstinence in the CM treatment conditions (Jones et al., 2001; Schottenfeld et al., 2011; Silverman et al., 2001). All three studies controlled for baseline frequency of substance use statistically (Jones et al., 2001; Schottenfeld et al., 2011) or by stratification built into the randomization scheme (Silverman et al., 2001). Schottenfeld et al. (2011) found voucher-based CM to be associated with greater duration of cocaine abstinence, and greater proportion of negative urine drug screens after 3 and 6 months of treatment. Three and 6 months after the intervention ended, CM groups continued to exhibit higher proportions of verified abstinence. Jones et al. (2001) compared no vouchers to escalating, resetting vouchers provided for verified cocaine abstinence during the first week of outpatient treatment following one week of residential treatment. Analysis of urine drug screens revealed that participants in the voucher condition provided significantly fewer opioid and

cocaine positive drug screens, but the number of consecutive negative drug screens did not differ between groups. Treatment effects on abstinence ceased once the contingencies were removed.

A series of articles review a therapeutic workplace program designed to test the efficacy of a voucher CM program built around a therapeutic work environment (Aklin et al., 2014; Silverman et al., 2001; Silverman et al., 2002). Participants provided drug-free urine samples to obtain access to a 5-day-per-week (3hr/day) work environment where they have the opportunity to obtain additional vouchers for work performance (framed as a chaining approach). The three articles follow the same participants longitudinally for eight years. Six-month outcomes revealed that 59% of urine drug screens were negative for opiates and cocaine in the therapeutic workplace condition compared with 33% in the usual care condition, and an average of 45% of participants attended the workplace each day (Silverman et al., 2001). Participants were allowed to continue in the workplace program for up to four years. Three-year outcomes revealed that 54% and 60% of urine samples were negative for cocaine and opiates, respectively, for the therapeutic workplace treated participants compared with 28% and 37%, respectively, for the usual care participants (Silverman et al., 2002). Participants were followed into year four (the final year of the therapeutic workplace), and beyond up to year eight (Aklin et al., 2014). This analysis revealed that participants in the therapeutic workplace continued to provide more negative drug screens than usual care participants in the final year of the program, but these differences were no longer significant in the years after the workplace closed.

Four RCTs failed to reveal efficacy for CM compared to usual care with regard to abstinence (Carroll et al., 1995; Elk et al., 1998; Jones et al., 2000; Tuten et al., 2012b). Of these, only Tuten et al. (2012b) controlled for baseline illicit substance use and did so statistically. Carroll et al. (1995) found no differences in complete illicit substance abstinence between women randomized to receive either fixed $15 vouchers for providing three consecutive urine samples that were free of illicit substances or a no voucher control condition. Elk et al. (1998) found no differences in cocaine abstinence between women randomized to receive either a fixed $18 voucher for each cocaine-negative urine sample plus a $20 bonus for providing three consecutive cocaine-negative urine samples per week or a no voucher control condition. Abstinence ceiling effects may have resulted in null findings in the study by Elk et al. (1998) as participants were included if they had ceased cocaine use prior to study entry, and 99% of cocaine urine drug screens were negative in both CM and non-CM conditions. Both the Carroll et al. (1995) and Elk et al. (1998) studies had very small samples sizes of 14 and 12, respectively. Jones et al. (2000) found no differences in cocaine and opioid abstinence between women randomized to receive either a fixed $5 voucher for each daily urine sample free from cocaine and opioids plus a bonus of $25 for five days or $50 for seven days of consecutive abstinence or a no voucher control condition. Tuten et al. (2012b) found no abstinence differences between two CM conditions (fixed and escalating reinforcement schedules) and treatment as usual. The authors suggested that delay in providing reinforcement following the target behavior and limited participant access to the reinforcers may have reduced the salience of the intervention. A further examination of the fixed versus escalating reinforcement schedule found no differences in abstinence between

these conditions when only the first five weeks of treatment was considered (Hutchinson et al., 2012).

