The effect of acute exercise on cigarette cravings while using a nicotine lozenge

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Abstract

Rationale It is imperative that smoking cessation aids effectively alleviate cigarette craving and withdrawal symptoms because their intensity has shown to predict relapse. The nicotine lozenge and a single session of exercise have both been shown to provide relief from craving for smokers who have stopped smoking. These two efficacious monotherapies have distinct mechanic pathways, and applying them concurrently may provide additive-craving relief benefit.

Objective This study aimed to examine whether an acute bout of moderate-intensity exercise provides additional craving relief to the nicotine replacement lozenge in recently quit smokers.

Results Thirty smokers who had abstained from smoking for 15 h were randomized to either the experimental (exercise and lozenge, n=15) or control (lozenge alone, n=15) condition. Craving was assessed before (baseline), during (10 and 20 min), and after (10, 20, 30, and 40 min) treatment.

Result A significant condition by time interaction effect was found for craving (F(6, 23)=2.70, p=0.039, Wilks’ Λ=0.59, ηp²=0.41). While both conditions demonstrated reductions in craving, the reduction was significantly greater for the experimental group.

Conclusion These findings demonstrate that an acute bout of exercise provides additional craving relief to the nicotine lozenge in recently quit smokers. We recommend smokers who attempt to quit employ both cessation aids simultaneously to maximize reductions in cravings.

Keywords Nicotine lozenge · Acute exercise · Cigarette craving · Desire to smoke

Introduction

Cigarette smoking continues to be the leading cause of preventable death in the world today (World Health Organization 2011). Despite the unfavorable morbidity and mortality outcomes associated with smoking cigarettes, a significant proportion of the population continues to engage in this behavior. Thus, substantial efforts have been directed towards developing individual-based cessation interventions that facilitate quitting and remaining smoke-free. It is imperative that cessation aids effectively manage cravings, in particular, those episodic in nature because they are associated with a very high risk of relapse (Shiffman et al. 1996). Episodic cravings are acute, intense, and typically provoked by environmental (e.g., someone smoking) or affective (e.g., emotional distress) stimuli (Shiffman 2000).

Several oral nicotine replacement therapy (NRT) formulations (e.g., gum, lozenge, and inhaler) have been recognized as a first-line treatment for smoking cessation because they effectively target episodic craving. Oral NRTs deliver nicotine through the oral mucosa membrane that lines the inside of the mouth, which is crucial because it elicits a fast-acting response. Being able to quickly administer a dose of nicotine during an “at-risk” moment will help avoid a lapse (Shiffman et al. 2005). The fundamental mechanism by which all NRT formulations exert
their effect is by binding to nicotinic acetylcholine receptors (nAChRs) that were formerly activated by nicotine obtained from cigarettes (Shiffman et al. 2005).

A recent Cochrane review by Stead et al. (2012) revealed that the nicotine gum, lozenge/tablets, and inhaler are all effective smoking cessation aids, with respective pooled risk ratios of 1.49 (95% confidence interval [CI] [1.40, 1.60], 55 trials), 1.95 ([1.61, 2.36], 6 trials), and 1.90 ([1.36, 2.67], 4 trials) compared to placebo or non-NRT control groups. While they exhibit comparable efficacy profiles, other factors must be weighed when selecting the most appropriate product for a single-dose randomized controlled trial. Two important factors to consider are (1) standardization of the amount of nicotine consumed and (2) ease of drug administration. The lozenge allows for more consistent nicotine dosing, whereas several confounding variables may influence the amount of nicotine absorbed by the gum and inhaler modalities. For example, up to 50% of the nicotine can remain in the gum if not properly chewed (Benowitz et al. 1987). In addition, the number and depth of inhalations as well as environmental factors, such as room temperature, impact the amount of nicotine absorbed from the inhaler (Lunell et al. 1997). The lozenge is also easier to administer and demands less activity (i.e., passively dissolves in mouth) than the gum (i.e., chew-and-park technique) or the inhaler (i.e., requires continuous puffing).

