Effect of exercise on cigarette cravings and ad libitum smoking following concurrent stressors

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HIGHLIGHTS

• Exercise provides immediate craving relief in smokers facing concurrent stressors.
• Exercise has no effect on ad libitum smoking.
• Indirect evidence for concurrent stressors and exercise on self-control strength.
• Concurrent stressors deplete self-control strength.
• Exercise replenishes self-control strength.

ABSTRACT

The health consequences of smoking are well documented, yet quit rates are modest. While exercise has supported decreased cravings and withdrawal symptoms in temporarily abstinent smokers, it has yet to be applied when smokers are experiencing concurrent stressors. This study examined the effect of an acute bout of moderate intensity exercise on cravings (primary outcome) and ad libitum smoking (secondary outcome) following concurrent stressors (i.e., temporary abstinence and environmental manipulation—Stroop cognitive task + cue-elicited smoking stimuli). Twenty-five smokers (>10 cig/day; Mean age = 37.4 years) were randomized into either exercise (n = 12) or passive sitting conditions. A repeated measure (RM) ANOVA showed that psychological withdrawal symptoms (a measure of distress) were significantly exacerbated after temporary abstinence and then again after the environmental manipulation for all participants (p<.0001, η² = .50). Furthermore, a treatment by time RM ANOVA revealed decreases in psychological withdrawal symptoms for only the exercise condition (p<.0001, η² = .42). A treatment by time RM ANOVA also revealed craving reductions for only the exercise condition (p<.0001, η² = .82). Exercise had no effect on ad libitum smoking. This is the first study to use a lab-based scenario with high ecological validity to show that an acute bout of exercise can reduce cravings following concurrent stressors. Future work is now needed where momentary assessment is used in people’s natural environment to examine changes in cigarette cravings following acute bouts of exercise.

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1. Introduction

Failure to cope with smoking-related and external stressors may lead to an increased likelihood of relapse and an eventual return to normal smoking behavior (Aveyard & West, 2007). A single bout of light-to-moderate intensity exercise has been shown to significantly reduce cravings in temporarily abstinent smokers (Daniel, Cropley, & Fife-Schaw, 2007; Elibero, Janse Van Rensburg, & Drobes, 2011; Faulkner, Arbour-Nicitopoulos, & Hsin, 2010). Two recent meta-analyses (Haasova et al., 2013; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012) provide empirical evidence for acute exercise having a positive effect on cigarette cravings and withdrawal symptoms during abstinence. Moreover, exercise is more than a distraction from cravings and withdrawal symptoms, as benefits of exercise last after the bout is over (Daniel, Cropley, & Fife-Schaw, 2006; Ussher, West, Doshi, & Sampuran, 2006). In addition, treatment expectations are unrelated to reductions in cravings and withdrawal symptoms following an acute bout of exercise (Daniel et al., 2007; Harper, FitzGeorge, Tritter, & Prapavessis, 2013).

In order to further evaluate the effects of acute exercise for managing cravings and withdrawal symptoms, we argue that it is crucial to...
determine the value of exercise using a cue-elicited smoking research paradigm. Cue-elicited research is originally derived from classical conditioning (Tiffany, 1995). Addicts are exposed to cues related to their addiction (e.g., drug paraphernalia) and psychological and/or physiological responses are measured. Generally, responses are measured through self-report using a measure of craving or desire for the drug. A meta-analysis conducted by Carter and Tiffany (1999) suggests that the cue-elicited research paradigm is useful for basic addiction research and robust for psychological responses.

Taylor and Katomeri (2007) showed that a single bout of exercise could moderate cue-elicited cravings and withdrawal symptoms during a temporary quit period. Following a 2-hour abstinence period, participants were randomized to either a 15-minute brisk walk or passive condition. Both groups completed a set of tasks (i.e., stressors) following their respective treatment conditions. Exercise attenuated strength of desire to smoke, tension, poor concentration and stress in response to a lit cigarette, but had minimal effects on cravings and withdrawal symptoms in response to other stressors (i.e., Stroop task and speech task). Moreover, participants who exercised lit up a cigarette (ad libitum smoking) 57 minutes later than passive controls after leaving the laboratory.

While the study conducted by Taylor and Katomeri (2007) advances knowledge, the cue-elicited stressors were presented after the treatment condition. A more ecologically valid scenario would be to present the stressors immediately after a period of temporary abstinence. This situation mirrors a real life situation where smokers often have to simultaneously deal with cue-elicited stressors along with the stressors associated with abstinence from smoking. The combined effects of both stressors may be greater than the effects experienced when a smoker only engages in a temporary quit attempt. Specifically, the severity of the psychological withdrawal symptoms (a measure of distress) will likely be higher for those experiencing concurrent stressors. This in turn will likely make it more challenging for treatments like exercise to work in attenuating cravings.