Non-randomized studies—Four studies used non-RCT procedures to examine CM's effectiveness or explored factors that may be associated with CM effectiveness (Chang et al., 1992; Elk et al., 1995; Jones et al., 2002, 2004). Chang et al. (1992) tested urine samples thrice weekly and found that pregnant women who could earn a small fixed incentive for providing three negative urine drug screens in one week provided significantly fewer positive drug screens, presented to more prenatal visits and had heavier infants. Using a multiple baseline design and shaping of successively lower levels of cocaine metabolites, Elk et al. (1995) revealed that fixed monetary incentives (which included thrice weekly incentives for reduced metabolites, and bonuses for full weeks of cocaine abstinence) resulted in significant reductions in cocaine use and increased compliance with prenatal care. Jones et al. (2002) used a similar fixed monetary incentive for polydrug abstinence combined with motivational interviewing and found that women who attended all possible visits demonstrated significantly greater substance abstinence and had heavier infants than did women who attended fewer visits, suggesting exposure to the intervention is an important element of its effectiveness. Jones et al., (2004) compared two groups receiving abstinence-contingent vouchers where one group received case management services to identify and remediate needs around housing, food, transportation. The groups did not differ significantly in the percentage of drug-free urine samples, but participants receiving case management were more likely than the other group to provide one drug-free or two consecutive drug-free urine samples.

One unique combined (CM, motivational enhancement and case management) intervention did not meet the inclusion criteria, but is worth discussing. Jones, Tuten & O'Grady (2011) provided the combined intervention to the male, non-treatment-seeking, opioid-dependent partner of pregnant women in treatment. This intervention produced greater treatment retention, increased involvement in recreational activities, less reliance on public assistance and greater support of their pregnant partners compared with a usual care condition (Jones et al., 2011).

Studies Targeting Substance Use Disorder Treatment Attendance

Four studies, all RCTs, targeted attendance at substance use disorder treatment and their details are presented in Table 3. Three studies controlled for baseline substance use, and did so statistically (Jones et al., 2001, Svikis et al., 1997, 2007). One study included an arm where CM targeted attendance (Jones et al., 2000), and one included attendance as target for only a portion of the study (Jones et al., 2001). In both of these studies, the attendance portion was in effect for one week, and individuals receiving CM had significantly higher attendance than those not receiving CM.

Svikis et al. (1997) compared the relative efficacy of four different schedules of reinforcement ($0, $1, $5 and $10/day of treatment attended) for improving initial (first 7 day) treatment attendance among pregnant women enrolling in methadone maintenance or drug-free day treatment following a residential stay. Women receiving methadone-assisted

treatment attended nearly twice as many treatment days as women not receiving methadone treatment. When the entire sample was examined, there was no significant benefit of adding vouchers for treatment attendance. However, among women not receiving methadone treatment, those who received higher magnitude incentives for attendance ($5 or $10/day) attended more full days of treatment and more total hours of treatment than women in the $0 and $1 treatment conditions. No significant differences were found on the basis of incentive condition for treatment retention. The lack of differences in the overall sample may have been due to a ceiling effect among the methadone-maintained women caused by the motivational benefits inherent in methadone-assisted treatment.

In a later study by the same group, Svikis et al. (2007) tested a voucher-based program where pregnant women could receive escalating vouchers for each full day (defined as 4 hours) of counseling they attended during a 7-day residential stay, and the first 7 days of a 30-day intensive outpatient treatment. Vouchers did not reduce the rate of treatment dropout compared with a treatment-as-usual control condition. However, those in the voucher condition were significantly more likely to attend treatment consistently with 45.2% of incentive-assigned women attending consistently compared with 16.0% of women in treatment-as-usual. This difference remained after controlling for age and substance use severity.

