Smoking and Exercise: Mechanisms and Effects During Simulated and Genuine Quit Attempts

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Graduate Program in Kinesiology
A thesis submitted in partial fulfillment of the requirements for the degree in Doctor of Philosophy
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SMOKING AND EXERCISE: MECHANISMS AND EFFECTS DURING SIMULATED AND GENUINE QUIT ATTEMPTS

(Thesis format: Integrated Article)

By

Stefanie De Jesus

Graduate Program in Kinesiology

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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Abstract

Cigarette smoking is a leading agent for premature morbidity and mortality among the global community. Most individuals surrender to tobacco use disorder due to the inability to cope with cravings and withdrawal symptoms. Exercise appears to provide acute relief. Currently, it is unclear how exercise attenuates these reductions. Furthermore, the available evidence has focused on acute outcomes besides smoking behaviour and is limited to simulated quit attempts. Three experimental studies were designed to address these outstanding issues. Not surprisingly, a bout of moderate intensity exercise was found in study 1 (chapter 2) to reduce cravings associated with a temporary period of nicotine deprivation compared to passive sitting. These reductions were mediated by positive and negative affect, but not cortisol. Using a randomized controlled trial design and a simulated quit attempt, study 2 (chapter 3) examined the effects of an acute bout of moderate intensity exercise on and interrelatedness among ad libitum smoking, smoking topography, affect, and tobacco withdrawal symptoms, with changes to cravings serving as a fidelity check. Results showed that exercise increased time to first puff but had a null effect on smoking topography. Exercise also alleviated cravings, affect, and tobacco withdrawal symptoms, which was related to smoking behaviour measures. The objective of study 3 (chapter 4) was to investigate the impact of a pre-quit period (i.e. forthcoming genuine quit attempt) during an exercise-aided smoking cessation program on cigarette consumption, expired carbon monoxide levels, smoking topography, and cigarette-related sensations. Reductions in number of cigarettes smoked, carbon monoxide, puff duration, smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, and craving, as well as an increase in average puff flow, were exhibited. Together, these
three studies extend the extant literature by: ascertaining the mechanistic role of affect; corroborating the utility of a short bout of exercise for *ad libitum* smoking behaviour, cravings, affect, and withdrawal symptoms; and revealing that harm reducing changes in cigarette consumption were not coupled with compensatory behaviour, in fact, it favourably positioned smokers to optimize their quit attempt efforts. Without question, exercise plays a catalytic role in interrupting the tobacco use disorder.

*Keywords:* exercise, smoking cessation, mechanisms, mediation, cortisol, affect, *ad libitum*, smoking topography, cravings, withdrawal symptoms, cigarette evaluation, compensation, harm reduction.
Acknowledgements

In the course of writing this thesis, I was reminded of the ebbs and flows of realizing this degree which would otherwise not be possible without the support and involvement of the following individuals.

First of all, I would like to thank my doctoral supervisor, Dr. Harry Prapavessis, for his valuable support and mentorship. To the members of my supervisory committee and thesis examining board (Drs. Guy Faulkner, Craig Hall, Robert Petrella, Andrew Strasser, and Michael Ussher): I greatly appreciate your insight and expertise. I would also like to express my gratitude to all of the participants who contributed to this research; these findings represent our collective efforts. Further, I would like to recognize Erin Murray for dedicating her time and energy to data collection and imputation. Thank you to the Ontario Graduate Scholarship and the Canadian Institutes for Health Research for funding my research program and for providing training opportunities.

Finally, to my unwavering champions, Sara, Mom, Dad, Ryan, and Cam: I am indebted to you for listening to all of my frustrations and being a constant source of perspective, encouragement, and strength. You have been critical to my achievements and empowered me to rise to meet the many challenges.
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Chapter One: Literature Review

Many individuals suffer from the repercussions of poor lifestyle choices and maladaptive behaviours, which substantially contribute to premature morbidity and mortality. Tobacco use is one such behaviour, from which smokers squander at least one decade of their lifespan (Jha et al., 2013; Pirie et al., 2013). Since the turn of the 21st century, reductions in smoking prevalence have decelerated (Reid, Hammond, Rynard, & Burkhalter, 2014). In Canada, 16.1% of individuals currently smoke (Reid et al., 2014).


Emperor of All Addictions

There is a myriad of evidence to support the short- and long-term health benefits of quitting smoking. Nonetheless, many attempts to stop smoking are unsuccessful due to the addictive properties of nicotine. In fact, nicotine may have higher dependence and tolerance potentials than heroin, cocaine, alcohol, and marijuana (Ferrence, Slade, Room, & Pope, 2000). That is to say, nicotine elicits greater levels of reliance and progressively
larger nicotine doses are required to achieve satiation, compared to other drugs, making nicotine the emperor of all addictions.

According to the fifth edition of the Diagnostic and Statistical Manual (DSM) of the American Psychiatric Association, nicotine addiction is now identified as a tobacco use disorder (2013). Tobacco use disorder is characterized by the demonstration of at least two of the following criteria during the preceding 12 months:

1. Tobacco is consumed in larger quantities or over a longer period
2. Unrelenting desire or unsuccessful attempts to reduce or control tobacco use
3. Substantial time spent in substance-related activities
4. Craving or a strong desire to consume tobacco
5. Domestic, academic, or occupational obligations neglected due to persistent tobacco use
6. Recurring tobacco use regardless of interpersonal issues caused or aggravated by tobacco
7. Engagement in social, occupational, or recreational activities negatively affected by persistent tobacco use
8. Continued tobacco use under hazardous conditions
9. Persistent tobacco use in the face of physical or psychological health concerns that were triggered or exacerbated by tobacco
10. Tolerance, as defined by progressively larger doses of tobacco are necessary in order to realize the desired effect
11. Manifestation of withdrawal symptoms.
During a period of tobacco reduction or complete abstinence, withdrawal symptoms such as sleep disturbance, difficulty concentrating, anxiety, fatigue, weight gain, decreased heart rate, and mood disorders are typically experienced (Aveyard & West, 2007; Hughes, Higgins, & Bickel, 2007). In addition to these withdrawal symptoms, tobacco use is reinforced by physiological, environmental, and psychosocial drivers, which are beyond the scope of this dissertation.

**Interventions for Smoking Cessation**

A panacea for tobacco use disorder cannot be found on pharmacy shelves, in a doctor’s office, or in the depths of human conversation. Of the nearly half of Canadian smokers who engaged in a quit attempt, one third attempting more than once, merely 13% of individuals were abstinent one year later (Reid et al., 2014). Although there are promising efforts, overcoming this behaviour is an arduous undertaking in light of its dynamic, interrelated, and multifactorial characteristics.

There are a number of behavioural and pharmacological methods to quit smoking (see Table 1). Unassisted cessation, whereby individuals quit smoking without any external intervention, has dismal success rates. Behavioural support by way of advice from healthcare professionals, cognitive behavioural therapy, or individual, group, and telephone counselling improves the likelihood of smoking cessation (Lancaster & Stead, 2004; Lemmens, Oenema, Knut, & Brug, 2008).

In contrast to self-imposed or professionally sought behavioural treatment, pharmacotherapy has been the most effective as it remedies withdrawal symptoms and attenuates the neurobiological cascade in the absence of tobacco. Nicotine replacement
therapy (NRT) provides lower doses of nicotine in the form of transdermal patch, gum, inhaler, and lozenge. More than one third (34.9%) of Canadian smokers used some form of NRT during their quit attempt (Reid et al., 2014). Non-nicotinic medications, such as varenicline and bupropion, are available by prescription and interrupt the dopamine and nicotinic acetylcholine receptor modes of action, respectively (NIDA, 2012; Wilkes, 2008). Implementing a cocktail of approaches, specifically cognitive behavioural and pharmacotherapies, provide the most benefit for smoking cessation (USDHHS, 2008).
### Table 1

*Abstinence rates for various smoking cessation interventions at 6-months post-quit*

<table>
<thead>
<tr>
<th>Smoking cessation intervention</th>
<th>Abstinence rate (95% C.I.)</th>
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<tbody>
<tr>
<td>Unassisted</td>
<td>4.00-7.00&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Physician advice to quit</td>
<td>10.20 (8.50–12.00)</td>
</tr>
<tr>
<td>Proactive telephone counseling (i.e. quitlines)</td>
<td>13.10 (11.40–14.80)</td>
</tr>
<tr>
<td>Individual counselling</td>
<td>16.80 (14.70–19.10)</td>
</tr>
<tr>
<td>Group counselling</td>
<td>13.90 (11.60–16.10)</td>
</tr>
<tr>
<td>Nicotine gum (6–14 weeks)</td>
<td>19.00 (16.50–21.90)</td>
</tr>
<tr>
<td>Nicotine patch (6–14 weeks)</td>
<td>23.40 (21.30–25.80)</td>
</tr>
<tr>
<td>Nicotine lozenge</td>
<td>24.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nicotine inhaler (2 mg)</td>
<td>24.80 (19.10–31.60)</td>
</tr>
<tr>
<td>Bupropion</td>
<td>24.20 (22.20–26.40)</td>
</tr>
<tr>
<td>Varenicline (1 mg/day)</td>
<td>25.40 (19.60–32.20)</td>
</tr>
<tr>
<td>Combined medication and counselling</td>
<td>27.60 (25.00–30.30)</td>
</tr>
</tbody>
</table>

<sup>a</sup> 95% C.I. not reported

(Hughes, 2003; USDHHS, 2008; Ward, Klesges, Zbikowski, Bliss, & Garvey, 1997)
Harm Reduction

Even with such incredible progress in tobacco control, a proportion of smokers have become hardened to cessation. To explain, these individuals may have no intention to quit or find it to be an especially difficult endeavour, and for these reasons, continue smoking. For those who are unlikely to be swayed by tobacco control policies, strategies, or interventions, a harm reduction approach may be more effective. The primary objective of harm reduction is to reduce the morbidity and mortality associated with tobacco use in individuals who are unable or unwilling to discontinue tobacco use (deRuiter & Faulkner, 2006). Harm reduction cannot eliminate all risks from tobacco use continuance, but, it does aim to diminish these risks. For an approach to be harm reducing, it should satisfy the following eight principles: 1) must reduce the occurrence of disease and death; 2) should not impose additional risks to safety or health; 3) must not contribute to an individual’s nicotine dependence; 4) should not reduce the likelihood of smoking cessation; 5) must not increase the prevalence of nicotine or tobacco dependence; 6) must permit smokers to become nicotine and tobacco free; 7) should not entice adolescents or lead to their misuse of tobacco; and 8) smoking cessation messages should be promoted in any harm reduction strategy.

