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Adolescent Tobacco/Nicotine Use & the Potential Role of Contingency Management-Based Interventions

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Abstract

The high prevalence of tobacco/nicotine use among youth, including e-cigarettes, is a public health problem in the U.S. Early exposure leads to an increased risk of dependence and health consequences in adulthood. We reviewed the literature on current treatment approaches for nicotine/tobacco use in adolescents/young adults and highlighted underexplored areas of treatment research. There are no current FDA-approved medications for treatment of nicotine/tobacco use disorders in adolescents. However, in research settings and on a case-to-case basis in clinical practice, medications (including nicotine replacement therapy, bupropion and varenicline) have been prescribed to this population with consideration of risk-benefit analysis when behavioral treatments are not sufficient to address dependence. Amongst the non-pharmacological interventions, there is evidence to support the potential for expanded use of contingency management (CM) in youth. Neural differences predisposing adolescents to substance use, along with higher attentiveness to value of options in decision making (flexible reward system), may enhance the effectiveness of reward-based approaches for treatment of substance use disorders in this population. The overall high rates of non-responders across psychosocial and pharmacological treatments highlight the importance of considering novel strategies to improve existing interventions. We suggest that future research be done which considers unique characteristics of today's adolescents, such as high social activism and engagement with the digital rewards, to tailor CM for this age group and assess its effectiveness. Adolescents could potentially benefit from rewards administered through digital media (e.g, video games, computer-based apps, and social media influencers).

Keywords

Tobacco/Nicotine Use disorder; Contingency Management; Reward; Behavior Therapy; Vaping; Adolescents

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Burden of Tobacco/Nicotine Use Disorders in Adolescents in the U.S.

According to the 2022 Centers for Disease Control and Prevention (CDC) National Youth Tobacco Survey, more than 1 in 10 youth (3.08 million) used a tobacco product during the past 30 days [1–3], including 16.5% of high school and 4.5% of middle school students. The most commonly-used route of nicotine intake was electronic (e-)cigarettes (i.e., vaping) (9.4%), followed by cigars and cigarettes. Among youth who currently use e-cigarettes, 1 in 4 used e-cigarettes daily, and 1600 youth per day under the age of 18 smoke their first cigarette [4].

The high prevalence of e-cigarette use among youth is a public health problem in the U.S., because its use is associated with increased risk for cigarette smoking initiation [5] and early smoking exposure leads to an increased likelihood of later nicotine dependence [6]. Initiation of regular cigarette smoking at age 18 to 20 (as opposed to age 21 or older) is associated with higher odds of nicotine dependence and lower odds of smoking cessation later in adulthood [7]. These issues in adolescents who use tobacco/nicotine indicate why cigarette smoking remains the leading cause of preventable disease, disability, and death in the United States, with an estimated 12.5 % of U.S adults smoking cigarettes [8].

Currently, there are no FDA-approved medications for the treatment of tobacco/nicotine use disorder in adolescents and psychotherapy is the primary non-pharmacological approach in this population. Contingency management (CM) is a type of psychotherapy which is growing in use in the treatment of substance use disorders (SUDs). It is based on operant conditioning and uses incentives (traditionally in the form of monetary reward) to increase target behaviors, which can include decreased substance use, improved treatment attendance, and other treatment goals. [9] The substantial role of dopamine in reward-based learning and addiction may explain potential mechanisms through which CM is effective in treatment of SUD [10] A Cochrane review of incentives for smoking cessation displayed high-certainty evidence in mixed population studies to support use of incentives to improve smoking cessation rates. [11] Despite neurobiological differences in responsivity to rewarding in adolescents, contingency management based interventions in treatment of tobacco/nicotine use disorders remain underexplored in this sub-population. [12]

Given the severity of the problem of adolescent smoking/vaping, in this paper we reviewed current and potentially underexplored approaches to treatment in this population, in order to generate potential future directions for treatment research in this population. We reviewed relevant literature on PubMed using the search terms “adolescent,” “teen,” “generation Z,” “smoking,” “tobacco,” “nicotine,” “vape,” “treatment,” “medication,” “cognitive behavioral therapy,” “motivational interviewing,” “contingency,” “reward,” and “mindfulness”. Given the results of this PubMed search (More than 45,000 articles), a more focused review of contingency management approaches was conducted to guide future directions by identifying additional relevant publications in the references and through further search using the same search terms in Google Scholar.