Infant Outcomes

Four RCTs targeting maternal nicotine abstinence reported infant outcomes (Higgins et al., 2014, Heil et al., 2008, Tappin et al., 2015, Tuten et al., 2012a). Tuten et al. (2012a) and Tappin et al. (2015) found no significant differences between CM and controls in any infant outcomes. In Heil et al. (2008) and Higgins et al. (2014), serial ultrasounds were collected during pregnancy and revealed significantly greater estimated weight gain in the abstinence-contingent groups compared to the non-contingent groups. However, there were no significant differences in birth weight or estimated gestational age at delivery in these individual studies. A secondary analysis that combined infant outcome data from Heil et al. (2008), a non-randomized pilot study (Higgins et al. 2004), and an unpublished study revealed significantly higher birth weights and lower incidence of low birth weight (<2500 g) among infants born to women who received abstinence-contingent vouchers (Higgins et al., 2010). This secondary analysis also found non-significant trends toward greater gestational age at delivery, and lower incidence of preterm delivery and neonatal intensive care unit admission.

Similarly few studies have examined the effects of CM interventions for illicit substance use on prenatal compliance or infant health outcomes. Three pilot studies with small samples had positive findings for maternal prenatal and/or infant outcomes (Elk et al., 1995; Elk et al., 1998; Chang et al., 1992). In one study, women who received reinforcement for attending substance use disorder treatment and prenatal clinic appointments thrice weekly had overall high compliance with prenatal care throughout the study (Elk et al., 1995). A second study by this group revealed that participants who received incentives for cocaine abstinence and attendance at prenatal visits attended significantly more appointments and had no adverse perinatal outcomes (compared with 80% in a comparison condition; Elk et

al., 1998). Chang et al. (1992) found that women who received reinforcement for abstinence in combination with an enhanced treatment program had heavier infants at delivery, delivered at a later gestational age and attended three times as many prenatal visits as women receiving usual care.

Additional studies focused on early treatment response rather than on comparisons of reinforcement and non-reinforcement conditions. For example, Elk et al. (1994) revealed that individuals who evidenced abstinence early in their treatment (and therefore did not require intensive treatment including incentives) attended significantly more prenatal sessions than did women who did not respond to initial care. Jones et al. (2002) found that treatment compliant women (who completed all four sessions of a brief intervention) demonstrated greater abstinence from illicit substances, and had infants with significantly greater birth weights than non-compliant women.

Discussion

The studies reviewed here support that CM is highly effective in reducing smoking during pregnancy, and are suggestive that CM can reduce illicit substance use during pregnancy. Generally, CM appears to be particularly well-suited for use among pregnant women, given the limited timeframe of pregnancy, strong within-subject effects of CM, and the potential to benefit both maternal and infant health. However, there are at least three areas where research is needed to more fully evaluate CM as an intervention for substance use in pregnancy. First, there are relatively few studies of CM in pregnancy and they vary significantly in their methodology, making it difficult to identify best practices for the population. Second, CM's effectiveness in reducing substance use has significant potential to improve both maternal and infant health, but the current evidence is often based on small sample sizes and is limited and contradictory. Third, the potential of CM to directly benefit maternal and infant health suggests CM could be especially cost-effective in this population, but there is extremely limited research into the cost-effectiveness of CM and cost is a common criticism of CM interventions in general.

The most consistent findings supporting CM came from studies targeting nicotine abstinence, and a recent meta-analysis found pregnant smokers treated with incentives to be 3.79 times more likely to abstain from smoking than controls (Cahill, Hartmann-Boyce, & Perera, 2015). Studies targeting illicit substances produced more mixed results. Compared to the studies targeting illicit substances, the studies targeting nicotine tended to include more participants, have longer durations of intervention, and made reinforcers contingent upon abstinence from a single substance (nicotine). The studies targeting illicit substances often required abstinence from multiple substances to earn reinforcers, which can be substantially more difficult to achieve than abstaining from a single substance.