Hence, the purpose of this study is to examine the effect of an acute bout of moderate-intensity exercise on cigarette cravings and ad libitum smoking following exposure to concurrent stressors (temporary smoking abstinence period and environmental manipulation—cognitive Stroop task + cue-elicited smoking stimuli). It was hypothesized that all participants would experience an increase in psychological withdrawal symptoms following temporary abstinence (stress condition 1) and a further increase in symptoms following environmental manipulation (stress condition 2). However, it was expected that participants who exercised would show lower psychological withdrawal symptoms after treatment compared to passive controls. It was also predicted that, compared to passive controls, those who exercised would experience lower cravings and would take longer to light up their first cigarette following exposure to the concurrent stressors.

2. Materials and methods

2.1. Design

This study used a stratified (age and sex), two-group (moderate intensity exercise and passive sitting) randomized controlled trial design. A computer-generated numbers table accomplished randomization for age (18–30 years, 31–50 years, 51–65 years) and sex (male, female). Participants were blinded to the existence of a second condition.

2.1.1. Sample size calculation

Previous research has shown Shiffman–Jarvik withdrawal symptoms psychological subscale scores of 2.55 at baseline increases to 3.72 (standard deviations not reported by authors) after a 13–16 hour period of temporary abstinence (Canamar & London, 2012). Moreover, no previous research exists to inform power analysis for psychological symptoms after temporary abstinence and environmental manipulation (concurrent stressors). It is anticipated that the additional environmental stressor will likely elevate psychological symptoms from 3.72 to 4.2 (SD = 1.0). Hence, in order to be adequately powered (.80) to detect this difference, a sample size of 25 smokers is needed with the alpha set at 0.05. Our sample size calculation for strength of desire to smoke (primary outcome) was based on previous research (Roberts et al., 2012) that showed a difference of −2.41 (SD = 2.0) between exercise and passive conditions within 5 min of post-treatment. Thus, a sample of 11 smokers per group was needed to detect similar differences in this variable at a power of .80 with an alpha of .05 (SamplePower 3, IBM-SPSS).

2.2. Participants

After receiving ethical approval from the host university, healthy male and female smokers were recruited using advertisements in local newspapers and online classifieds in the local community. Smokers were eligible if they were 18–65 years of age; smoked an average of 10 cigarettes or more per day for at least two years; and had no contraindications to physical activity as determined by the Physical Activity Readiness Questionnaire (Thomas, Reading, & Shephard, 1992). Females who were pregnant or intending on becoming pregnant before completion of the study and those who were unable to temporarily abstain from smoking for 18 h were ineligible. Thirty-six participants had given consent and were randomized, but participants were ineligible due to an inability to abstain for 18 h (n = 5), lost contact (n = 4), or lost interest (n = 2). Twenty-five participants satisfied all criteria and completed the study.

2.3. Measures

2.3.1. Psychological distress (fidelity check)

Psychological distress was measured with the Shiffman–Jarvik withdrawal scale (Shiffman & Jarvik, 1976). Five items were measured on a 7-point Likert scale anchored at 1 definitely do not feel and 7 definitely feel. Only this subscale of the Shiffman and Jarvik inventory was administered, as it represented items (e.g., “do you feel more tense than usual?”) that directly assessed psychological distress and would likely change from baseline to post-abstinence (stress condition 1) and then again from post-abstinence to post-environmental manipulation—cognitive Stroop task + cue-elicited smoking stimuli (stress condition 2). Internal consistency (Cronbach’s alpha) for the subscale was acceptable: baseline α = .73; post-abstinence α = .82; post-environmental manipulation α = .80; 2-minutes post-treatment α = .76.

2.3.2. Cravings (primary outcome)

Cigarette cravings were measured using the strength of desire to smoke scale (West, Hajek, & Belcher, 1989). This scale uses a single item ‘How strong is your desire to smoke right now?’ and is scored on a 7-point Likert scale from 1 not at all to 4 somewhat and 7 extremely. 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).