Ample research demonstrates that a single nicotine lozenge can significantly reduce cigarette craving in temporarily abstaining smokers (e.g., Kotlyar et al. 2007; McRobbie et al. 2010; Shahab et al. 2011). However, as advised by pharmaceutical companies, NRTs should be augmented with other treatments to maximize symptom relief. Applying two efficacious monotherapies concurrently may provide additive benefit and greater symptom relief. Meditation, deep breathing, cognitive relaxation techniques, and exercise are examples of acute strategies that have been postulated to relieve cravings and could be implemented with a nicotine lozenge. Of these adjunctive strategies, exercise is the strongest contender because its effects on craving and withdrawal symptoms have been most scientifically validated.

The effects of acute exercise on nicotine-deprived smokers have been comprehensively studied and summarized in two meta-analyses (i.e., Hassova et al. 2013; Roberts et al. 2012). Roberts et al. used aggregate data to conduct their analyses, whereas Hassova et al. used individual participant data (IPD), which is a more rigorous statistical approach. The included studies used a temporary abstinence paradigm and involved different types (e.g., isometric, cycling, walking, and running) and modes (e.g., cycling, walking, running, and isometric) of exercise that ranged in intensity (light to vigorous) and duration (5 to 18 min). Craving was assessed using the “desire to smoke” (DtS) and/or “strength of desire to smoke” (SoD) item(s), both of which are rated on 7-point Likert scales. Based on the aggregated data of 10 trials, Roberts et al. (2012) calculated a weighted mean difference in DtS between exercise and control conditions of −1.90 points (95% CI [−3.06, −0.75]) in favor of exercise. Similarly, the weighted mean difference in SoD of nine trials favored the exercise condition by −2.41 points [−3.45, −1.37]. These findings are analogous to those reported by Hassova et al. who used individual participant data. For example, across 36 studies, the weighted mean difference on DtS between exercise and control conditions was −2.04 points (95% CI [−2.60, −1.46]) in favor of exercise. Furthermore, their meta-analysis of 15 studies favored the exercise condition by −1.91 points [−2.59, −1.22] for SoD. The effect sizes found in these studies were moderate to large in size (ranging from 0.4 to 1.9; Cohen 1988). This is comparable to, or many cases exceed, the effect sizes found with oral NRTs.

With respect to craving time effects, the magnitude of craving relief appears greatest during or immediately after exercise. However, significant effects have been shown to last up to 30 min post-exercise (Scherbo et al. 2010; Ussher et al. 2009). The speed at which exercise relieves urges to smoke may be faster than that of the nicotine lozenge. While significant reductions have been reported within 3 to 5 min of administering a lozenge, maximal relief is not attained until after 30 min (Hansson et al. 2012). The timing of this effect is in accordance with pharmacokinetic studies that reveal maximal blood nicotine levels at 25 min (McEwen et al. 2008) and 30 min (Kotlyar et al. 2007) post-administration.

Exercise-induced reductions in cigarette craving have been observed with various types of exercise and across all intensities. Even 10 min of isometric exercise (Ussher et al. 2009) or a low-intensity yoga session (Elbero et al. 2011) has shown to significantly reduce craving relative to passive controls. However, recent work by Hassova et al. (2014) found that the benefits of exercise are significantly influenced by the intensity at which it is performed. Hassova et al. conducted a one-stage IPD meta-analysis on 930 subjects. They rescaled the DtS and SoD craving items from 0 to 100; thus, a difference between groups of −10 indicated that post-intervention craving scores were 10% lower in the exercise group compared to the controls. The analysis revealed mean differences of −9.22 (95% CI [−15.24, −3.20]), −34.56 (95% CI [−2.59, −1.22]), and −31.29 (95% CI [−2.59, −1.22]), for light-, moderate-, and vigorous-intensity exercise, respectively. These findings suggest that exercising at a light intensity results in craving reductions of a smaller magnitude compared to those resulting from moderate or vigorous intensities. However, no substantial difference exists between the effects of moderate- and vigorous-intensity exercise on craving relief. From a clinical standpoint because moderate-intensity exercise (e.g., brisk
walking) is more convenient and tolerable than vigorous-intensity exercise, quitters may be more likely to execute and adhere to this behavior.