One hundred seventy articles were initially identified as being potentially relevant, leading to a final set of fifty-six articles on the topic being presented in this article. In the following

paper, we review existing literature on treatment for tobacco/nicotine use disorder in the adolescent population, highlight the importance of CM-based approaches for treatment of tobacco/nicotine use disorder, and suggest future directions for personalization of CM approaches for the adolescent population.

Current Treatments for Tobacco/Nicotine Use Disorders in Adolescents

Current first-line treatments for tobacco/nicotine use disorders include both pharmacological and non-pharmacological interventions. FDA-approved medications for treatment of tobacco use disorders in adults 18 years and older are nicotine replacement therapy (including gum, lozenge, transdermal patch, nasal spray, and oral inhalers), bupropion sustained release formula, and varenicline [13]. These medications are not FDA-approved for adolescents younger than 18 years old, but on a case-by-case basis are prescribed to this population when behavioral treatment is ineffective in addressing dependence [14]. In a meta-analysis of nine randomized clinical trials of pharmacotherapy in 1118 smokers of ages 12–20, pharmacotherapy was found to increase short term abstinence; however, no meaningful benefit was found for long term abstinence [15]. Results were most promising for bupropion, particularly in combination with psychosocial interventions [15, 16]. In a double-blind, placebo-controlled study of adolescent smokers, combined bupropion SR and CM appeared to be efficacious and superior to either intervention alone [17], and other initial studies of CM for adolescent tobacco/nicotine use have shown promise as well (Table 1).

Despite a marked increase in use of electronic delivery systems among adolescents, very few studies have been done examining treatment strategies. Overall, prior studies of pharmacotherapy for tobacco use disorders (including e-cigarette use) in youth are limited by the small number of trials and difficulties with medication adherence and study retention [16].

Moreover, despite an increase in attempts to improve access to treatment for adolescents with substance use disorders, overlapping and conflicting state and Federal laws can be confusing for both patients and providers, and creates a barrier to providing care to this population [18, 19]. On the patients' side, minors may refrain from seeking help for treatment of substance use due to concern that their health-related information will be shared with parents or that they will be burdened with the cost of treatment. Breach of confidentiality in documentation of billing and health insurance claims may occur even when state laws allow minors to consent independently [20]. On the providers' end, in addition to the safety concerns, potential legal issues for prescribing non-FDA-approved medications without parental involvement may implicitly and explicitly lead to a preference for non-pharmacological approaches when treating the adolescent population.

Current non-pharmacological interventions with the strongest evidence for smoking cessation in teenagers include social and cognitive-based approaches (e.g., Cognitive Behavioral Therapy (CBT)), motivation-focused therapies (e.g., Motivational Interviewing [MI], Trans Theoretical Model), and Contingency Management (CM) [21, 22]. CBT for smoking cessation typically focuses on problem solving and coping skills, along with restructuring of unhelpful thinking and behavioral patterns of individuals to help achieve

abstinence and prevent relapse [23]. CBT may help patients change maladaptive thoughts such as “I need to smoke” to “I am experiencing craving for smoking” or “I want to smoke”. MI is a patient-centered conversational therapy that aims to overcome ambivalence about smoking cessation and encourages people to stop using nicotine/tobacco by underlining their reasons for quitting and supporting their reasons for change [24]. CM provides positive reinforcement usually in the form of monetary reward for achieving a behavioral target (abstinence from nicotine/tobacco)[25].