There are several methods available to smokers that may mitigate cigarette related harm. These include potentially reduced exposure products, medicinal nicotine, smokeless tobacco, and behaviour change (i.e., reduction in cigarette consumption). Unfortunately, little research has evaluated whether these methods uphold the principles of harm reduction and their impact. Currently, nicotine replacement therapy is upheld as the only harm reduction strategy to fulfill each of the above principles (Hatsukami,
Henningfield, & Kotlyar, 2004), yet deRuiter and Faulkner (2006), among others, have made a case for the adoption of physical activity as the second harm reduction strategy for nicotine dependency. Physical activity is an all-encompassing term that refers to energy expenditure above resting norms and is often used interchangeably with exercise, which is structured, supervised activity with the goal of increasing health and fitness. Regardless, both are cost-effective, can be maintained, and may be particularly attractive for individuals who are inclined to make multiple positive health behaviour changes. Support for exercise as a harm reduction approach is provided throughout this chapter.

**Chronic Exercise Interventions**

To combat barriers and symptoms predictive of relapse, exercise has been recommended as an adjunctive, non-pharmacological strategy to the aforementioned cessation modalities. This approach is particularly appealing to the majority of the smoking population who opt not to use medication during their quit attempts (Amodei & Lamb, 2008; Cokkinides, Ward, Jemal, & Thun, 2000; Lader & Goddard, 2003; Zhu, Melcer, Sun, Rosbrook, & Pierce, 2000). This reluctance may stem from adverse side effects, contraindications due to one’s health condition, financial barriers, and the perceived desirability of a natural, unmedicated quit attempt (Cummings et al., 2004; Hammond, McDonald, Fong, & Borland, 2004; Juliano & Brandon, 2004; Mooney, Leventhal, & Hatsukami, 2006; Vogt, Hall, & Marteau, 2008). Ultimately, smoking and physical activity are two incompatible behaviours. This is supported by research indicating that smokers who are physically active are more confident that they can refrain from smoking (King, Marcus, Pinto, Emmon, & Abrams, 1996), less nicotine dependent
(deRuiter, Faulkner, Cairney, & Veldhuizen, 2008; Ward et al., 2003), make more cessation attempts (deRuiter et al., 2008), and are more successful at quitting smoking (Marcus, Albrecht, Niaura, Abrams, & Thompson, 1991; Ward et al., 2003) than inactive smokers. Therefore, an alternative smoking cessation modality, such as physical activity, is likely to be met with approval.

Recently, a systematic review of 20 randomized controlled trials with a minimum of a six month follow-up period was conducted (Ussher, Taylor, & Faulkner, 2014). Significantly higher quit rates for the exercise condition, versus control (i.e. standard care), following treatment were found for only four (Bock et al., 2012; Marcus et al., 1991; Marcus et al., 1999; Martin, Kalfas, & Patten, 1997) of the 20 studies (Abrantes et al., 2014; Bize et al., 2010; Bock et al., 2012; Ciccolo et al., 2011; Hill, 1985; Horn et al., 2011; Kinnunen et al., 2008; Maddison et al., 2014; Marcus et al., 1991; Marcus et al., 1995; Marcus et al., 1999; Marcus et al., 2005; Martin et al., 1997; McKay, Danaher, Seeley, Lichtenstein, & Gau, 2008; Prapavessis et al., 2007; Russell, Epstein, Johnson, Block, & Blair, 1988; Ussher, West, McEwen, Taylor, & Steptoe, 2003; Whiteley et al., 2012). Furthermore, only one demonstrated the continued benefit of exercise abstinence at three and 12-month follow-up, in comparison to control (Marcus et al., 1999). Notwithstanding the null effects of exercise, Ussher and colleagues (2014) noted small sample sizes, inadequate compliance to the exercise intervention, insufficiently intense exercise interventions, negligible participant education of the benefits of exercise, and limited generalizability among studies that did not show a significant benefit for exercise compared to control on long-term abstinence.
Although there was limited evidence that the addition of exercise to conventional quit smoking methods enhanced abstinence rates, regular physical activity yields other benefits for quitters and continued smokers. To illustrate, vascular health (e.g., peripheral resistance, compliance, inertia, brachial velocity) and lung function improved among women involved in an exercise-aided smoking cessation intervention (Fitzgeorge, Harper, Prapavessis, Faulkner, & Maddison, 2011; Nielson et al., 2014). Furthermore, exercise-based smoking cessation programs have shown significant improvements in cardiovascular disease biomarkers, Type 2 diabetes, systemic inflammation, exercise performance, and high-density lipoprotein for quitters (Albrecht, Marcus, Roberts, Forman, & Parisi, 1998; Korhonen, Goodwin, Miesmaa, Dupuis, & Kinnunen, 2011; Linke, Ciccolo, Ussher, & Marcus, 2013; Niaura, Marcus, Albrecht, Thompson, & Abrams, 1998), and risk reductions in cardiovascular mortality and colorectal cancer (Colbert et al., 2001; Hedblad, Ogren, Isacsson, & Janzo, 1997) for continued smokers. Physical activity also elicits psychological gains among individuals attempting to quit. For example, research has found improvements in perceived coping ability (Steptoe, Edwards, Moses, & Matthews, 1989) and quality of life (Bloom et al., 2013) as well as decreased rates of mood and sleep disturbances, stress, and anxiety (Abrantes et al., 2014; Stathopoulou, Power, Berry, Smits, & Otto, 2006; Taylor, 2000; Taylor & Faulkner, 2008). Aside from setting up smokers to conquer their quit attempt with less difficulty, physical activity also affords individuals numerous positive physiological and psychological outcomes.

**Acute Exercise Interventions**
Despite the marginal findings from the aforesaid systematic review, a large body of recent evidence has converged to support the acute effects of a bout of exercise on cravings, withdrawal symptoms, affect, and other smoking-related outcomes.

**Cravings.**

Over the last decade, a number of studies have ascertained short-term craving reduction following a single period of exercise. This treatment effect has been cumulatively examined by recent systematic reviews (Ussher et al., 2014) and meta-analyses (Haasova et al., 2013; Haasova et al., 2014; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012). Reviews included a systematic search of relevant electronic databases for journal articles, conference abstracts, theses and dissertations using predetermined keywords with different temporal criteria. Eligible studies for the meta-analyses had to assess cravings by way of ‘strength of desire to smoke’ or ‘desire to smoke’ on a 7-point Likert scale, entail a randomized cross-over or parallel arm design, at least a 2-hour period of temporary smoking abstinence, and absence of pharmaceutical smoking cessation therapy. The latter meta-analysis also required that studies involve a passive control condition. Study characteristics were heterogeneous among the studies included in these systematic reviews and meta-analyses. Participants engaged in walking, running, cycling, or isometric exercises of varying intensities. The bout of activity ranged from 5 to 40 minutes.

By and large, there was solid evidence that a single bout of exercise acutely decreased cravings (Ussher et al., 2014). From ten trials (Arbour-Nicitopoulos, Faulkner, Hsin, & Selby, 2011; Faulkner, Arbour-Nicitopoulos, & Hsin, 2010; Janse Van Rensburg...
& Taylor, 2008; Janse Van Rensburg, Taylor, & Hodgson, 2009a; Janse Van Rensburg, Taylor, Hodgson, & Benattayallah, 2009b; Janse Van Rensburg, Taylor, Hodgson, & Benattayallah, 2012; Scerbo, Faulkner, Taylor, & Thomas, 2010; Taylor, Katomeri, & Ussher, 2006; Taylor & Katomeri, 2007; Ussher, Nunziata, Cropley, & West, 2001), Roberts and colleagues (2012) calculated the weighted mean difference of ‘desire to smoke’ between exercise and control conditions to be −1.90 points, in favour of exercise (95% CI −3.06 to −0.75). Furthermore, the weighted mean difference in ‘strength of desire to smoke’ between exercise and control conditions was calculated to be −2.41 points in support of exercise (95% CI −3.45 to −1.37]) from nine studies (Everson, Daley, & Ussher, 2006, 2008; Janse Van Rensburg et al., 2012; Scerbo et al., 2010; Taylor & Katomeri, 2005; Taylor & Katomeri, 2007; Ussher et al., 2001; Ussher, West, Doshi, & Sampuran, 2006; Ussher, Cropley, Playle, Mohidin, & West, 2009). From this systematic review and meta-analysis, the authors found that the residual effects of exercise on cravings extended from 5 to 30 minutes beyond the bout of activity and only slight differences in the magnitude of effect across light, moderate, and vigorous intensities.

From individual participant data, Haasova colleagues found comparable results (2013). Namely, an average standardized mean difference of −2.03 (95% CI −2.60 to −1.46) for ‘desire to smoke’ across 17 studies was demonstrated, favouring the exercise over control group (Daniel, Cropley, Ussher, & West, 2004; Daniel, Cropley, & Fife-Schaw, 2006; Faulkner et al., 2010; Haasova, Oh, & Taylor, 2011; Janse Van Rensburg & Taylor, 2008; Janse Van Rensburg et al., 2009a; Janse Van Rensburg et al., 2009b; Janse Van Rensburg, Elibero, Drobes, Ehlke, & Watson, 2011; Janse Van Rensburg et
al., 2012; Katomeri, 2009; Oh, 2011; Scerbo et al., 2010; Taylor, Katomeri, & Ussher, 2005; Taylor & Katomeri, 2007; Thompson, 2009; Ussher et al., 2001; Ussher et al., 2006). In addition, a meta-analysis of 15 studies revealed an average standardized mean difference of −1.91 (95% CI −2.59 to −1.22) between exercise and control conditions for ‘strength of desire to smoke’, in favour of exercise (Daniel et al., 2004; Daniel et al., 2006; Everson et al., 2008; Faulkner et al., 2010; Haasova et al., 2011; Janse Van Rensburg et al., 2012; Katomeri, 2009; Oh, 2011; Scerbo et al., 2010; Taylor et al., 2005; Taylor & Katomeri, 2007; Thompson, 2009; Ussher et al., 2001; Ussher et al., 2006; Ussher et al., 2009).