Although the literature is robust that a single bout of exercise has shown to consistently alleviate cigarette craving, the mechanisms through which exercise exerts its effect are not well understood. To date, a number of potential mechanisms that may explain why exercise alleviates cravings have been examined (Hassova et al. 2013, 2014; Roberts et al. 2012; Taylor et al. 2007). These include distraction (Daniel et al. 2006; Ussher et al. 2006), treatment expectancy (Daniel et al. 2007; Harper et al. 2013), affect and mood (i.e., Elibero et al. 2011; Hassova et al. 2014; Taylor et al. 2007), shifts in attention (Janse van Rensburg et al. 2009, 2012), and cortisol (Roberts et al. 2014; Scerbo et al. 2010). While previous findings indicate that distraction and treatment expectancy hypotheses seem doubtful as significant contributors, the role that affect and cortisol play in the exercise-craving relationship have produced mixed results and warrant further investigation. Furthermore, other biological mechanisms, such as catecholamines and heart rate variability, have shown potential but remain in the early stages of investigation (Roberts et al. 2014).

The proposed mechanisms of acute exercise differ from the process by which the nicotine lozenge exerts its effect. Combining monotherapies with distinct mechanisms of action or therapeutic pathways has the potential to yield additive-craving benefit (Ebbert et al. 2010). To date, only one study has examined the acute effects of combining exercise with an NRT product (i.e., patch) on craving (Harper et al. 2012). In a 14-week exercise-aided NRT cessation program, Harper et al. (2012) found female recently quit smokers on the nicotine patch reported a decrease craving after a bout of moderate-intensity exercise. Significant reductions in craving pre- to post-exercise were found at all three assessment points of the program: (1) week 5 (1 week after quitting while on the 21-mg NRT dose); (2) week 11 (7 weeks after quitting while on the 14-mg NRT dose); (3) week 13 (9 weeks after quitting while on the 7-mg NRT dose). Thus, Harper et al. found that exercise provided additional symptom relief while on an NRT. Although these findings are encouraging, it cannot be said for certain that these reductions in craving are specifically related to exercise because there was no control condition solely receiving the NRT patch. To validate this work, a more robust methodology must be used that compares the combined treatment to a control condition. Furthermore, the steady release of nicotine from the transdermal patch alleviates background cravings; hence, the instantaneous effect of both a nicotine lozenge and acute exercise on episodic cravings in recently abstinent smokers remains unknown.

The purpose of the present study was to examine whether an acute bout of moderate-intensity exercise provides additional craving relief to the NRT lozenge in recently quit smokers. It was hypothesized that participants in the treatment condition (acute exercise and nicotine lozenge) would report greater reduction in craving than those in the control condition (nicotine lozenge alone).

Methods

Participants

Thirty smokers (10 males and 20 females) who wanted to quit were enrolled in the study. Inclusion criteria included (1) aged 18 to 65 years, (2) smoked a minimum of five cigarettes per day, (3) reported no contraindications to either physical activity or NRT, and (4) indicated that they were serious about quitting smoking. Exclusion criteria included (1) females who were pregnant, intending on becoming pregnant, or breast-feeding while in the study and (2) inability to abstain from smoking for a minimum of 15 h without nicotine replacement aids.

Measures

Craving Cigarette craving was assessed using the “I have a desire to smoke” statement (Tiffany and Drobes 1991). Desire to smoke was scored on a 7-point Likert scale, from 1 (strongly disagree) to 4 (neither agree nor disagree) and 7 (strongly agree). A single-item measure of cravings is considered appropriate for assessing reactivity in situations where cravings are expected to be high, and there are a large number of repeated assessments over a short period of time (Sayette et al. 2000).

Demographic and smoking behavior The following information was collected: age, gender, smoking status (e.g., number of cigarettes smoked per day), and smoking history (e.g., number of years smoking regularly, number of previous quit attempts). In addition, height (m) and weight (kg) were provided, and body mass index (BMI: kg/m²) was calculated.