2.3.3. Time to first cigarette (secondary outcome)

Ad libitum smoking was calculated as the difference in time (min) from leaving the laboratory after post-abstinence assessment to the time (min) of their first cigarette. This method is consistent with previous research in acute smoking research designs (Taylor & Katomeri, 2007). Participants either emailed the study’s email address or called and left a message on a secure phone line with the time and date of their first cigarette.
2.4.1. Moderate intensity exercise

Participants randomized to this condition completed a single, 15-minute bout of moderate intensity exercise. Exercise consisted of a 2-minute warm-up, followed by 10 min of walking at a rate, which allowed participants to reach 45% to 68% of their heart rate reserve, and then a 3-minute cool down on a treadmill (Woodway, Waukesha, WI). Heart rate was monitored using a Polar RS100 heart rate monitor.

2.4.2. Passive sitting

Participants were asked to sit alone in a quiet room for 15 min.

2.5. Procedure

Eligible participants were asked to complete a baseline assessment (Visit 1). Baseline assessments included verification of smoking status using the piCO+™ Smokerlyzer® (Bedfont Scientific Ltd., Kent, England) carbon monoxide (CO) monitor. A breath CO reading of greater than 10 parts per million (ppm) was the threshold for inclusion, as used in previous research (Daniel et al., 2007). Resting heart rate, height and weight were recorded for all participants. Next, participants completed the following questionnaires: (1) demographic information; (2) the 7-day Physical Activity Recall Questionnaire (Blair et al., 1985); (3) Fagerstrom Test for Cigarette Dependence (FTCD; Heatherton, Kozlowski, Frecker, & Fagerström, 1991); (4) cigarette cravings; (5) Shiffman™–Jarvik withdrawal subscale (psychological symptoms subscale); and (6) smoking ladder (Biener & Abrams, 1991).

Post-abstinence assessments (Visit 2) were scheduled approximately one week after baseline. Prior to the second assessment, participants were asked to abstain from smoking (stress condition 1) and completed the Shiffman–Jarvik psychological withdrawal symptoms subscale for 18 h. Temporary abstinence was verified using expired CO (<10 ppm). Next, participants assessed their strength of desire to smoke (cravings) and completed the Shiffman–Jarvik withdrawal subscale (psychological withdrawal symptoms).

All participants then performed the modified Stroop task (Wallace & Baumeister, 2002) and cue-elicited smoking stimuli (stress condition 2). The modified Stroop task incongruously matches words and printed ink color, whereby participants are required to say aloud the color of the printed ink and not the word (Williams, Mathews, & Macleod, 1996). However, when participants came across words printed in red ink they were required to override the first rule and say the actual word itself. Next, researchers asked participants to place a cigarette of their preferred brand on the desk in plain sight (cue-elicited smoking stimulus) before completing the Stroop task. Also, they were informed that for every error incurred, one dollar would be subtracted from their total ad libitum smoking comparing means between groups. Finally, bivariate correlations were conducted to establish whether relationships existed between variables. Level of significance was accepted at p < .05 for all statistical tests. Data were analyzed using SPSS for Windows version 21 (IBM, United States).

3. Results

With the exception of resting heart rate, there were no significant differences on any baseline measures between eligible and ineligible participants (p-values ranged between .37 and .96). Eligible participants’ demographic information and smoking characteristics are presented in Table 1. Groups did not differ on any baseline characteristics. In addition, moderate intensity exercise (M = 5.5, SD = 2.5) and passive control (M = 6.1, SD = 2.4) did not differ on CO scores measured post-abstinence (Visit 2), t (23) = −.589, p > .05.

3.1. Fidelity check

3.1.1. Exercise

All participants adhered to the prescribed moderate intensity prescription for 10 min at 45–68% of their heart rate reserve.

3.1.2. Concurrent stressors

A significant time effect was found for psychological withdrawal symptoms, F (2, 23) = 24.3, p < .0001, η² = .50. Post-hoc paired t-tests showed an increase in psychological symptoms from baseline to post-abstinence (stress condition 1), t (24) = −4.23, p < .0001, η² = .43 and from post-abstinence to post-environment manipulation (stress condition 2), t (24) = −2.65, p = .01, η² = .23 (Fig. 1).

3.1.3. Treatment effect for reducing stressors

A significant group by time interaction effect was found, F (1, 23) = 16.7, p < .001, η² = .42, where those in exercise condition decreased their psychological withdrawal symptoms compared to their passive control counterparts (Fig. 1).

3.2. Main analyses

3.2.1. Cravings

A significant group by time interaction effect, F (6, 18) = 13.4, p < .0001, η² = .82, was found for strength of desire to smoke. Post-hoc t-tests showed that the exercise group reported significantly lower craving scores at all post concurrent stressor time points compared to their passive control counterparts (Fig. 2).
3.2.2. Ad libitum smoking

Independent t-test revealed no significant difference for ad libitum smoking for moderate intensity exercise ($M = 12.7, SD = 9.52$) and passive control ($M = 14.1, SD = 12.6$), $t(17) = -2.62, p = .08, \eta^2 = .003$.