Additionally, the studies targeting illicit substance use tended to be conducted within the context of substance use disorder treatment programs, many of which provided multifaceted services aimed at reducing substance use which could have occluded any additive benefit of CM. Perhaps CM has a unique place in treatment programs when used to address use of substances that may not be the primary aim of the program. The studies by Jones et al.

(2001) and Tuten et al. (2012a) where pregnant women receiving methadone-assisted treatment for opioid use disorder earned reinforcers for abstaining from cocaine and nicotine, respectively, are exemplars.

Overall, the studies that found no effect of CM tended to be lacking in areas noted by a meta-analysis of CM interventions to be significant factors in CM's effectiveness (Lussier et al., 2006). Lussier et al. (2006) found that reinforcers of greater magnitude (i.e., higher dollar value) produce greater effects. The studies by Ondersma et al. (2012) and Jones et al. (2000) both showed no effect of CM and used the smallest magnitude reinforcers. Nonetheless, Donatelle et al (2000) used the same size reinforcer ($50 per month) as Ondersma et al. (2012) with success. The second factor Lussier et al. (2006) found associated with CM effectiveness was immediacy of reinforcer delivery. Only Tuten et al. (2012b) explicitly reported a delay in reinforcer delivery; however delays may have occurred in other studies, but were not reported. Future research on CM in pregnancy should consider magnitude and immediacy in their design and reporting.

Regarding maternal health, a secondary analysis compiling data from Higgins et al. (2004), Heil et al. (2008), and Higgins et al. (2014) revealed decreases in depression ratings from antepartum to postpartum among women receiving CM for nicotine abstinence (Lopez, Skelly, & Higgins, 2015). CM for smoking cessation during pregnancy was also found to increase breastfeeding duration (T. Higgins et al., 2010), which is highly beneficial for the maternal-infant dyad (Ip et al., 2007). CM has also been shown to directly increase adherence with prenatal care (Elk et al., 1998), which is also strongly associated with improved maternal and infant outcomes. Thus, overall, there is good preliminary evidence to suggest that CM may benefit pregnant women in the form of improved compliance with healthy activities that are associated with infant and maternal health.

There is also potential for CM interventions targeting substance use to result in improved infant outcomes directly, but a scant few studies reported these data. Those studies that reported infant outcomes found either non-significant trends toward improvement in CM groups or no differences between CM and controls. Infant outcomes can be influenced by many additional factors that may not be adequately controlled for in these studies, such as maternal stress, nutrition, and obesity (Catov, Abatemarco, Markovic, & Roberts, 2010; Catov, Flint, MinJae, Roberts, & Abatemarco, 2015; Catov, Abatemarco, Althouse, Davis, & Hubel, 2015). When data from multiple studies were pooled, a significant effect of CM on infant outcomes was evident (Higgins et al., 2010). This finding suggests that additional research should be conducted with larger sample sizes capable of detecting these complexly-influenced outcomes.

An important criticism of CM interventions is that their effects on abstinence tend to cease once the contingencies are removed (Benishek et al., 2010; Kirby et al., 2006). This lack of post-treatment benefit is not universal, as some studies have found significant long-term benefits of CM (e.g., Higgins et al., 2000). However, the immediate infant health benefits of maternal abstinence from substance use may make pregnancy a uniquely beneficial time to use CM intervention, despite a potential lack of long-term efficacy. For example, there is strong research evidence to demonstrate that smoking cessation during pregnancy has acute

benefits for infant health (Li, Windsor, Perkins, Goldenberg, & Lowe, 1993). As noted above, our current understanding of the infant health benefits of CM interventions is based on limited data. Future studies should continue to examine the role CM may play in improving infant health via its impact on abstinence during pregnancy.