Using comparable methods, Haasova and colleagues (2014) explored potential mediators and moderators of the exercise-craving reduction relationship and the differential effects of exercise (i.e. type, intensity, duration) on cravings, which was rescaled from the 1-7 point scale to 0-100. In accordance with their previous observations, fixed effect mean differences between exercise and control groups for ‘desire to smoke’ of −33.78 (95%CI −42.39 to −25.16) and ‘strength of desire to smoke’ of −31.56 (95%CI −42.14 to −20.99) were revealed. Despite statistically significant relationships, none of the demographic covariates or measures of affect were found to moderate or mediate, respectively, craving relief due to exercise. From assessing the differential effects of various exercise attributes, Haasova et al. reported that moderate and vigorous intensity exercise reduced cravings to a similar extent, compared to light intensity exercise. Therefore, there is no added benefit from vigorous intensity exercise for sedentary smokers seeking craving relief. This recommendation may promote adoption and maintenance of this strategy during a quit attempt.
**Tobacco withdrawal symptoms.**

There is also increasing evidence that exercise attenuates tobacco withdrawal symptoms, which comprise anxiety, irritability, depression, tension, restlessness, poor concentration, and stress (Roberts et al., 2012; Taylor et al., 2007). Taylor et al. (2007) reported that exercise significantly attenuated at least two withdrawal symptoms during and following exercise, compared to a passive condition, in eight (Bock et al., 1999; Daniel et al., 2004; Daniel et al., 2006; Katomeri & Taylor, 2006a; Katomeri & Taylor, 2006b; Taylor et al., 2006; Taylor & Katomeri, 2007; Ussher et al., 2001; Ussher et al., 2006) of the nine studies (Bock et al., 1999; Daley et al., 2004; Daniel et al., 2004; Daniel et al., 2006; Katomeri & Taylor, 2006a; Katomeri & Taylor, 2006b; Taylor et al., 2006; Taylor & Katomeri, 2007; Ussher et al., 2001; Ussher et al., 2006).

By comparison, Roberts and colleagues (2012) noted that three (Daniel, Cropley, & Fife-Shaw, 2007; Everson et al., 2008; Ussher et al., 2009) of the five (Arbour-Nicitopoulos et al., 2011; Daniel et al., 2007; Everson et al., 2008; Ho, 2009; Ussher et al., 2009) studies that evaluated tobacco withdrawal symptoms using the Mood and Physical Symptoms Scale (MPSS) found exercise had a beneficial effect on one or more of the aforementioned withdrawal symptoms. Interestingly, they also demonstrated that MPSS was heightened during, but not after, a vigorous bout of exercise, suggesting that more challenging levels of physical exertion had an adverse impact on temporarily abstinent smokers.

**General mood and affect.**
Only two systematic reviews to date have elucidated the impact of exercise on affect (Roberts et al., 2012; Taylor et al., 2007). Taylor et al. (2007) established that there was a significant improvement in mood and affect during and after exercise in three studies (Bock et al., 1999; Taylor et al., 2006; Thayer, Peters, Takahaski, & Birkhead-Flight, 1993). Only one study did not observe any changes in state anxiety following exercise, compared with a control group (Reesor, 1983). Roberts and investigators (2012) identified five (Arbour-Nicitopoulos et al., 2011; Elibero, Janse Van Rensburg, & Drobes, 2011; Everson et al., 2008; Ho, 2009; Williams et al., 2011) such studies, four (Arbour-Nicitopoulos et al., 2011; Elibero et al., 2011; Everson et al., 2008; Williams et al., 2011) of which showed that exercise positively affected at least one measure of affect. Namely, positive affect, well-being, and energy increased, whereas negative affect and psychological distress decreased. In the same way as tobacco withdrawal symptoms, one study revealed that positive well-being and psychological distress increased and decreased, respectively, during vigorous intensity exercise (Everson et al., 2008).

Other outcomes.

The systematic review by Taylor et al. (2007) and Roberts et al. (2012) also observed other outcomes due to exercise after a period of nicotine deprivation. First, Taylor and colleagues found that ad libitum time to first puff was delayed between 8 and 57 minutes in four studies (Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Reesor, 1983; Taylor & Katomeri, 2007; Thayer et al., 1993), as well as harm reducing smoking topography (i.e. time smoking, puff count) in two studies (Mikhail, 1983; Reesor, 1983), as a result of exercise. Roberts et al. (2012) identified only one study (Faulkner et al.,
2010) which demonstrated a significant delay in time to smoke and non-significant smoking topography patterns, all in favour of the brisk walking condition compared with passive sitting. Likewise, Kurti and Dallery (2014) found significantly longer delays to smoke following 20 minutes of moderate intensity exercise (20.9 minutes) than inactivity (4.0 minutes). In contrast, Fong and colleagues (2014) revealed non-significant differences for latency to smoke between moderate intensity exercise (12.7 minutes) and passive sitting (14.1 minutes). They attributed these marginal differences to the concurrent stressors, whereby any post-exercise craving reduction was tempered by overnight abstinence, the Stroop cognitive task, and cue-elicited smoking stimuli. Other consequences from a bout of exercise are later described in greater detail, but include cortisol, plasma adrenocorticotrophic hormone, heart rate, and systolic blood pressure (Ho, 2009; Scerbo et al., 2010).

Against this background, it is clear that participation in a brief bout of exercise yields several benefits with respect to cravings, tobacco withdrawal symptoms, affect, smoking behaviour, and biological outcomes during a simulated quit attempt.

**Possible Mechanisms behind the Acute Effects of Exercise**

Systematic reviews and meta-analyses have revealed that bouts of exercise attenuate cravings, tobacco withdrawal symptoms, affect, smoking behaviour, and other biomarkers after a temporary period of abstinence. Understanding the mechanisms by which exercise induces craving reductions specifically will better allow researchers and healthcare professionals to infer causality and implement interventions guided by the
processes that yield such desirable outcomes. A number of cognitive, biological, and affective mechanisms have been proposed to account for the craving relief afforded by exercise.

**Cognitive hypotheses.**

A commonly used technique during a quit attempt is the deliberate suppression of smoking related thoughts and behaviours. Previous research has found that exercise above a ‘ventilatory threshold’ increases cognitive demand (Ekkekakis & Acevedo, 2006) and low intensity ‘mindful’ exercises, such as isometrics, stretching, and yoga, heightens cognitive focus (Taylor et al., 2007). As such, exercise was initially believed to act as a distraction. Comparing a bout of isometric exercises and distracting ‘body scanning’ technique (i.e. control group), Ussher and colleagues (2009) noted similar craving reductions. However, in other experiments, distraction was found not to play a mechanistic role as craving relief was significantly greater during and ten minutes after the moderate intensity cycling condition, in contrast to the group subjected to a distracting task (Daniel et al., 2006; Ussher et al., 2001). Thus, if distraction was mechanistically involved, reductions in cravings would be evident during both exercise and control conditions, which was not the case. Upon removal of the stimulus (i.e. exercise), craving relief did not dissipate, thereby refuting distraction as a possible mechanism.

Expectancy and credibility are important sources of judgment which may have implications for treatment outcome. Daniel and colleagues (2007) randomized participants to a positive expectancy group, ambiguous expectancy group, or negative
expectancy group. Although participants’ expectancies were successfully manipulated, reductions in cravings and withdrawal symptoms were evident following a short bout of moderate intensity exercise, irrespective of group allocation. Harper et al. (2013) found that female smokers involved in an exercise-aided quit smoking program with high levels of exercise expectancy and credibility experienced greater reductions in cravings and tobacco withdrawal symptoms, compared to female smokers with low levels of exercise expectancy and credibility. These findings may be reflective of participants’ engagement in a real quit attempt, and hence, were more invested in the treatment outcome. Also, exercise-related expectancy and credibility were not manipulated in this study; participants naturally expressed these notions. Overall, expectancy is not believed to play a major role in mediating the effects of exercise on cravings associated with smoking abstinence.

**Biological hypotheses.**

In light of the biological changes that transpire during smoking, a quit attempt, and exercise, several related mechanisms have been considered to explain the exercise-craving reduction relationship.

Given the innate upper capacity of the brain’s information-processing centre, it is believed that exercise requires an attentional shift from cognitive to somatic cues. This was tested by Janse Van Rensburg and colleagues (2009b, 2012) in a few experiments using a randomized crossover design and functional Magnetic Resonance Imaging (fMRI). Following a simulated quit attempt, smokers undertook 10 minutes of exercise and passive sitting conditions. Participants then viewed a series of smoking related and
neutral images in an fMRI scanner. Janse Van Rensburg et al. demonstrated a significant activation of the reward processing, motivation, and visuo-spatial attention areas of the brain for the control, but not exercise group (2009b, 2012). In fact, exercise was associated with a hypo-activation of these areas and an attentional shift by transferring the brain’s information processing from the pleasure-rewarding and visuospatial centres to the ‘default’ mode. Further research is required to explicitly test the mechanistic role of this neurobiological process.