In comparing the efficacy of CBT, CM, and combination of the two in teen smokers, one study showed that treatments containing CM were more effective than CBT for impulsive adolescents and adolescents with significant deficits in self-regulation [26]. In a separate randomized trial, rates of short-term abstinence among adolescent smokers treated with CM were not further enhanced by adding CBT [27] (Table 1). Similarly, in another study of adolescents, abstinence outcomes were higher in participants in the CM+CBT group at the end of 1 week and 1 month of treatment when compared with the CBT-alone group [28]. *Such results support the utility of CM techniques for nicotine/tobacco cessation in adolescents.*

Motivation-focused interventions have been shown to be more promising as an adjunctive than a standalone intervention. In a comparison of enhanced MI to brief advice for smoking cessation in adolescents, biochemically-confirmed abstinence rates were low and did not differ significantly by group at any follow up point [29]. Another study showed that a telephone-based MI plus CBT intervention was effective in increasing teen smoking cessation [30].

Mindfulness-based interventions have shown promising effects in treatment of nicotine/tobacco use disorder by bringing automatic smoking behavior into awareness and decoupling of craving and smoking. In a study of college student smokers, participants receiving brief mindfulness-based instructions smoked significantly fewer cigarettes over a 7-day follow-up period as compared to those in a no-instruction control group despite having no significant differences on measures of urges [31]. Low adherence in many teen cessation programs has been a problem and is thought to be due to incongruency between teens’ preferences and the way programs are delivered [32]. In order to adapt to teens’ preferences, a recent study assessed feasibility of a Smartphone App with Mindfulness Training for Adolescent Smoking Cessation and showed a greater decrease in smoking compared to control groups [33].

Across psychosocial and pharmacological interventions, more than half of participants in intervention groups continue to smoke at the end of treatment [22]. In a review of smoking cessation interventions, only one study showed a significant effect at 1-year follow up for a combination of individual counseling, small group sessions, and nicotine replacement therapy [34]. These results highlight the importance of considering novel strategies to improve existing interventions, especially to attempt to enhance long-term abstinence.

Contingency Management (CM) for Nicotine Use in Adolescents

The aforementioned studies and others [35] suggest that interventions targeting youth after initial experimentation with nicotine/tobacco, but before regular patterned smoking behaviors, are of high importance in tackling the burden of tobacco use disorders in the U.S (especially with the high prevalence of e-cigarette use by youth). CM is a treatment for tobacco use disorder with promising evidence for effectiveness in research settings. Traditionally, CM provides positive reinforcement typically in the form of monetary reward for patients achieving a target behavior [36], such as smoking abstinence (measured via expired CO, urinary cotinine, and anabasine levels), adherence to medications, and/or attendance of group and/or individual psychotherapy sessions [25].

In a feasibility study, CM showed promising results for adolescent smokers from rural Appalachia. Participants could earn up to approximately $800 for 5–6 weeks of abstinence and those treated with CM had greater reductions in exhaled carbon monoxide (CO) levels (a marker for recent smoking) than participants in a control treatment group [37]. Another similar study in adolescents showed reduced CO levels during treatment while contingent rewards were in place, with subsiding effects post-treatment [38] (Table 1).

While CM has shown promise in research settings, it is underutilized in real world clinical practice [39], despite the fact that prior research shows that adding CM to CBT and behavioral activation for smoking cessation enhances the efficacy of treatment and is highly cost-effective [40]. Similarly, in another study of CM, addition of a voucher-based protocol to CBT required additional resources but achieved significantly better outcomes [41]. In this study, the cost of voucher-based CM needed to increase the number of participants that maintained abstinence at 6-month follow-up by one was $73.88, while the average cost for CBT condition per participant was $150.23. Given the high cost of treating complications of nicotine/tobacco use, it has long been reported in multiple populations that smoking cessation interventions are highly cost-effective, in addition to benefits for individual health [42–44].