Cost is another common criticism of CM interventions. When CM interventions are aimed at pregnancy, the duration, and thus the cost, of the intervention are limited to the relatively brief time period of pregnancy. The methodology of CM interventions can also affect their cost, but several alternatives have yet to be evaluated among pregnant women. Virtually all of the studies reviewed here involved voucher- or cash-based CM where every incidence of abstinence earns a reinforcer. Prize-based CM where those meeting criteria earn a chance to receive a reinforcer has been suggested to be an effective and sometimes less costly alternative (Stitzer & Petry, 2006).

Reinforcers without cash value, such as take-home methadone doses, have also been effective in CM interventions, but have yet to be examined in pregnancy (Stitzer, Bigelow, & Liebson, 1980). Finally, CM in pregnancy has potential to be highly cost-effective when infant health outcomes are considered, but only one cost-effectiveness study has been published (Boyd et al., 2016).

In summary, the current literature supports that CM is highly effective at reducing smoking during pregnancy and suggests it may be effective for reducing illicit substance use during pregnancy. CM interventions for reducing substance use among pregnant women may be uniquely suited for treating this population. However, there are several limitations of the literature that should be addressed to determine its ultimate value as an efficacious intervention. Some of these limitations include small study sample sizes, lack of consistency in CM procedures across studies, and inconsistent findings on infant and maternal health. Additionally, it is important to explore specific mechanisms of CM interventions that may affect its effectiveness, such as reinforcement magnitude and frequency. Although CM has a long research history of effectively reducing substance use, its ultimate benefit in the context of pregnancy will depend on the results of studies exploring these essential features of the intervention.

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Table 1

Details of studies targeting nicotine.

Study	N	Study design	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Ker et al. (1996)	22	Non-randomized	**1** **2**	Fixed vouchers redeemed for prizes No intervention	8 weeks	**1** **2**	Not reported NA	NRT[1] optional	Expired CO ≤3 ppm	CM > control; expired CO in incentive program equal to non-smokers pooled across both programs	None	Not reported
Walsh et al. (1997)	252	RCT	**1** **2**	Single prize entry + counseling Self-help	4 weeks avg.	**1** **2**	$75 max NA	None	Urinary cotinine <500 nmol/L	CM > control, 16% vs. 2% at midpoint	CM > control, 13% vs. 6% at end of pregnancy, 10% vs. 1% at 6–12 weeks postpartum	Not reported
Donatelle et al. (2000)	220	RCT	**1** **2**	Fixed voucher for participant and social supporter + psychoeducation Psychoeducation	10 months	**1** **2**	$500 max. NA	None	Salivary cotinine ≤ 30 ng/ml, salivary thiocyanate ≤ 100 μg/ml	CM > control, 32% vs. 9% at 8 months gestation, 21% vs. 6% at 2 months postpartum	None	Not reported
Higgins et al. (2004)	58	Non-randomized	**1** **2**	Escalating, resetting vouchers Non-contingent vouchers	≥12 weeks during pregnancy and 12 weeks postpartum	**1** **2**	$397 avg. $313 avg.	None	Expired CO ≤6 ppm, urinary cotinine ≤ 80 ng/ml	CM > control, 37% vs. 9% at end of pregnancy, 33% vs. 0% at 12 weeks postpartum	CM > control, 27% vs. 0% at 24 weeks postpartum	Not reported
Heil et al. (2008)	82	RCT	**1** **2**	Escalating, resetting vouchers Non-contingent vouchers	≥12 weeks during pregnancy and 12 weeks postpartum	**1** **2**	$461 avg, $413 avg.	None	Expired CO ≤6 ppm, urinary cotinine ≤ 80 ng/ml	CM > control, 41% vs. 10% at end of pregnancy, 24% vs. 3% at 12 weeks postpartum	CM = control, 8% vs. 3% abstinent at 24 weeks postpartum	Significantly greater ultrasound-estimated weight gain in CM group No significant differences at delivery, trends toward higher birth weight and gestational age in CM group
Gadomski et al. (2011)	588	Non-randomized	**1** **2**	Fixed vouchers + counseling Fixed vouchers + counseling (different location)	52 weeks	**1–3** 360 max. **4** NA		None	Expired CO ≤6 ppm	50–61% quit during pregnancy, 38–77% at 3 months	None	Not reported