Cortisol is a primary stress hormone released by the hypopituitary-adrenocortical axis. In regular smokers, cortisol levels are 36% higher than non-smokers (Ussher et al., 2006) and within 12 to 24 hours of a quit attempt, cortisol levels plummet (Steptoe & Ussher, 2006). Although this is positive for long-term health, this exacerbates tobacco withdrawal symptoms (al’Absi, Hatsukami, Davis, & Wittmers, 2004). Declines in cortisol are also theorized to increase distress and nicotinic acetylcholine receptor sensitivity (Pomerleau & Pomerleau, 1990). And so, any means of attenuating changes in cortisol during smoking abstinence may minimize withdrawal symptoms. Short bouts of exercise have been associated with raising cortisol levels among non-smokers (Jacks, Sowash, Anning, McGloughlin, & Andres, 2002) and smokers (Pomerleau et al., 1987). A handful of studies have explored the role of cortisol in mediating the exercise-craving reduction relationship. Scerbo and colleagues (2010) observed higher cortisol concentrations post-exercise, versus passive control, but these changes were not related to changes in cravings. Identical patterns were also exhibited by Janse Van Rensburg et al. (2013) and Ho et al. (2014). More recently, Roberts and colleagues (2015) did not find either time or interaction effects for cortisol levels following overnight abstinence as
measured through saliva and blood. Although this evidence has begun to erode the likelihood of the mechanistic role of cortisol, flaws related to study design, abstinence period, as well as lack of power and pre-abstinence measure of cortisol, provide grounds for replication and continued investigation.

Similar to cortisol, catecholamines, specifically epinephrine and norepinephrine, are released in response to nicotine (Laustiola, Kotamäki, Lassila, Kallioniemi, & Manninen, 1991). Pronounced decreases in these neurotransmitters are evident during abstinence and potentially contribute to the negative symptoms experienced during a quit attempt (Ward et al., 1991). During a single bout of exercise, epinephrine and norepinephrine increase in a dose response fashion, such that a greater intensity and duration of exercise produces a greater release of these catecholamines (Richter & Sutton, 1994). In abstaining smokers, Roberts et al. (2015) found significant differences in norepinephrine between light, moderate, and vigorous intensity exercise groups at 5 minutes post-exercise. Regression analyses revealed that changes in norepinephrine did not mediate the relations between exercise and cravings. These preliminary findings highlight that catecholamines may help explain how exercise attenuates cravings during smoking abstinence.

Increased concentrations of dopamine, a neurotransmitter, has been found to mediate the pleasure and rewarding effects of drug administration, including nicotine (Jain & Mukherjee, 2003). In rat models, exercise increases the release of dopamine into the striatum, diminishing the appetite for self-administered drugs (Hattori, Naoi, & Nishino, 1994; Wilson & Marsden, 1995). This relationship did not manifest following
30 minutes of vigorous intensity exercise among healthy, active human participants (Wang et al., 2000). Hence, dopamine is unlikely to serve as a leading mechanism.

A phenomenon known as heart rate variability (HRV), driven by the sympathetic and parasympathetic nervous system (PSNS), has also been considered as a potential mechanism. Heart rate variability refers to the variability in the time interval between heart beats and decreases with smoking consumption (Lucini, Bertocchi, Malliani, & Pagani, 1996; Niedermaier et al., 1993) and increases approximately 4-6 weeks following abstinence (Stein, Rottman, & Kleiger, 1996). Roberts and colleagues (2015) established for the first time that significant differences for HRV between light, moderate, and vigorous intensity exercise groups during and 25 to 35 minutes post-exercise exist. Upon further analyses, HRV did not mediate the well-established effects of exercise on cravings, possibly due to a lack of power. Additional research is required in order to address limitations with previous research and determine the mechanistic role of HRV in the acute exercise and cravings paradigm.

Finally, there is mounting evidence that nicotine metabolism can predict smoking behaviour and cessation rates (Schnoll et al., 2009). Nicotine metabolism involves cytochrome P680 2A6, a hepatic enzyme, which breaks down nicotine to cotinine and then 3-hydroxycotinine. Depending on the genotype, individuals vary in their rate of nicotine metabolism. Future research is warranted to study whether nicotine metabolism accounts for the effects of exercise on urges to smoke and tobacco withdrawal symptoms during a real or induced quit attempt.

**Affective hypotheses.**
Previous research has documented the favourable consequences of physical activity on positive and negative affect (Hassmen, Koivula, & Uutela, 2000; Penedo & Dahn, 2005; Reed & Ones, 2006; Schlicht, 1994). To elucidate the interrelationship between an acute bout of exercise, cravings, and affective responses, two conceptual frameworks have been applied: Nesbitt’s Paradox (Schachter, 1973) and the circumplex model of affect (Russell, 1980).

A temporary period of smoking abstinence is accompanied by decreased arousal and heightened emotional stress, which are attenuated by returning to cigarette smoking (Schachter, 1978). Thus, nicotine has a paradoxical role in regulating mood, as it serves both as a stress-reducing and stimulating modality. This is referred to as Nesbitt’s paradox (Schachter, 1973). To diminish tobacco withdrawal symptoms, an effective aid must reproduce these stress-reducing and stimulating properties of nicotine. Some studies have directly examined the exercise-craving reduction relationship within the context of Nesbitt’s Paradox and found that exercise reduced tension and stress in abstaining smokers, compared with a control group (Daniel et al., 2004; Taylor et al., 2006; Ussher et al., 2001). These changes in tension and stress were observed during and up to 20 minutes post-exercise. Taylor and colleagues (2006) also revealed that the craving relief triggered by exercise was mediated by tension (emotional stress) and not through increased energy or vigor (stimulation).

At the same time, the circumplex model of affect (Russell, 1980) posits that affective states emanate from two dimensions: arousal and valence. Nicotine from cigarette smoke activates the pleasure and reward pathways in the mesolimbic system and nucleus accumbens through nicotinic acetylcholine receptors (D’Souza & Markou, 2011).
Not surprising, individuals return to cigarette smoking as a means to regulate negative affective states (Tart et al., 2010). In non-smoking populations, a bout of exercise has been found to increase affective valence (Ekkekakis, Parfitt, & Petruzzello, 2011) and arousal (i.e. activation; Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000; Reed & Ones, 2006) during exercise, which subsides to low activation pleasant states post-exercise. There has been limited, direct application of the circumplex model to the acute exercise paradigm. Taylor et al. (2006) and Haasova et al. (2014) both reported higher levels of valence and arousal after a short bout of exercise and that these changes in affect did not mediate changes in cravings. Employing a different measure of affect (e.g. Mood and Physical Symptoms Scale), other studies have also suggested that a session of exercise positively affects mood in smokers (Arbour-Nicitopoulos et al., 2011; Elibero et al., 2011; Everson et al., 2008; Janse Van Rensburg et al., 2013; Tart et al., 2010; Williams et al. 2011). What’s interesting is that Everson et al. (2008) discovered that compared to a bout of moderate intensity exercise, vigorous intensity exercise produced pronounced increases in psychological distress in temporarily abstaining younger adult smokers. On the whole, these patterns corroborate affect as a possible mechanism. Among the aforementioned studies that tested for mediation (Elibero et al., 2011; Haasova et al., 2014; Janse Van Rensburg et al., 2013; Tart et al., 2010), only two studies found that positive affect (Janse Van Rensburg et al., 2013) and negative affect (Tart et al., 2010) mediated the effects of exercise on ‘desire to smoke’. Due to the highly variegated nature of these studies, further consideration of affective mechanisms is justified.
An assortment of cognitive, biological, and affective factors have been purported to play mechanistic roles in the attenuation of cigarette cravings as a result of acute exercise. Many of these hypotheses have not been adequately tested and should be regarded as potential avenues for future research.

**Smoking Behaviour**

Granted that physical activity has been associated with far-reaching benefits, what’s less known is its impact on smoking behaviour. A smoker’s interaction with a cigarette is highly complex, multidimensional, and individualistic. Moreover, no two individuals use tobacco in an identical manner, even if brand and total daily cigarette consumption were held constant. To this end, a selection of subjective and objective methods exists to characterize smoking behaviour, each differing in accuracy, precision, and feasibility (Frederiksen, Miller, & Peterson, 1977).

Admittedly, subjective methodologies to assessing cigarette consumption (i.e. self-report) are practical for large samples and are low in cost and participant burden. Even so, self-reported responses can be swayed by cultural factors, social desirability, recall bias, reactivity, and inaccurate discrimination of the target behaviour under question (Bowling, 2005; Tomlin, Pinney, Buncher, McKay, & Brown, 1998).

In much the same way, latency to smoke is another useful characteristic of smoking behaviour. Also referred to as *ad libitum* smoking, it is defined as the time that elapses between one significant event (e.g. completion of an intervention, waking time) and smoking a cigarette at one’s discretion. It can be measured by a researcher or self-reported, the former obviously being more accurate and reliable. *Ad libitum* smoking
provides a limited profile of the behaviour but appeals to possible suppression or acceleration of cigarette consumption. Extending the period of time between cigarettes could potentially decrease the total number of cigarettes smoked and exposure to carcinogens and other toxins. There are no definitive health benefits associated with delayed *ad libitum* smoking (Hughes & Carpenter, 2005); for that reason, it is not a suitable proxy measure for harm reduction due to the possibility for compensation (deRuiter & Faulkner, 2006). Other research has found that negative affect decreases time to *ad libitum* smoking (Heckman et al., 2015) and that craving is a powerful predictor of *ad libitum* smoking (Kurti & Dallery, 2014; Shiffman et al., 2002; Shiffman, Paty, Gwaltney, & Dang, 2004). To improve the utility of this outcome measure, future research is required to establish cutpoints in order to determine clinical significance.

By comparison, multiple indicators afford biologically meaningful information and are considerably more accurate than self-report questionnaires. The most commonly used method is expired carbon monoxide (CO) breath levels which offer an immediate and non-invasive estimate of smoking behaviour using relatively inexpensive infrastructure. However, carbon monoxide can be confounded by its short half-life, environmental pollution (including traffic and second-hand smoke; (Joumard, Chiron, Vidon, Maurin, & Rouzioux, 1981), occupational exposure (Middleton & Morice, 2000), hyperventilation (Vesley, Takeuchi, & Rucker, 1999), substantial physical activity (Middleton & Morice, 2000), smoking other substances (e.g., marijuana; Moolchan et al., 2005), and numerous inflammatory lung diseases (Hovarth et al., 1998; Zayasu et al., 1997) which can increase the chances of false positives and negatives as this tool is not representative solely of tobacco smoking behaviour. The analysis of biological fluids,
such as nicotine, cotinine, or thiocyanate, can potentially address the limitations associated with carbon monoxide, but they are often obtrusive, costly, and require additional resources for administration.