Physical activity The short-form Intentional Physical Activity Questionnaire (IPAQ; Craig et al. 2003) was used to measure current levels of physical activity. The IPAQ assesses walking (3.3 metabolic equivalent of task (METs)), moderate (4.0 METs), and vigorous (8.0 METs) physical activities. Separate MET-minutes were computed for each level physical activity by multiplying the MET score of an activity by the minutes performed weekly. A total physical activity score was computed by summing the MET-minute scores for each activity. Based on this physical activity score, participants’ were classified as low, moderate, or high.
Cigarette dependence Perception of cigarette dependence was measured using the Fagerström Test for Cigarette Dependence (FTCD; Fagerström 2012). The FTCD contains six items that were summed to yield a total score out of 10 points. A five-level categorization system was used ranging from very low to very high dependence. These classes have been scored as very low (0 to 2), low (3 to 4), medium (5), high (6 to 7), and very high (8 to 10). The FTCD has shown high internal consistency ($\alpha=0.64$, $p<0.001$) and adequate test–retest reliability ($r=0.88$; Pomerleau et al. 1994). In the current study, the Cronbach’s alpha was slightly below the acceptable level ($\alpha=0.619$); however, the mean inter-item correlation was adequate, falling within the range of 0.2 to 0.4 (Briggs and Cheek 1986).

Procedure

Following ethical approval from the host institution, smokers were recruited by advertising in the local newspaper and at medical clinics. For those eligible and interested, a first visit was scheduled where initial screening was confirmed and the Physical Activity Readiness Questionnaire (PAR-Q; Canadian Society for Exercise Physiology 2012) was completed. The study required participants to come to a laboratory on campus twice, before (visit 1) and after quitting (visit 2). At visit 1, smoking status was confirmed with by breath carbon monoxide (CO) reading of greater than 10 parts per million (ppm). Resting heart rates were collected and participants then completed the demographic and smoking behavior, IPAQ, and FTCD questionnaires.

Visit 2 was scheduled within 1 week of the initial visit. Participants quit smoking cigarettes and refrained from using nicotine products 15 h prior to the second visit. Upon arriving at the laboratory, participants provided another breath CO sample to confirm their smoke-free status (<6 ppm). Once abstinence was confirmed, participants’ heart rates were collected and the craving questionnaire was completed. Those who reported craving scores of 1 or 2 (out of 7) were excluded because these baseline values were considered too low as a craving response to 15 h of not smoking. All eligible participants received a single dosage of a Nicorette® 2-mg lozenge (Johnson and Johnson 2008–2014). The 2-mg strength is recommended for smokers who smoke less than a pack of cigarettes (i.e., less than 25). These smokers would be expected to score low to moderate on cigarette dependency using the FTCD (i.e., 3–5/10). Immediately after administering the lozenge, participants were randomized into experimental or control conditions. Those in the experimental condition completed a single bout of moderate-intensity exercise. The session entailed a 2-min warm-up, 15 min of moderate-intensity exercise, and a 3-min cool-down on a treadmill. Moderate intensity was defined as 45 to 68% of heart rate reserve (HRR; Karvonen et al. 1957). The researcher controlled the incline and speed of the treadmill to ensure that participants were exercising at the appropriate intensity level. Meanwhile, participants in the control condition sat alone in a laboratory room for 20 min and were allowed to read if they desired. Following treatment, both conditions sat passively for 40 min. Craving was assessed before (baseline), during (10 and 20 min), and after (10, 20, 30, and 40 min) treatment at 10-min intervals. The flow of participants through the study can be found in Fig. 1. Participants received no behavioral support towards quitting smoking once they completed the study.

Sample size calculation

Previous research has shown that the mean reduction in cravings (i.e., desire to smoke) from a single dose of a 2-mg strength nicotine lozenge is 1.43 (Muramoto et al. 2003). Based on the meta-analysis conducted by Roberts et al. (2012), a mean reduction 1.90 in cravings was produced following an acute bout of exercise. It is anticipated that participants receiving both exercise and the nicotine lozenge will experience a larger and additive reduction in craving (experimental mean=3.33, standard deviation (SD)=1.0) compared to those receiving the nicotine lozenge alone (control mean=1.43, SD=1.0). Hence, in order to be adequately powered (power=0.99) to detect this difference with the alpha set at 0.05, a sample size of 30 smokers is needed (SamplePower 3, IBM-SPSS).