Study	N	Study design	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
			3	Fixed vouchers + smoking cessation specialist counseling						postpartum, 25–64% 6 months postpartum, 0–44% 12 months postpartum, no data for controls		
			4	No vouchers,								
Ondersma et al. (2012)	110	RCT	**1**	Fixed vouchers	10 weeks	**1–2**	$250 max.	None	Expired CO ≤3 ppm, urinary cotinine <100ng/ml	CM = controls	None	Not reported
			2	Fixed vouchers + Computer-based counseling		**3–4**	NA					
			3	Computer-based counseling								
			4	No intervention								
Tuten et al. (2012a)	102	RCT	**1**	Escalating, resetting vouchers	≥12 weeks	**1**	$157 avg,	None	Expired CO, decreasing across first 12 weeks tailored for each subject, from week 12 on ≤3ppm Urine GCMS[2] to quantify cotinine for statistical comparisons	CM > controls, 31% vs. 0% vs. 0% at week 12	No significant differences at 6 weeks postpartum in self-reported cigarettes smoked or mean cotinine levels	No significant differences in birth weight, Apgar, NICU stay length, % treated for neonatal abstinence syndrome
			2	Non-contingent vouchers		**2**	$97 avg.					
			3	Treatment as usual		**3**	NA					
Radley et al. (2013)	383	Single arm	**1**	Fixed vouchers	≥12 weeks during pregnancy and 12 weeks postpartum	**1**	£300 max.	NRT optional	Expired CO ≤6 ppm	CM facilitated quitting, 54% abstinent at 4 weeks, 32% abstinent at 12 weeks, 17% abstinent 3 months postpartum	None	Not reported
Higgins et al. (2014)	118	RCT	**1**	Escalating, resetting vouchers	≥12 weeks during pregnancy and 12 weeks postpartum	**1**	$444 avg.	None	Expired CO ≤6 ppm, bonus for group 2 if ≤4 ppm during week 1, urinary cotinine ≤80 ng/ml	Both CM > control, 46% vs. 40% vs. 13% at early pregnancy, 36% vs. 45% vs. 18% at late pregnancy	CM = control, 18% vs. 15% vs. 8% at 24 weeks postpartum	Significantly greater estimated weight gain in group 1 compared to other groups based on serial ultrasound data No significant differences at delivery
			2	Escalating, resetting vouchers with higher initial values		**2**	$557 avg.					
			3	Non-contingent vouchers		**3**	$384 avg.					

Study	N	Study design	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Glover et al. (2015)	24	RCT	**1** **2** **3**	Fixed vouchers redeemable at department store Fixed vouchers redeemable for packages of products Treatment as usual	8 weeks	**1–2** NZ$200 max. **3** NA		NRT optional	Expired CO ≤6 ppm	Both CM > control, no statistical analyses	None	Not reported
Harris & Reynolds (2015)	17	RCT	**1** **2**	Escalating, resetting vouchers (web-based) for 6 weeks, two random checks with fixed vouchers Telephone counseling	6 weeks	**1** **2**	$296 avg. NA	None	Expired CO tailored to each subject, decreasing over 4 days to ≤4 ppm	CM = control	CM = control at random checks during remainder of pregnancy	Not reported
Ierfino et al. (2015)	239	Single arm	**1**	Escalating, resetting vouchers	Unclear; 32 visits from “early pregnancy” to 6 months postpartum	**1**	£157 avg.	NRT optional	Expired CO ≤6 ppm Salivary cotinine <15 ng/ml, salivary anabasine (unknown cut-off) for statistical comparisons	CM facilitated quitting, 60% made at least one quit attempt, 20% abstinent at delivery, 10% abstinent at 6 months postpartum	None	Not reported
Tappin et al. (2015)	612	RCT	**1** **2**	Fixed voucher Treatment as usual	≥12 weeks, bonus assessment at 34–38 weeks gestation	**1** **2**	£400 max. NA	NRT optional	Expired CO ≤9 ppm Salivary cotinine <14.2 ng/ml or urinary cotinine < 44.7 ng/ml for statistical comparisons	CM > control. 23% vs. 9% as measured at 34–38 weeks gestation	CM > control, 15% vs. 4% based on self-report collected at 6mo postpartum	No significant differences in birth weight, stillbirth/ miscarriage, or premature birth