3.2.3. Relationships among the variables

There was no significant correlation between strength of desire to smoke (cravings) measured post-treatment and ad libitum smoking (Table 2). No significant correlations were found between ad libitum smoking and demographic variables, smoking status, and post-treatment psychological withdrawal symptoms. Post-treatment psychological withdrawal symptoms were significantly correlated with post-treatment cravings, cigarettes smoked per day, and FTCD scores. Cigarettes smoked per day were significantly correlated with FTCD scores.

4. Discussion

The present study examined the effect of a single bout of exercise on strength of desire to smoke (cravings) and ad libitum smoking following concurrent stressors. Results showed that following concurrent stressors (i.e., temporary abstinence and environmental manipulation—Stroop cognitive task + cue-elicited smoking stimuli), significant reductions in cravings were seen for those in the moderate intensity exercise condition, but not for those in the passive control condition. There were no significant differences between groups for ad libitum smoking.

Psychological withdrawal symptoms of the Shiffman and Jarvik (1976) withdrawal scale were used as a surrogate measure of stress as items were salient to distress and likely to change in response to both stressor conditions (i.e., temporary abstinence and environmental manipulation—Stroop cognitive task + cue-elicited smoking stimuli). We found a significant increase in psychological withdrawal symptoms following temporary abstinence and again following the environmental manipulation (see Fig. 1). Furthermore, we found a significant decrease in these symptoms for only those in the exercise arm following the concurrent stressor condition (see Fig. 1). Using a model of self-control strength (Baumeister, 2003), these data taken together, suggest that self-control strength was being depleted following concurrent stressors and then replenished following exercise. This potential mechanistic line of investigation deserves future research attention.

Insofar as cravings are concerned, heightened and sustained craving scores prior to treatment supports the tenet that concurrent stressors had an impact on them (see Fig. 2). There was a 2.58 (46%) to 2.75 (49%) reduction in strength of desire to smoke from concurrent stressors to during exercise treatment (i.e., 5, 10 and 15 min), whereas the point reduction from concurrent stressors to immediately post treatment was 2.08 (37%). These reductions are in line with other studies (see Haasova et al., 2013; Roberts et al., 2012). Overall, our findings are clinically relevant as they show that exercise (a non-pharmacological agent) can provide immediate craving relief in

![Fig. 1](https://example.com/f1.png)

**Fig. 1.** Increase in psychological withdrawal symptoms (stress) from (1) baseline to (2) post-abstinence and then again from post-abstinence to (3a) post-environmental manipulation. The effect of exercise on psychological withdrawal symptoms measured at pre-treatment (3b) and 2-minutes post-treatment (4). Means and standard error are presented; asterisks indicate significant differences between groups at specific time points ($p < .05$).

![Fig. 2](https://example.com/f2.png)

**Fig. 2.** The effect of exercise on strength of desire to smoke compared to passive control (mean and standard error). Time points are baseline (1); post-abstinence (2); post-environmental manipulation (3); during treatment — 5 min (4); during treatment — 10 min (5); end of treatment — 15 min (6) and immediately post-treatment (7). Means and standard and error are presented; asterisks indicate significant differences between groups at specific time points ($p < .05$).