Aside from direct treatment studies, neurodevelopmental models of addiction suggest that CM may be particularly useful in adolescents, who generally have heightened sensitivity of striatal-reward function (exaggerated neural response in ventral striatum to reward) [45, 46], a generalized increased reward valuation, and lower loss aversion, which may underlie their vulnerability to problematic substance use [47, 48]. The same neural differences predisposing adolescents to substance use may also enhance the effectiveness of reward-based approaches for treatment of substance use disorders. Along these lines, behavioral and neural data suggest that adolescents are more attentive to value of options in their decision-making, which was interpreted as evidence of a more flexible reward system [46] Furthermore, results of one study showed that adolescents heightened sensitivity in reward circuits led to better choices when presented with advantageous risk-taking behaviors than adults [46]. An implication of having a more flexible reward system in the adolescent brain is their gravitation towards (approach behavior) choices and causes that they highly value [46]. These findings highlight a neural mechanism which may underlie the potential advantage of using CM for treatment of substance use disorders in adolescents. Furthermore,

these studies of neural mechanism suggest that the introduction of novel rewards within CM protocols will magnify the subjective value of rewards and enhance adherence and efficacy of the treatment in this population.

Future Directions

Multiple characteristics of adolescents today (also known as generation Z [49]) suggest potential novel strategies to enhance CM research and usage in those who use tobacco/nicotine. One such characteristic is their activism regarding social and political issues. In a recent study of generation Z [50], 48% had donated to a cause of importance to them and only 22% did not consider themselves as social activists. Tapping into social and political values of this population by creating personalized donation options within a contingency management reward system may enhance the effectiveness of this treatment in adolescents. Prior research of the affect-driven model of adolescent exploration supports this hypothesis by suggesting that adolescent decisions are often influenced by feelings associated with a stimulus and social factors rather that the knowledge of outcomes and consequences [51, 52].

Another core characteristic of generation Z [49] is a high level of engagement with the digital world. They are avid consumers of technology, and their daily lives are often encompassed mainly within digital environments. A survey published by Common Sense Media, a nonprofit research organization, found that children ages 8 to 12, use about five and a half hours of screen media daily on average. This use is even higher in teens ages 13 to 18 with an average use of eight and a half hours per day [53]. Computer-based applications (Apps) and video games are platforms that adolescents are drawn to and using such media to deliver reinforcements may address the financial burden of CM, especially for maintenance of abstinence and relapse prevention over longer periods of time. A study evaluated a game-based CM App in 28 treatment-seeking smokers ranging in age from 18–64 years [54]. Study results supported the use of game-based virtual goods as rewards for smoking abstinence. Using CM within video games to target nicotine (such as e-cigarette) use in the adolescent population with nicotine use is an area yet to be reported upon. Furthermore, to engage more adolescents in CM, telehealth and Apps may be used to monitor target behaviors. In a recent study, CM delivered via telehealth for e-cigarette cessation among motivated young adults (17–21) was shown to be feasible and acceptable. Here, participants used an App which prompted them to submit videos of saliva cotinine testing which had been mailed to them. The majority of participants completed treatment and rated the intervention components favorably [55] (Table 1). Given the high use of the internet by adolescents, use of online behavioral data to identify individuals at risk of substance use, as well as their values and interests, may also help with development of effective personalized reward systems within CM, along with timely application of CM. Furthermore, these digital platforms may be used to educate adolescents on the long-term impact of nicotine use, including e-cigarettes. While social media influencers promote and sell tobacco products, [56], another potential treatment avenue would be for champions to be recruited from adolescent social media influencers to work with medical experts to facilitate dissemination of educational information on tobacco/nicotine use disorders.

Despite high levels of evidence to support effectiveness of CM approaches in treating substance use disorders, there is a paucity of research assessing CM in tobacco use disorders (and particularly e-cigarette usage) in adolescents. We suggest that future research be done which tailors CM for this age group and assesses its effectiveness.