The aforementioned methods have utility in evaluating abstinence and relapse rates but provide a restricted portrayal of the interface between smoker and cigarette. It also does not allow for an estimation of compensatory behaviour, whereby smokers adjust multiple dimensions of how they smoke a cigarette in order to achieve a desired effect. Nicotine dosing can include modifying the quantity, depth, duration, and speed of puffs, as well as the manual manipulation of the cigarette. These features interact to produce negative health consequences (Djordjevic, Stellman, & Zang, 2000). Hence, shortfalls associated with subjective and biological measurements of smoking behaviour could be overcome through the inclusion of smoking topography.

Smoking topography provides an exhaustive representation of the physical attributes of smoking behaviour and is an emerging outcome of interest (De Jesus, Hsin, Faulkner, & Prapavessis, 2015). It consists of the quantification of variables such as puff count, puff volume, average flow, puff duration, and interpuff interval. Smoking topography has also been used to estimate exposure levels to carbon monoxide (Zacny, Sitzer, Brown, Yingling, & Griffiths, 1987) and carcinogenic toxins (Djordjevic, Hoffmann, & Hoffman, 1997) and portrays the rewarding and reinforcing effects of nicotine from a behavioural perspective. In any case, the analysis of smoking topographical indices is integral to the comprehensive understanding of this addictive behaviour and in establishing the harm from it (De Jesus et al., 2015).
Initially, the measurement of smoking topography heavily relied on behavioural techniques. Self-report has seldom been utilized to quantify the manner in which cigarettes are smoked. Shahab and colleagues (Shahab, West, & McNeill, 2008) evaluated the reliability and validity of self-report by comparing it to both machine-determined smoking topography and nicotine uptake by cotinine analysis. They found that smokers had better judgement regarding the time spent between puffs and the number of puffs, but limited acuity of puff intensity and depth, when compared to more objective measures of smoking behaviour. De Jesus and Prapavessis (2014) were able to replicate and extend the strength of the association, as reported by Shahab et al., between subjectively and objectively measured smoking topography parameters with more refined self-reported items. The magnitude of the correlations was moderate and suggested that smokers can reasonably discern their smoking behaviour through a more precise self-report measure. For large samples or population studies, the assessment of smoking topography through self-report would vastly improve feasibility, but current self-report measures warrant more attention.

Prior to the advent of topography apparatuses, observation in the lab setting and natural environment provided a crude indication of smoking topography. For example, the use of videotapes and timers and unobtrusive surveillance measured puff count and total smoking duration, but not indices such as interpuff interval and puff volume. Another indirect measure of smoking topography includes cigarette weighing, before and after smoking, as an estimate of the quantity of tobacco smoked and elements that entered the smoker’s system (June et al., 2011). The evolution of more objective smoking topography instruments transpired over the last 30 years. Pneumotachographs (Zacny et
al., 1987), pressure transducers (Ossip-Klein, Martin, Lomax, Prue, & Davis, 1983), portable recorders (Hatsukami, Morgan, Pickens, & Champagne, 1990), flowmeters (Ahijevych, Gillespie, Demirci, & Jagadeesh, 1996), and puff analyzers (Sutton, Russell, Iyer, Feyerabend, & Saloojee, 1982) have been previously utilized.

More recently, a portable, computerized device (Clinical Research Support System (CReSS) Pocket; Plowshare Technologies®, Borgwalt, KC. Inc., Virginia, USA) has been developed to quantify smoking topography. Compared to fixed systems, such as earlier instruments and the CReSS Desktop, the CReSS Pocket affords the acquisition of behavioural data in the smoker’s natural setting, thereby improving ecological validity. With its use, participants should be afforded proper instruction and the opportunity to become familiar with the smoking topography device to ensure accurate data collection (De Jesus et al., 2015). This battery-powered, hand-held unit has an orifice flowmeter mouthpiece, which produces a pressure drop when a puff is taken. This is converted to a flow velocity from which many of the topography indices are derived. The CReSS Pocket computes time to first puff, puff count, puff volume, puff velocity, puff duration, and interpuff interval.

The evaluation of smoking topography devices has been conducted under different conditions. Lee and colleagues (Lee, Malson, Waters, Moolchan, & Pickworth, 2003) reported that smoking behaviour is not influenced by smoking through a mouthpiece and that the CReSS system provides a valid and reliable measure of topography. Furthermore, smoking topography data varied slightly between conventional mouthpiece-free video recordings, or using a desktop or portable computerized device.
Given these findings and the utility of this outcome measure, it is no surprise that smoking topography has been examined in diverse contexts.

Numerous studies have observed inter-individual variability in smoking topography as a function of demographic factors. Namely, smoking topography indices have been confounded by sex (Eissenberg, Adams, Riggins III, & Likness, 1999), personality (Lombardo & Carreno, 1987), stress level (Lombardo & Carreno, 1987), nicotine yield (Djordjevic et al., 2000), cigarette type (menthol versus non-menthol; Ahijevych & Parsley, 1999), ethnicity (Ahijevych et al., 1996), and body mass index (Blendy et al., 2005). Researchers have also integrated the study of smoking topography across various disciplines and populations: adolescents (Moolchan et al., 2009), nicotine metabolism (Strasser, Malaiyandi, Hoffmann, Tyndale, & Lerman, 2007), smokers with schizophrenia (Tidey, Rohsenow, Kaplan, & Swift, 2005), exercise (Faulkner et al., 2010), abstinence (Kolonen, Tuomisto, Puustinen, & Airaksinen, 1992), and smoking cessation (Strasser, Pickworth, Patterson, & Lerman, 2004). Undeniably, the measurement of smoking topography is becoming more pervasive in the literature.

**Smoking Behaviour and Exercise**

In consideration of the progression of smoking behaviour measurement, initial exercise research was devoted to *ad libitum* smoking and visually derived smoking topography as outcomes of interest. To begin, Reesor (1983) compared the effects of high-intensity cycling, low-intensity stretching and isometrics, and inactive conditions on smoking latency and topography with a between-subject design. Without a defined abstinence period, he found an increased delay of time to first cigarette with exercise
participants in both of the exercise arms smoked less than the passive control; and that individuals in the stretching and isometric condition took fewer puffs than the control condition. In the same year, another Canadian graduate student conducted a similar study. Mikhail (1983) subjected participants to moderate intensity cycling (66-69% maximum heart rate), vigorous intensity cycling (82-85% maximum heart rate), and passive conditions using a within-subject experimental design. During the 60 minute observation period, Mikhail learned that exercise intensity was inversely correlated to smoking duration (i.e. the period of time between lighting and extinguishing the cigarette). Other indices of smoking topography, such as weight of cigarettes consumed and puff count, were not significantly affected by exercise. A decade later, Thayer and colleagues (1993) supported these observations since 5 minutes of brisk walking significantly increased ad libitum smoking by 50% (17 minutes) compared to an equal period of inactivity (9 minutes).

In recent years, the field of exercise and smoking witnessed the emergence of stronger research designs and a defined period of temporary smoking deprivation. Following a two hour period of temporary cigarette deprivation, subjects completed 15 minutes of walking or sitting in a counterbalanced within-subject design (Katomeri & Taylor, 2006b). They discovered that time to first cigarette was significantly delayed by 66 and 31 minutes for the exercise and control conditions, respectively. In a study along similar lines, these same investigators found that after two hours of abstinence, participants randomized to a 15 minute brisk walking condition smoked their first cigarette a net of 57 minutes later than those in the passive control condition (Taylor &
Katomeri, 2007). Kurti and Dallery (2014) found similar results (delay of 20.9 minutes for exercise and 4.0 minutes for inactive groups). In contrast to these results, Fong et al. (2014), reported that an acute bout of moderate intensity activity produced non-significant differences in ad libitum smoking, compared to a passive sitting condition, following concurrent stressors (i.e., overnight abstinence, Stroop cognitive task, and cue-elicited smoking stimuli) which mitigated the exercise-craving reduction relationship.

With respect to smoking topography, Faulkner and colleagues (2010) were the first to implement a handheld smoking topography device to measure ad libitum smoking behaviour in the context of exercise after a temporary period of abstinence. They revealed that brisk walking, versus a passive sitting condition, significantly increased time to first puff by 72 minutes (compared to 57 minutes in passive sitting condition) and decreased puff volume and puff duration once they controlled for the duration of smoking abstinence. This study was limited by a within-subject study design, lack of power, physically active sample, and an inadequate period of smoking abstinence. Consequently, Schneider and colleagues (2014) sought to more rigorously replicate the research question posed by Faulkner et al. (2010). Using a randomized controlled trial, Schneider and colleagues (2014) resolved that an acute bout of exercise had a negligible impact on objectively measured smoking topography, which was not measured ad libitum, in comparison to a passive sitting condition. Research has inconsistently revealed the potential effects of acute exercise on smoking topography and the necessary conditions under which these effects come to fruition (i.e. hours of abstinence, ad libitum).
Based on the accumulated evidence for the acute paradigm, it follows that long-term physical activity may also impact smoking behaviour; however, this area of research is not well-established. Recent studies have demonstrated that, compared to a control group, smokers in an exercise program significantly decreased the number of cigarettes smoked over the course of several weeks (Leelarungrayub et al., 2010; Maddison et al., 2014; Taylor, Houston-Miller, Haskell, & Debusk, 1988; Taylor et al., 2014). From examining the feasibility of a community-based, exercise-aided Commit to Quit smoking cessation program, investigators also noted a significant decrease in the mean number of cigarettes smoked (Whiteley et al., 2007). Thompson and colleagues (2015) also observed similar results upon evaluating a smoking reduction intervention for economically disadvantaged smokers which focused on support to increase physical activity. In contrast to standard care, the physical activity arm saw a decrease in cigarette consumption. What’s less known is how regular physical activity influences objectively measured smoking topography. Needless to say, the benefits of exercise on cigarette use maintain that these two behaviours cannot co-exist.