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**Table 1**

Mean and standard deviations for baseline (Visit 1) characteristics.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Experimental ($n = 12$)</th>
<th>Control ($n = 13$)</th>
<th>$F$</th>
<th>$\eta^2$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>35.7 (4.9)</td>
<td>39.1 (5.2)</td>
<td>.320</td>
<td>.01</td>
<td>.57</td>
</tr>
<tr>
<td>Female gender, number (percent)</td>
<td>7 (58.3)</td>
<td>7 (53.8)</td>
<td>.047</td>
<td>.002</td>
<td>.83</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.6 (6.49)</td>
<td>24.2 (4.83)</td>
<td>2.36</td>
<td>.09</td>
<td>.14</td>
</tr>
<tr>
<td>Moderate/vigorous intensity activity in the past week (hours)*</td>
<td>2.71 (1.65)</td>
<td>2.31 (1.57)</td>
<td>.717</td>
<td>.01</td>
<td>.58</td>
</tr>
<tr>
<td>Resting heart rate (bpm)</td>
<td>87.0 (13.9)</td>
<td>83.5 (8.98)</td>
<td>.556</td>
<td>.02</td>
<td>.46</td>
</tr>
<tr>
<td><strong>Smoking status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Years smoked</td>
<td>17.8 (13.3)</td>
<td>21.2 (14.7)</td>
<td>.366</td>
<td>.02</td>
<td>.55</td>
</tr>
<tr>
<td>Cigarettes per day</td>
<td>13.0 (5.95)</td>
<td>15.2 (6.08)</td>
<td>.796</td>
<td>.03</td>
<td>.38</td>
</tr>
<tr>
<td>FTCD</td>
<td>3.58 (2.07)</td>
<td>4.08 (2.66)</td>
<td>.265</td>
<td>.01</td>
<td>.61</td>
</tr>
<tr>
<td>Expired CO (ppm)</td>
<td>17.0 (7.04)</td>
<td>22.2 (9.67)</td>
<td>.435</td>
<td>.09</td>
<td>.14</td>
</tr>
<tr>
<td>Smoking ladder</td>
<td>6.11 (1.53)</td>
<td>7.09 (1.01)</td>
<td>.562</td>
<td>.03</td>
<td>.41</td>
</tr>
<tr>
<td>Strength of desire</td>
<td>3.75 (1.49)</td>
<td>2.85 (1.86)</td>
<td>1.78</td>
<td>.07</td>
<td>.20</td>
</tr>
<tr>
<td>Psychological withdrawal symptoms</td>
<td>2.96 (.893)</td>
<td>2.69 (1.13)</td>
<td>.449</td>
<td>.02</td>
<td>.51</td>
</tr>
<tr>
<td>Length of smoking abstinence (hours)</td>
<td>18.1 (.370)</td>
<td>17.8 (1.19)</td>
<td>.569</td>
<td>.03</td>
<td>.46</td>
</tr>
<tr>
<td>Days between visits</td>
<td>6.40 (.183)</td>
<td>6.52 (.144)</td>
<td>.546</td>
<td>.03</td>
<td>.47</td>
</tr>
</tbody>
</table>

Note. BMI = Body Mass Index; bpm = beats per minute; FTCD = Fagerstrom Test for Cigarette Dependence; CO = carbon monoxide; ppm = parts per million.

* 7-day Physical Activity Recall Questionnaire.
smokers experiencing highly challenging and ecologically valid scenarios (i.e., environmental stressors occurring at the same time as stressors experienced from abstaining from smoking).

For individuals unable or unwilling to quit smoking, delaying time between cigarettes may reduce the number of cigarettes smoked and harm inflicted (deRuiter & Faulkner, 2006). We found that exercise had no effect on ad libitum smoking, compared to passive sitting. Measuring ad libitum smoking in a similar manner as the present study, Taylor and Katomeri (2007) found that, compared to controls, those who exercised waited an average of 57 min before lighting up their next cigarette. One plausible explanation is that concurrent stressors mitigated the residual effects of post exercise craving reductions, which in turn made time to lighting up one’s first cigarette essentially the same for both groups. Although we have no repeated measurement of post exercise craving data, we suspect that the single 2 minute post exercise data point assessed (see Fig. 2) reflects the start of an upward movement in cravings for the exercise group because of the concurrent stressors they experienced prior to exercise. Previous studies (Daniel et al., 2006; Ussher et al., 2006) have shown craving reduction effects lasting up to 30 min post exercise following temporary abstinence only. Experimental work that assesses post-exercise cravings and ad libitum smoking following concurrent stressors is warranted. This study is not without limitations. Researchers did not examine the duration of the effects of exercise on cravings post-treatment, which has been examined in previous studies. Next, the study was conducted in a laboratory, under controlled conditions and included individuals who were able to temporarily abstain from smoking for a prolonged period of time. Hence, inferences drawn from the study cannot be applied to a more naturalistic setting and all tobacco users. Finally, due to the small sample size, the findings cannot be generalized to smokers with a different demographic and smoking profile.

4.1. Conclusions

This is the first study to use a more valid lab-based scenario and show that a single bout of moderate intensity exercise reduces cravings following concurrent stressors. Exercise had no effect on ad libitum smoking. Future work is now needed where momentary assessment is used in participants’ natural environment to examine changes in cigarette cravings following acute bouts of exercise.

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Contributors

HP conceived the study, AJF, SD, SB and HP contributed to the final design of the study. AJF executed the study. AJF and HP ran the statistical analysis of the study. AJF prepared the first draft of the manuscript that was jointly interpreted and edited by the other authors. All authors contributed to and approved the final version of the manuscript.

Conflict of interest

My coauthors and I do not have any personal or financial conflicts of interest related to the research, nor do we have other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, this work.

References