Note:

[1]Nicotine replacement therapy,

[2]Gas chromatography/mass spectrometry.

Table 2

Details of studies targeting illicit substances.

Study	N	Study design	Target of CM	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Chang et al. (1992)	12	Non-randomized	Polydrug	**1** **2**	Fixed vouchers + enhanced substance use disorder treatment Treatment as usual	Not reported	**1** **2**	$15/week max. NA	Methadone	Urine testing, unknown method	CM > control, no statistical comparisons, but CM participants had greater abstinence and attended more prenatal visits	None	No statistical comparisons, but CM group had higher birth weights and gestational age
Carroll et al. (1995)	14	RCT	Polydrug	**1** **2**	Fixed vouchers + enhanced substance use disorder treatment Treatment as usual	23 weeks avg.	**1** **2**	$345 max. NA	Methadone	Urine testing, unknown methods	CM = control, no differences in illicit drug use, CM participants had significantly more prenatal care visits	None	Not statistically significant, but trends toward higher birth weight and gestational age in CM group
Elk et al. (1995)	7[1]	Multiple baseline across subject	Cocaine	**1**	Fixed vouchers with bonuses	16 weeks avg.	**1**	$816 max.	None	Urine immunoassay, TLC[2], and quantification of immunoassay results	Significant decrease in cocaine use, increased attendance at prenatal appointments	None	Not reported
Elk et al. (1998)	12	RCT	Cocaine	**1** **2**	Fixed vouchers with bonuses + treatment as usual Treatment as usual	16 weeks avg.	**1** **2**	$1184 max. NA	None	Urine immunoassay, TLC[2]	CM = control, nearly all subjects abstained from cocaine in both groups	None	Adverse perinatal outcomes significantly less common in CM group
Jones et al. (2000)	25	RCT	Opioids and cocaine	**1** **2**	Fixed vouchers with bonus for 5–7 days of abstinence No vouchers	1 week	**1** **2**	$85 max. NA	Methadone	Urine test, unknown method	CM = controls Incentives group attended more hours of treatment than control group	None	Not reported
Jones et al. (2001)	85	RCT	Cocaine	**1** **2**	Escalating, resetting vouchers No vouchers	1 week	**1** **2**	$359[3] avg. NA	Methadone	Urine immunoassay, GCMS[4] confirmation	CM > controls Abstinence from opioids also higher in CM group, though not a target of CM	No difference between groups at 2–4 weeks following incentives	Not reported