![Flow of participants through the study](Fig 1 Flow of participants through the study)
A pilot sample ($n=10$) was used to determine the optimal timing of administering the lozenge and commencing exercise to examine its additive effect. Previous research shows that maximum blood nicotine levels are reached 25 (McEwen et al. 2008) and 30 min (Kotlyar et al. 2007) after administering a lozenge. Exercise has shown a more rapid effect on craving, with reductions occurring almost immediately after onset. To account for the potential lag of the lozenge, a sequential approach was initially used where the experimental condition started exercising 10 min after administering the lozenge. However, preliminary data showed that the lozenge reduced cravings as early as 10 min after product placement (Fig. 2). Therefore, the protocol was altered so the exercise and lozenge were administered simultaneously.

Statistical analyses

As a fidelity check, a one-way analysis of covariance (ANCOVA) was conducted to compare the groups’ heart rate data collected after 20 min of treatment. Heart rate data collected immediately prior to treatment (i.e., baseline) were used as the covariate in this analysis. One-way analysis of variances (ANOVAs) and chi-square tests were used to determine treatment group equivalence at baseline for the following data: (a) demographic and smoking behavior variables assessed at visit 1 and (b) baseline (pre-treatment) craving and withdrawal symptoms scores and CO levels assessed at visit 2. For the main research question, a 2 (condition: moderate-intensity exercise vs. passive sitting) × 7 (time: baseline, 10-min treatment, 20-min treatment, 10-min post-treatment, 20-min post-treatment, 30-min post-treatment, and 40-min post-treatment) repeated measures ANOVA was used to determine whether group differences could be seen across time for craving. As recommended by Thomson et al. (2005), significant interactions were described and main effects were only reported when no significant interaction was found. The assumption of circularity was assessed using Mauchly’s test of sphericity, and a violation of this assumption was accounted for by reporting the multivariate statistic (Stevens 1996).

Results

Fidelity check

Two participants (1 = control; 1 = experimental) did not have complete heart rate data and were thus removed from the following analysis. After adjusting for pre-treatment values, those exercising ($n=14$, $M=107.57$, $SD=6.97$) had significantly higher heart rates after 20 min of treatment compared to those sitting passively ($n=14$, $M=79.50$, $SD=18.18$, $F=105.42$, $p<0.001$, $\eta^2=0.81$). All 14 participants in the exercise condition with complete heart rate data adhered to the moderate-intensity prescription (45 to 68 % HRR), while those in the control condition remained below this threshold.

Group equivalency at baseline

Demographic and smoking behavior information is shown in Table 1. No significant group differences were found for age, weight, height, BMI, gender, or level of physical activity. No significant group differences were found for the following smoking behavior variables assessed at visit 1: CO level, number of cigarettes smoked daily, number of years smoked, FTCD score, number of previous quit attempts, and seriousness of quit attempt were not significantly different between groups. There was no significant group difference in CO levels or baseline (pre-treatment) craving scores assessed at visit 2.

Craving

A significant condition by time interaction effect was found for desire to smoke ($F(6, 23)=2.70$, $p=0.039$, Wilks’ $\Lambda=0.59$, $\eta^2=0.41$). Both groups demonstrated a decrease in craving over time; however, the experimental
The present study examined whether an acute bout of moderate-intensity exercise produced additional cigarette craving relief to the nicotine lozenge in the initial 15 h of abstinence for smokers undergoing a real-life quit attempt. Findings from the present study indicate that exercising at a moderate intensity reduces cigarette cravings to a greater degree than sitting passively in recently quit smokers who are consuming a nicotine lozenge. Both groups showed decreases in craving from baseline; however, the experimental condition (acute exercise and nicotine lozenge) had lower scores at each assessment point compared to the control condition (nicotine lozenge alone).