Other Smoking Experiences

As mentioned, tobacco use disorder is as much a biologically entrenched act, as it is behavioural, environmental, and psychosocial. Less attention has been paid to the non-nicotinic, reinforcing factors. In other words, smoking behaviour (i.e. cigarette consumption and smoking topography) is maintained by various physical, cognitive, and affective sensations (Rees et al., 2012; Rose, Behm, Westman, Bates, & Salley, 2003; Rose, 2006; Shiffman & Kirchner, 2009). These subjective sensory experiences consist of
smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, aversion, and craving reduction. In scanning the literature, these sensations have only been studied as they relate to nicotine manipulation, satiation, pharmacotherapy (i.e. varenicline, bupropion SR), or have been descriptive in nature. To our knowledge, only one study to date has been interested in changes in cigarette-related sensations with respect to physical activity. Taylor and colleagues (2014) learned that the previously mentioned sensory experiences decreased with increased physical activity levels over the course of an 8-week physical activity and smoking reduction counselling intervention, versus standard care. Considering this overlooked area of smoking and exercise research, further investigation is warranted.

In summary, three broad shortcomings emerged where exercise and smoking literature intersect. Persistent evidence has highlighted the therapeutic effects of acute exercise on desire to smoke; yet, the mechanisms behind this cause-and-effect relationship have not been adequately laid to rest. Although cognitive experiences (i.e. distraction, expectancy) are unlikely, researchers have speculated that mediators may have biological and affective underpinnings. Considering relationships between cortisol, smoking, and exercise, as well as limitations with previous research, cortisol is a biological mechanism of interest. In addition, there is mixed evidence for the involvement of affective mechanisms in the exercise-craving reduction relationship; it is currently not well understood.

Second, the scope of available research on the acute effects of exercise during a temporary period of nicotine abstinence and relationships among these outcomes is
incomplete. In other words, the consideration of objectively measured smoking behaviour in the acute exercise paradigm is in its infancy. What remains to be elucidated is whether the effects of a bout of moderate intensity exercise on *ad libitum* smoking and smoking topography can be replicated with a rigorous design and improved ecological validity, and whether relationships exist between smoking-related exposure elements, affect, and tobacco withdrawal symptoms.

Finally, motivated by extant work described in this chapter, the potential harm reduction impact of chronic exercise on and interaction among smoking-related behaviour and sensory experiences has been neglected. It is unknown whether these interactions are a function of behavioural compensation via smoking topography. Moreover, perhaps such behavioural changes are prompted by dissatisfaction with sensory experiences. What also remains to be elucidated is whether these variables fluctuate in relation to milestones, such as an impending quit date. In answering these questions, research may shed light on the behavioural and psychological profile of smokers as they approach their quit date. By way of explanation, an exercise-aided smoking cessation intervention may serve as a gateway for facilitating behavioural (i.e. cigarette consumption, smoking topography) and sensory harm reduction interactions ahead of the quit date. Correspondingly, smokers may be at an advantage in realizing smoking cessation and with greater ease as cigarette dependency (i.e. number of cigarettes smoked), smoking intensity, and cigarette satisfaction would have decreased. The fundamental goal of the aforementioned interventions is complete abstinence; thus, this area of research is important as it can improve the effectiveness of such programs, contribute to optimizing smokers’ chances of success, and improve stagnant quit rates.


**Dissertation Objectives**

Driven by the findings and research chasms communicated in this chapter, the objectives of this dissertation were:

1. To investigate biological (i.e. cortisol) and affective mechanisms responsible for the attenuating effects of exercise on smoking outcomes (study 1, chapter 2).

2. To investigate the effects of a bout of moderate intensity exercise on and relationships among cravings, *ad libitum* smoking, smoking topography, affect, and tobacco withdrawal symptoms after a temporary period of abstinence compared to a control condition, as well as to investigate mechanisms for delayed *ad libitum* smoking (study 2, chapter 3).

3. To investigate the changes in and interrelatedness of cigarette consumption, expired carbon monoxide levels, smoking topography, and cigarette-related sensations during the first three-weeks (i.e., pre-quit period) of a supervised, laboratory-based, exercise-aided smoking cessation program and whether potential changes provide evidence for compensational smoking (study 3, chapter 4).

This dissertation is presented in an integrated-article format. Owing to this format, effort was taken to minimize redundancy throughout the dissertation.
References


increasing aerobic exercise. Poster presented at the annual meeting for the Society of Research on Nicotine and Tobacco, Boston, MA.


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Chapter Two: Biological and Affective Mechanisms through which Acute Exercise Attenuates Cigarette Cravings

Introduction

Lung cancer is the leading cause of cancer death among Canadians (Canadian Cancer Society (CCS), 2015), in which cigarette smoking is responsible for 85% of these cases (CCS, 2007). Altered metabolic functioning and DNA damage, which promote carcinogenicity, can be avoided by sustained smoking cessation at any age (U.S. Department of Health and Human Services (USDHHS), 2010). Despite immediate and long-term benefits to the integrated systems of the human body, only a fraction of Canadians remain abstinent within one year of their quit attempt (Reid et al., 2014).

The fact of the matter is that quitting smoking can be an insurmountable endeavour. Smoking cessation is met with high failure rates due to the highly addictive properties of nicotine and consequently, the inability to cope with tobacco withdrawal symptoms such as sleep disturbance, anxiety, fatigue, weight gain, and mood disorders (Aveyard & West, 2007; Hughes, 2007). Extraordinary efforts have been made to develop effective treatments at individual and population levels for nicotine dependence. These include pharmacotherapy (e.g. nicotine replacement therapy, varenicline, buproprion, etc.), counselling, cognitive behavioural therapy, and mobile phone interventions. Cigarette packaging, quitlines, and taxation are some examples of mass-reach strategies which also promote smoking cessation.
Exercise, in the form of incidental or structured activity, has been explored as an adjunct to traditional cessation strategies. In a recent systematic review of 20 randomized controlled trials, there was scant evidence to support exercise-based smoking cessation interventions for long-term abstinence (Ussher, Taylor, & Faulkner, 2014). The integrity of the remaining trials was compromised by small sample size, study design, and generalizability, among other limitations.

Nevertheless, acute exercise as a tool for managing smoking cessation related attributes among temporarily abstinent smokers has been corroborated. Researchers have investigated the effects of short, individual bouts of exercise ranging from five to upwards of 30 minutes and of varying intensities (e.g. isometric, moderate to vigorous physical intensities, Hatha yoga, etc.) on individuals who engaged in a simulated (e.g. abstinence period of 30 minutes to 24 hours) quit attempt. The results were overwhelmingly positive. In comparison to a passive condition, systematic reviews and meta-analyses have reported significant reductions in cigarette cravings, tobacco withdrawal symptoms (e.g. stress, anxiety, tension, poor concentration, irritability, and restlessness), negative affect, and smoking behaviour (i.e. delay in ad libitum latency to smoking) (Haasova et al., 2013 and 2014; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012; Taylor, Ussher, & Faulkner, 2007; Ussher et al., 2014). More specifically, bouts of moderate and vigorous intensity exercise were found to provide comparable craving relief, but superior to that of light intensity exercise (Haasova et al., 2014).

Elucidating the mechanisms behind the therapeutic effects of acute exercise on cravings and withdrawal symptoms is part and parcel of advancing smoking cessation
strategies. In the aforementioned reviews, cognitive, biological, and affective hypotheses have been postulated to substantiate this cause-and-effect relationship.

Initially, investigators speculated that cognitive experiences, such as distraction and expectancy, were the processes behind exercise-induced craving relief. Reductions in desire to smoke during and after a bout of moderate-intensity exercise were not found to be mediated by cognitive distraction, as these effects did not dissipate post-exercise (Daniel, Cropley, & Fife-Schaw, 2006; Ussher, Nunziata, Cropley, & West, 2001). Furthermore, expectations of the treatment effects of exercise were unrelated to changes in cravings and moderately associated with withdrawal. This is supported by research involving the manipulation of treatment expectations (Daniel, Cropley, & Fife-Schaw, 2007) and an exercise-aided quit smoking program (Harper, Fitzgeorge, Tritter, & Prapavessis, 2013). What can be clearly seen from the studies reviewed here is that distraction and expectancy are not mechanisms by which exercise exerts its effect on cravings.

Numerous biological mechanisms have been hypothesized, and some tested, to explain how exercise attenuates cravings. Using fMRI, Janse Van Rensburg and colleagues (2009, 2012) demonstrated the upper capacity of the brain’s information-processing centre, in that; moderate intensity exercise produced a shift in activation of the reward and visuospatial areas to the ‘brain default mode’. During nicotine deprivation, cortisol levels plummet. Interestingly, physical activity, like cigarettes, has a stimulating effect on circulating cortisol, hence minimizing cravings and withdrawal symptoms (Mastorakos & Pavlatou, 2005; Pomerleau et al., 1987). A few studies optimized these biological patterns but found that cortisol does not play a mediating role in the exercise-
craving reduction relationship (Ho et al., 2014; Janse Van Rensburg, Elibero, Kilpatrick, & Drobes, 2013; Roberts et al., 2015; Scerbo, Faulkner, Taylor, & Thomas, 2010).

However, these studies were not without limitations, including study design, short abstinence period, as well as lack of power and a pre-abstinence measure of cortisol. For these reasons, further investigation of cortisol as a potential mechanism is warranted.

Fluctuations in dopamine, catecholamines (e.g. epinephrine and norepinephrine), and heart rate variability as a result of exercise may suggest their mechanistic involvement but are not entirely understood (Roberts et al., 2015). It is also unknown whether the rate of nicotine metabolism (i.e. cytochrome P680 2A6) is malleable to doses of exercise, and hence, serve as a mediator.