Study	N	Study design	Target of CM	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Silverman et al. (2001)	40	RCT	Opioids and cocaine	**1**	Escalating, resetting vouchers for abstinence and workplace performance	24 weeks	**1**	$1013 avg.	Methadone	Urine immunoassay	CM > control, CM participants had significantly greater abstinence from cocaine and opioids	None	Not reported
				2	Treatment as usual		**2**	NA					
Jones et al. (2002)	31	Non-randomized	Polydrug	**1**	Fixed vouchers among compliant clients	4 weeks	**1**	$120 avg.	None	Urine immunoassay	All participants could earn vouchers; those who attended all four opportunities to earn vouchers had significantly higher abstinence than those attending 3 or fewer visits	Not statistically significant, but trend for compliant women to be abstinent at delivery	Significantly higher birth weights among compliant participants, no significant difference in gestational age, birth weight ≤2500g, Apgar, hospital length of stay
				2	Fixed vouchers among non-compliant clients		**2**	$23 avg.					
Jones et al. (2004)	130	Non-randomized	Polydrug	**1**	Fixed vouchers + motivational interviewing + case management	4 weeks	**1**	$46 avg.	Methadone optional	Urine immunoassay	No overall difference between CM groups in abstinence, though significantly more women in the case management group provided one drug-free urine and two consecutive drug-free urines	None	Not reported
				2	Fixed vouchers + motivational interviewing		**2**	$37 avg.					
				3	Drug-free controls		**3**	NA					
Schottenfeld et al. (2011)	145	RCT	Cocaine	**1**	Escalating, resetting vouchers + community reinforcement	24 weeks	**1**	$935[5] max.	None	Urine immunoassay	CM > controls, significantly greater abstinence in CM groups compared to controls, no interaction of CM with CRA or 12-step	CM > controls at 3, 6 months post intervention	Not reported
				2	Non-contingent vouchers + community reinforcement		**2**	$935 max., yoked to group 1 earnings					
				3	Escalating, resetting vouchers + 12-step facilitation		**3**	$935 max.					
				4	Non-contingent vouchers + 12-step facilitation		**4**	$935 max., yoked to group 3 earnings					

Study	N	Study design	Target of CM	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Tuten et al. (2012b)	133	RCT	Opioids and cocaine	**1**	Escalating vouchers	13 weeks	**1**	$296 avg.	Methadone	Urine immunoassay	CM = control, no significant difference in abstinence between groups	None	Not reported
				2	Fixed vouchers		**2**	$437 avg.					
				3	Non-contingent vouchers		**3**	$220 avg.					

Note:

[1]Results from 5 non-pregnant, tuberculosis patients excluded,

[2]Thin layer chromatography,

[3]Includes previous week when attendance was the CM target, data reported in Table 3,

[4]Gas chromatography, mass spectrometry,

[5]All participants also received $5 vouchers for attending counseling sessions

Table 3

Details of studies targeting attendance to substance use disorder treatment.

Study	N	Study design	Target of CM	Treatment groups		Length of CM intervention	Max. possible or avg. earned		Medication	Verification method	Results	Post-intervention follow-up	Maternal/infant outcomes
Svikis et al. (1997)	142	RCT	Attendance	**1**	Fixed vouchers $1/day	1 week	**1**	$7 max.	Methadone optional	NA	CM = controls among methadone patients	None	Not reported
				2	Fixed vouchers $5/day		**2**	$35 max.			CM > controls among non-methadone patients, $5–$10/day significantly more effective than $0–$1/day		
				3	Fixed vouchers, $10/day		**3**	$70 max.					
				4	No vouchers		**4**	NA					
Jones et al. (2000)	68	RCT	Attendance	**1**	Fixed vouchers with bonus for 5–7 days of attendance	1 week	**1**	$85 max.	None	NA	CM = controls	None	Not reported
							2	NA					
				2	No vouchers								
Jones et al. (2001)	85	RCT	Attendance	**1**	Escalating, resetting vouchers	1 week	**1**	$359[1] avg.	Methadone	Urine immunoassay, GCMS[2] confirmation	CM > controls	No difference between groups at 2–4 weeks following incentives	Not reported
				2	No vouchers		**2**	NA					
Svikis et al. (2007)	91	RCT	Attendance	**1**	Escalating voucher schedule	2 weeks	**1**	$525 max.	Methadone optional	NA	CM > control, CM participants attended significantly more days of treatment, more consistent attendance	None	Not reported
				2	Treatment as usual		**2**	NA					

Note:

[1]Includes following week when abstinence from cocaine was the CM target, data presented in Table 2,

[2]Gas chromatography, mass spectrometry.