The largest reduction in craving occurred during the 20-min treatment period for both conditions (i.e., steepest slopes (exercise + lozenge) condition was of a greater magnitude (Table 2 and Fig. 3).

### Discussion

The present study examined whether an acute bout of moderate-intensity exercise produced additional cigarette craving relief to the nicotine lozenge in the initial 15 h of abstinence for smokers undergoing a real-life quit attempt. Findings from the present study indicate that exercising at a moderate intensity reduces cigarette cravings to a greater degree than sitting passively in recently quit smokers who are consuming a nicotine lozenge. Both groups showed decreases in craving from baseline; however, the experimental condition (acute exercise and nicotine lozenge) had lower scores at each assessment point compared to the control condition (nicotine lozenge alone).

The largest reduction in craving occurred during the 20-min treatment period for both conditions (i.e., steepest slopes

### Table 1  Demographic and smoking behavior variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Exercise condition</th>
<th>Control condition</th>
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<td></td>
<td>M</td>
<td>SD</td>
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<td>Demographic</td>
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<td>Visit 2 CO level</td>
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<td>Number of cigarettes per day</td>
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<td>Number of years smoking</td>
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<tr>
<td>Number of quit attempts</td>
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<td>2.34</td>
</tr>
</tbody>
</table>

Seriousness of quit attempt is scored on a 10-point scale where a higher score indicates a stronger seriousness to attempting to quit smoking

*BMI* body mass index, *IPAQ* International Physical Activity Questionnaire, *CO* carbon monoxide, *FTCD* Fagerström Test for Cigarette Dependence

### Table 2  Means, standard deviations, and 95 % confidence intervals for craving before, during, and after treatment

<table>
<thead>
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<th>Time</th>
<th>Exercise condition</th>
<th>Control condition</th>
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<td></td>
<td>M</td>
<td>SD</td>
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<td>Baseline</td>
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<td>10-min treatment</td>
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<td>20-min treatment</td>
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<td>10-min post-treatment</td>
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<td>30-min post-treatment</td>
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<tr>
<td>40-min post-treatment</td>
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</table>
in Fig. 3). From baseline to 10 and 20 min of treatment, the experimental condition had decreases of 31.7 and 48.3 %, respectively, and the control condition dropped by 16.0 and 37.5 %, respectively. Thus, the experimental condition had a 15.7 and 10.8 % larger reduction in craving than the control at these two time points. Craving scores for both conditions continued to decrease following treatment. However, these reductions were smaller in magnitude than those reported during and immediately after treatment. From baseline to post-treatment assessment points (i.e., 10, 20, 30, and 40 min), the experimental condition had respective declines of 52.9, 50.6, 52.9, and 56.4 %, whereas the control condition had reductions of 40.9, 44.3, 45.5, and 46.7 %, respectively. The difference at 40-min post-treatment favored the experimental condition by 10.3 % which is comparable to the 10.8 % difference that was found immediately after treatment. Therefore, the benefit of supplementing the nicotine lozenge with exercise was preserved even after treatment stopped.

The results of the present study substantiate the work of Harper et al. (2012) who found that acute exercise alleviated cigarette cravings in smokers on the nicotine patch. Specifically, participants reported 20.8, 16.7, and 22.7 % reductions in cravings following exercise while having quit and been on the patch for 1, 7, and 9 weeks, respectively. The reduction in craving scores immediately following exercise reported in the present study (48.3 %) is twice as large as those found by Harper et al. during the first week of quitting (20.8 %). This may be because the two studies differed in their durations of abstinence and NRT products used. It has been suggested that cravings are most intense during the initial days of abstinence. Hence, recently quit smokers (i.e., 15 h of abstinence in the present study) should report higher baseline cravings and, in turn, greater change scores, than those who have been smoke-free for days or weeks (i.e., the study of Harper et al.). The steady release of nicotine from the transdermal patch alleviates background cravings, while the instantaneous effect of both the nicotine lozenge and exercise targets episodic cravings. Therefore, a larger reduction in episodic craving would be expected in the present study because two acute cessation aids were used that provide immediate relief. Nonetheless, both studies provide strong evidence that an acute bout of exercise can supplement, and is not redundant to, the craving relief experienced with NRT products.