Finally, the interrelatedness among affect, exercise, and smoking is best conceptualized by Nesbitt’s Paradox (Schachter, 1973) and the circumplex model of affect (Russell, 1980). The former refers to the contradictive role of nicotine as a stress-reducing and stimulating cigarette substituent, while the latter model posits that affect is defined by two dimensions, arousal and valence. Multiple studies have revealed positive changes in tension, stress, affect (i.e. valence and arousal), and mood in abstaining smokers in the acute exercise condition, in contrast to passive control condition (Arbour-Nicitopoulos, Faulkner, Hsin, & Selby, 2011; Daniel, Cropley, Ussher, & West, 2004; Elibero, Janse Van Rensburg, 2011; Everson, Daley, & Ussher, 2008; Janse Van Rensburg et al., 2013; Tart et al., 2010; Taylor, Katomeri, & Ussher, 2006; Ussher, Nunziata, Cropley, & West, 2001; Williams et al. 2011). Three of these studies found evidence that exercise exerted positive effects on cravings through positive (Janse Van Rensburg et al., 2013) and negative affect (Tart et al., 2010; Taylor et al., 2006). Recently
published meta-analyses revealed a significant increase in positive feelings (i.e. valence) and arousal following a bout of exercise (Haasova et al., 2014; Roberts et al., 2012) during a temporary period of cessation. These dimensions, however, did not mediate the well-established effects of exercise on cravings (Haasova et al., 2014). Nevertheless, extending the acute paradigm for affective outcomes with consistent dimensions of affect, an adequately powered sample, and robust design (i.e. between-subject, randomized controlled trial, etc.) is necessary.

Considering the evidence to date, the purpose of this study was to further investigate biological (i.e. cortisol) and affective mechanisms responsible for the attenuating effects of exercise on cravings among individuals temporarily refraining from cigarettes. By addressing existing limitations in the literature and using an acute paradigm, it was hypothesized that an acute bout of exercise delivered during a temporary period of nicotine deprivation would be associated with reductions in cravings and negative affect and attenuations in cortisol and positive affect. Furthermore, it was also hypothesized that cortisol, positive affect, and negative affect would play a mechanistic role in the exercise-craving reduction relationship.

**Method**

**Design**

The current study was part of a parent study examining the effect of an acute bout of exercise on *ad libitum* smoking behaviour (see Chapter 3), which used a two-arm randomized controlled trial design (see Figure 1 for flow diagram). A stratified
randomization scheme for gender (male, female), age (18-30 years, 31-50 years, 51-64 years), nicotine dependence (moderate, severe), and physical activity level (active, inactive) was implemented. Randomization was accomplished using a computer-generated randomized numbers. Group allocation was concealed from participants (i.e. the existence of another condition), but not researchers.

Participants

One hundred and ten participants were recruited from places of employment, healthcare organizations, post-secondary institutions, and through advertisements placed in newspapers and online in London, Ontario. To be eligible to participate, individuals were required to satisfy the following inclusion criteria: be 18 to 64 years of age, smoke 10 cigarettes or more per day for more than two years, and be able to read and write in English. Individuals who had any medical condition that was contraindicative for exercise, answered “Yes” to one or more questions on the PAR-Q (Canadian Society for Exercise Physiology, 2002), had other substance dependency problems, were pregnant or intending on being pregnant over the course of the study, engaged in a serious quit attempt in the last six months, or was suffering from an illness (e.g. chest cold) that would affect their typical smoking behaviour were excluded from the study.

Primary Outcome

Cravings.

Desire to smoke was evaluated on a seven-point scale (1 - strongly disagree, 4 - neither agree nor disagree, 7 - strongly agree) for the statement ‘I have a desire to
smoke’ (Tiffany & Drobes, 1991). This scale has been proven to be a valid and reliable measure of cravings (Tiffany & Drobes, 1991).

**Mediator Variables**

**Cortisol.**

To measure cortisol, participants provided 1–2 mL of saliva by placing a Salivette cotton roll in their mouth. Participants were asked to gently chew on the cotton roll for approximately 1 minute, until it was sufficiently saturated, at which point it was deposited into a plastic tube (Salivette; Sarstedt Ltd.). All samples were stored at -80°C until analysis.

Saliva samples were assayed in duplicate to determine cortisol levels using a highly sensitive enzyme immunoassay (Salimetrics, State College, PA). The test used 25 μL of saliva per determination, has a lower limit of sensitivity of 0.007 μg/dL, standard curve range from 0.012 μg/dL to 3.0 μg/dL, an average intra-assay coefficient of variation of 4.6%, and an average inter-assay coefficient of variation of 5.9%. Method accuracy determined by spike and recovery averaged 105.3% and linearity determined by serial dilution averaged 105.3%. Values from matched serum and saliva samples show the expected strong linear relationship, \( r (47) = 0.91, p < 0.0001 \) (Salimetrics, 2013, 2014).

**Affect.**

Affect was measured using the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). This inventory assesses the degree to which 20
positive (PA; \( n = 10 \)) and negative (NA; \( n = 10 \)) affective states are experienced. Each item is rated on a 5-point Likert scale (1 - very slightly or not at all, 3 - moderately, 5 - extremely). Positive and negative affect items were scored (i.e. summed) separately and can range from 10 to 50, with higher values indicating a greater tendency of positive or negative emotion. This questionnaire has been reported to be a valid and reliable (\( \alpha = 0.86 \) to 0.90 for positive affect; \( \alpha = 0.84 \) to 0.87 for negative affect) measure of affect in non-clinical populations (Watson et al., 1988). Consistency was found to be acceptable at baseline (PA \( \alpha = 0.77 \); NA \( \alpha = .76 \)), pre-condition (PA \( \alpha = .76 \); NA \( \alpha = .75 \)), and post-condition (PA \( \alpha = .78 \); NA \( \alpha = .76 \)).

**Other Measures**

**Demographics and anthropometry.**

Demographic measures, such as age and gender, were collected using self-report. Anthropometric data (i.e. height and weight) were noted in order to calculate Body Mass Index (BMI; kg/m\(^2\)).

**Smoking status and history.**

Information concerning current smoking status (e.g. number of cigarettes smoked per day, etc.) and smoking history (e.g. number of years smoking, age of first cigarette, etc.) were garnered through self-report.

**Cigarette dependency.**
Cigarette consumption, dependence, and urges were characterized using the self-reported Fagerström Test for Cigarette Dependence (FTCD; Fagerström, 2012; Heatherton, Kozlowski, Frecker, & Fagerström, 1991). This instrument consists of six items with dichotomous (i.e. yes/no; scored from 0 to 1) and multiple-choice (scored from 0 to 3) response items which were summed to yield a single score. This score was interpreted according to five categories: a score of zero to two signified a very low dependence, a score of three to four indicated a low dependence; a score of five was a moderate dependence; a score of six to seven corresponded to a high dependence; and a score of eight to ten was a very high dependence. The FTCD (formerly the Fagerström Test for Nicotine Dependence) has demonstrated high internal consistency ($\alpha = .64$) and test-retest reliability (Pomerleau, Carton, Lutzke, & Flessland, 1994). For this study, the FTCD demonstrated poor internal consistency ($\alpha = .30$), with a mean inter-item correlation value of 0.05.

**Carbon monoxide.**

Smoking behaviour (i.e. usage and temporary abstinence) was biochemically verified using breath carbon monoxide (CO) levels with the piCO+™ Smokerlyzer® (Bedfont Scientific Ltd., Kent, England). An expired air reading of 6 parts per million (ppm) or less confirmed abstinence. The recommended calibration procedure was performed every day the CO monitor was being utilized.

**Physical activity behaviour.**
The short-form International Physical Activity Questionnaire (IPAQ; Craig et al., 2003) was used to assess walking, moderate, and vigorous physical activity levels during the previous seven days through self-administration. Physical activity levels were converted into a composite score which reflected the metabolic equivalent task (MET) minutes/week: walking = 3.3 METs; moderate = 4.0 METs; and vigorous = 8.0 METs. Participants were categorized as inactive (<1500 MET-minutes per week) or active (≥1500 MET-minutes per week).

**Intervention**

**Moderate intensity exercise.**

Participants randomized to the experimental condition were invited to engage in a single bout of moderate intensity exercise on a Woodway PPS treadmill (Woodway, Waukesha, WI). The session involved a warm-up period, 10 minutes of moderate intensity exercise, and a cool-down period. Moderate intensity was defined as 40-68% of the heart rate reserve (HRR; Karvonen, Kentala, & Mustala, 1957). Heart rate reserve was computed using the following formula: maximum heart rate $(HR_{max} = 220 – \text{age}) – \text{resting heart rate (HR}_{rest})$. Resting heart rate was recorded at baseline because research has demonstrated a reduction in HR in the order of 8.5 beats per minute after 11 to 15 hours of smoking abstinence (Perkins, Epstein, Stiller, Marks, & Jacob, 1989).

The lower bound of participants’ exercise prescriptions (40% HRR) was calculated accordingly: $[(HR_{max} – HR_{rest}) \times .4] + HR_{rest}$. The upper bound of participants’ exercise prescriptions (68% HRR) was calculated accordingly: $[(HR_{max} – HR_{rest}) \times .68] + HR_{rest}$. Compliance to the exercise prescription was monitored using a Polar RS100 Heart
Rate monitor (Kempele, Finland), which consisted of an electrode strap, connector, and a watch. The heart rate transmitter was dampened for conductivity purposes and securely held in place under the participants’ bust line by an elastic strap. Heart rate feedback served as a guide for participants to attain the appropriate intensity. Study investigators were in command of the treadmill incline and speed and manipulated these factors to meet the exercise prescription while respecting participants’ fitness capacity.

**Passive sitting.**

The passive sitting condition required that participants sit alone for 10 minutes in a quiet room. Contact with the study investigator was minimized and participants were not deterred from reading.