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Table 1:

Contingency management for nicotine/tobacco use disorder in adolescents

Study	Participants	CM Target Behavior	Study Arms	CM Rewards	Results/Conclusion
Gray, et al. 2011 Reference #17	134 adolescent smokers, average age 18.4 (1.9), 18.4 (1.9), 18.1 (1.9) and 19 (1.8) in study arms 1 to 4 respectively	Exhaled CO-verified abstinence (< 7 ppm) at Week 1, and self-reported abstinence confirmed with urine cotinine (≤100 ng/ml) thereafter	6-weeks of: (1) bupropion SR + CM, (2) bupropion SR + non-CM, (3) placebo + CM, or (4) placebo + non-CM (medication double-blinded)	Up to 11 cash payments (at 1 week of treatment and twice weekly thereafter). Payment for initial visit $10, subsequent consecutive abstinent visits escalating by $3 (max compensation of $275)	Bupropion SR plus CM superior to either intervention alone 27% abstinence for bupropion SR + CM, 8% for bupropion SR + non-CM, 10% for placebo + CM, and 9% for placebo + non-CM
Krishnan-Sarin, et al. 2013 Reference # 27	82 adolescent smokers, average age of 16.1 (SD=1·8) years	Abstinence verified by breath CO (< 7 ppm) and urine cotinine ([during the first week: less than the level on the earlier day or ≤ level 2 (30–100 ng/ml); during subsequent weeks: ≤ level 2 (30–100 ng/ml)	4-week course of (1) CM alone, (2) CBT alone, or (3) CM+CBT (random assignment)	Payment for initial visit $2.00, progressively increasing by $1.00 for subsequent consecutive abstinent visits. Max compensation up to $262 for continuous abstinence	Reward-based smoking cessation interventions have high rates of short-term abstinence; adding CBT did not appear to improve outcomes further
Reynolds, et al. 2015 Reference #37	62 adolescent smokers recruited from rural Appalachia, average age 16.6 (1.5) in Active Treatment (AT) and 16.7 (1.3) Control Treatment (CT)	Three breath CO samples per day meeting the criterion for abstinence (≤4 ppm). Also, urinary cotinine.	AT: Vouchers for breath samples indicating abstinence, CT: vouchers for submitting breath samples with no requirement for CO verified abstinence	$3 for the first breath sample meeting criterion for abstinence, amount increased in increments of $0.25 for each consecutive criterion sample. An additional $5 bonus for every five consecutive criterion samples. Max compensation amount in abstinence phase $737.25. Vouchers redeemable for purchases approved and ordered by staff	Significant reduction in urinary cotinine levels only in AT during treatment, and only AT participants maintained reductions until six weeks of treatment
Harvanko, et al. 2018 Reference #38	127 adolescent smokers, average age 16.9	Abstinence, Breath CO level < 4ppm, videorecorded and uploaded online to Mōtiv8, which has shown good feasibility for adolescent smoking cessation, was used to verify breath CO measurements	AT reinforced for providing CO measurements on schedule and below a <4pmm, CT reinforced for providing CO measurements on schedule	Same as Reynolds et al study Vouchers redeemable on a website that lists common online vendors	Significantly less smoking reported in AT during treatment compared to CT, but not at follow-up. No significant differences for urinary cotinine. Overall low treatment adherence, (37% and 51% of possible CO samples submitted among AT and CT, respectively)
Palmer, et al. 2022 Reference #55	27 young adults vaping nicotine, average age 20.3 (1.2)	Saliva abstinent cotinine samples (cut-off <30 ng/mL) after the quit day until the end of treatment (EOT; Days 7–28; 10 expected submissions)	4 weeks AT: financial incentives contingent on cotinine-verified abstinence via DynamiCare Health's smartphone app 4 weeks, CT: incentives for submitting cotinine, regardless of abstinence	$20 per abstinent saliva sample for AT and per saliva sample regardless of abstinence for CT submitted during the quit attempt and EOT (Days 7–28; 10 quit attempt samples; $200 possible) via the mobile app	Telehealth-based vaping cessation for youth with CM reward was feasible and acceptable. AT submitted 112/220 (55%) abstinent cotinine samples during quit attempt, while CT submitted 4/50 (8%) negative saliva cotinine (cut-off < 30 ng/mL) samples. No differences in abstinence between groups at EOT or follow-up.

Abbreviations: Contingency Management (CM), Carbon Monoxide (CO), Active Treatment (AT), Control Treatment (CT), End of Treatment (EOT)