These findings suggest that acute exercise and the nicotine lozenge are functioning, through distinct mechanisms. The manner by which the nicotine lozenge exerts its effect on cigarette craving is better understood than that of exercise. As previously mentioned, NRT products effectively suppress cravings by binding to nicotine-deprived nAChRs in the brain that were once stimulated by nicotine in cigarettes. In regards to explaining the exercise–craving relationship, it is unlikely that the aforementioned cognitive hypotheses (i.e., distraction and expectancy) are significant contributors (Daniel et al. 2007; Harper et al. 2013) where the affect (Hassova et al. 2014; Taylor et al. 2007) and cortisol (Roberts et al. 2014; Scerbo et al. 2010) hypotheses have produced mixed results. Other biological mechanisms (i.e., catecholamines and heart rate variability) are plausible and have shown promise but have not yet been rigorously investigated (Roberts et al. 2014). Another possibility is that the two interventions may be interactive. Previous work (e.g., Klemsdal et al. 1995), for instance, has shown that exercise increases the circulation of nicotine from nicotine replacement products (i.e., patch). This in turn would likely enhance the speed at which it affects cravings. Therefore, future research should aim to test these additive and interactive hypotheses to gather a better understanding of the acute effects of exercise. Understanding the mechanisms by which exercise influences craving will not only substantiate the causality of this relationship but also provide insight for developing exercise-aided interventions that maximize craving relief (Taylor et al. 2007; Ussher et al. 2014).

While the benefit of combining the two modalities has been demonstrated in a laboratory setting, the ecological validity of this finding must be further examined. For example, perceived environmental and psychological barriers may discourage smokers from using this combined treatment approach in a naturalistic setting. Therefore, using ecological momentary assessment (i.e., smart-phone application), researchers could gather information pertaining to the challenges smokers encounter to incorporating exercise with the nicotine lozenge during a real-life craving episode. From there, tailor-made feedback statements could be developed that help mitigate specific obstacles. These statements could then be delivered through the
smart-phone application when individuals are at-risk of relapse and experiencing intense cravings.

There are a number of strengths to the present study. For instance, the subjective assessments were validated, objective measures (i.e., heart rate data, CO reader) were used when appropriate, the randomization minimized contamination of extraneous variables, and the post-treatment period was sufficient in duration (40 min) to examine the residual effects of treatment. Furthermore, incorporating a pilot sample was advantageous because it exposed the optimal timing of administering the two treatment modalities. Lastly, using a sample of smokers undergoing a real-life quitting attempt enhanced the ecological validity of the present study. The majority of previous studies involve temporarily abstaining smokers who are likely to return to smoking. As a result, their reported symptoms may not be entirely representative of those experienced by real-life quitters. The fact that baseline scores for desire to smoke were somewhat higher than most previous studies supports this notion.

Despite the aforementioned strengths, there are limitations of this study that must be acknowledged. For example, the researcher and participants were not blinded to their allocated treatment. In addition, the generalizability of these findings is limited to mild to moderate cigarette-dependent smokers who have quit only 15 h prior. A related limitation is the exact hours participants refrained from smoking were not recorded. Furthermore, the present trial was conducted in a laboratory setting and participants refrained from smoking were not recorded. Furthermore, the present trial was conducted in a laboratory setting and participants refrained from smoking were not recorded. Furthermore, the present trial was conducted in a laboratory setting and participants refrained from smoking were not recorded.

In conclusion, findings from the present study demonstrate that an acute bout of exercise provides additional craving relief to the nicotine lozenge in recently quit smokers. Therefore, individuals should employ both cessation aids simultaneously to maximize reductions in cravings. More research is required to untangle the underlying mechanisms through which exercise exerts its effect. Furthermore, the feasibility of engaging in a bout of exercise when experiencing heightened cigarette cravings in a natural environment must be examined.

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