**Procedure**

Ethics approval was conferred by Western University’s Research Ethics Board (REB#18110, Appendix C) and was registered with Clinical Trials, a service of the United States National Institutes of Health (NCT01431365). This study was carried out in accordance with the ethical research principles outlined in the Declaration of Helsinki (World Medical Association, 2008) and the World Health Organization’s (WHO) Handbook for Good Clinical Research Practice (WHO, 2005). The design, conduct, and analysis of this study are reported in keeping with the CONSORT statement (Moher et al., 2010). A flow diagram of the study design and procedure can be seen in Figure 1.

Prior to the start of the study, individuals who expressed interest and contacted investigators were screened for eligibility criteria by telephone or e-mail. Eligible
participants visited the Exercise and Health Psychology Laboratory (EHPL) at Western University (baseline), where eligibility criteria were confirmed. Smoking status was verified by breath analysis with the piCO+™ Smokerlyzer® (Bedfont Scientific Ltd., Kent, England). An exhaled CO cut-off of 10 ppm was required for study inclusion (Schneider, De Jesus, & Prapavessis, 2014). Participants reviewed the Letter of Information (Appendix A) and provided consent. Afterwards, the following baseline assessments were completed: demographic questionnaire, smoking status and history questionnaire, resting heart rate, Cravings, PANAS, FTCD, and IPAQ. Finally, participants provided one vial of saliva for cortisol analysis, which was stored in a -80°C locked freezer at the EHPL before they were transported to Salimetrics (101 Innovation Blvd. Suite #302 State College, PA, USA). Using a computer generated, stratified randomization scheme, participants were randomized into the moderate intensity exercise group (experimental condition) or the passive sitting group (control condition).

One week later, participants returned for their second visit after abstaining from smoking cigarettes and/or using nicotine products for 18 hours. To minimize potential within-subject interference of diurnal variations in cravings and cortisol levels, baseline and follow-up appointments were scheduled for the same time of the day.

First, smoking abstinence was validated from a breath CO sample of 6 ppm or less. For participants who were unsuccessful at refraining from smoking and/or nicotine products for 18 hours, another opportunity to do so was provided. Next, the following data were collected, pre-condition, from all participants: salivary cortisol sample, Cravings, and PANAS.
Immediately after the completion of these measures, participants underwent ten minutes of moderate intensity exercise while wearing a Polar RS100 Heart Rate monitor (Kempele, Finland) or passive sitting. Post-condition, all participants provided an additional saliva sample for cortisol analysis and worked on Cravings and PANAS inventories. Participants were debriefed at the conclusion of the study.
Figure 1

Flow diagram of study design and procedure

Note. CO = Carbon monoxide; FTCD = Fagerström Test for Cigarette Dependence; IPAQ = International Physical Activity Questionnaire; PANAS = Positive and Negative Affect Scale; HR = heart rate.
Power Calculation

A formal power calculation was not computed since the sample size was derived from the parent study. Nevertheless, sample size was retrospectively evaluated for adequacy by inputting the means and standard deviations of related research into software (Sample Power, 3, IBM-SPSS). Scerbo et al. (2010) showed a 0.017-point mean difference in cortisol post-condition between groups (i.e. exercise and control). Using these descriptive statistics, the current study was underpowered at 0.16 to detect significant changes in cortisol ($n = 50$ per group with complete data, $\alpha = 0.05$). Previous research (Janse Van Rensburg et al., 2013) found a 4.94-point mean difference in positive affect post-condition between groups. It was calculated that the current study would be underpowered at 0.69 to detect these significant changes in positive affect ($n = 50$ per group with complete data, $\alpha = 0.05$). Finally, Taylor and colleagues (2006) calculated a mean difference of 5.6 points in negative affect (i.e. tension) post-condition. As such, this study would be adequately powered at 1.00 to detect this difference ($n = 50$ per group with complete data, $\alpha = 0.05$). Therefore, the current sample size was determined, post facto, to be adequate to detect differences between groups in negative affect only.

Statistical Analyses

Group equivalency.

To assess equivalency between the experimental and control conditions at baseline, one-way analyses of variance (ANOVAs) and chi-square tests were employed to analyze relevant demographic, smoking behaviour, as well as primary and secondary outcome variables. Pre-condition CO and salivary cortisol levels, along with number of
hours abstained, and primary and secondary outcome variables were also assessed for differences between groups using ANOVAs.

**Manipulation check.**

To verify that the period of temporary abstinence was sufficient to induce changes in cigarette cravings, cortisol, positive affect, and negative affect among all participants, a repeated measures ANOVA was conducted between baseline and pre-condition. Adherence to the exercise prescription, by way of heart rate, was examined with descriptive statistics. To confirm that moderate intensity exercise was effective at attenuating cravings, compared to the control condition, a group (exercise and passive) by time (pre-condition and post-condition) repeated measures ANOVA was implemented.

**Mediation analyses.**

To test the mediating effects of cortisol and affect on craving through exercise, the method recommended by Preacher and Hayes (2004) was implemented. This approach involves formally testing for indirect effects using Sobel and bootstrapping tests. To demonstrate mediation, a significant Sobel test ($p < 0.05$, two-tailed) was required. Seeing as though this test assumes normality, which is often not the case with the sampling distribution of products, the bootstrap test was also conducted. Bootstrapping also affords greater statistical power and minimizes Type I error, compared to more frequently used techniques (i.e. Baron & Kenny, 1986). The null hypothesis was rejected (i.e. the indirect effect is significant and mediation is established).
if the 95% confidence interval (CI), derived from 1,000 bootstrap resamples, did not include zero.

Due to the temporal sequence in which the intervention and surveys that represented the mediators and dependent measure were administered, mean and standardized residual change scores for positive and negative affect, cortisol, and cravings were computed. The Preacher and Hayes (2004) approach was implemented across three models: 1) mean scores for mediator and dependent variables; 2) residual change score mediator and mean score for dependent variable; and 3) residual change scores for mediator and dependent variables.

The level of significance was accepted at $p < 0.05$ for all statistical tests (Tabachnick & Fidell, 1996). In accordance with Cohen (1988), 0.01 constitutes a small effect size, 0.06 constitutes a moderate effect size, and 0.14 constitutes a large effect size ($\eta^2$). The aforementioned statistics were completed using IBM SPSS Statistics (Version 22).

**Results**

**Group Equivalency**

One hundred and ten participants were randomized into the parent study (see Figure 2 for the flow of participants throughout the study). Baseline demographic and smoking related characteristics of the experimental and passive conditions are reported in Table 2. There were no significant differences between groups for age ($F [1, 108] = 0.04,$
\( p = 0.84, \eta^2 = 0.00 \), gender \((\chi^2 (1, n = 110) = 0.01, p = 0.09, \phi = 0.03)\), or physical activity patterns \((\chi^2 (1, n = 105) = 0.03, p = 0.82, \phi = 0.04)\). However, groups did differ in BMI \((F [1, 103] = 5.41, p = 0.02, \eta^2 = 0.05)\).

Regarding smoking experiences and dependency, participants randomized to the moderate intensity exercise or passive control group did not differ in number of years smoking \((F [1, 106] = 0.11, p = 0.75, \eta^2 = 0.00)\), number of cigarettes smoked per day \((F [1, 107] = 0.32, p = 0.57, \eta^2 = 0.00)\), and age of first cigarette \((F [1, 107] = 0.53, p = 0.47, \eta^2 = 0.01)\). Significant differences did emerge between groups for cigarette dependency \((FTCD; (F [1, 108] = 5.81, p = 0.02, \eta^2 = 0.05)\).

Group differences were also examined for primary and secondary outcome measures at baseline. Baseline equivalence of the two groups was established for cortisol \((F [1, 96] = 0.16, p = 0.69, \eta^2 = 0.00)\), positive affect subscale \((F [1, 108] = 0.19, p = 0.66, \eta^2 = 0.00)\), and negative affect subscale \((F [1, 97] = 0.02, p = 0.89, \eta^2 = 0.00)\). Cravings \((F [1, 107] = 4.49, p = 0.04, \eta^2 = 0.04)\) and CO breath levels \((F [1, 108] = 6.08, p = 0.02, \eta^2 = 0.05)\), on the other hand, significantly differed between groups.

Finally, group equivalency was assessed following a temporary period of smoking abstinence, but prior to enduring the respective condition. The experimental and passive conditions were equivalent in terms of CO levels \((F [1, 97] = 3.02, p = 0.09, \eta^2 = 0.03)\), number of hours abstained \((F [1, 97] = 0.97, p = 0.33, \eta^2 = 0.01)\), cravings \((F [1, 94] = 3.57, p = 0.06, \eta^2 = 0.04)\), cortisol \((F [1, 95] = 0.42, p = 0.52, \eta^2 = 0.00)\), positive affect subscale \((F [1, 97] = 0.05, p = 0.82, \eta^2 = 0.00)\), and negative affect subscale \((F [1, 97] = 0.66, p = 0.42, \eta^2 = 0.01)\).
Figure 2

Flow diagram of participants

Enrollment

Assessed for eligibility
\( n = 159 \)

Excluded \( n = 49 \)
- Not meeting inclusion criteria \( n = 26 \)
- Declined to participate \( n = 23 \)

Randomized \( n = 110 \)

Allocated to Moderate Intensity Exercise Condition
\( n = 56 \)
- Received allocated intervention \( n = 51 \)
- Did not receive allocated intervention \( n = 5 \)

Lost to Follow-up \( n = 5 \)
- Discontinued intervention \( n = 5 \)
- Could not abstain \( n = 1 \)
- Unable to contact/lost interest \( n = 4 \)

Analyzed \( n = 51 \)

Allocated to Passive Sitting Condition
\( n = 54 \)
- Received allocated intervention \( n = 48 \)
- Did not receive allocated intervention \( n = 6 \)

Lost to Follow-up \( n = 6 \)
- Discontinued intervention \( n = 6 \)
- Could not abstain \( n = 1 \)
- Unable to contact/lost interest \( n = 4 \)

Analysis

Analyzed \( n = 48 \)
Table 2

Demographic and smoking related characteristics of participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Exercise Condition (n = 56)</th>
<th>Passive Condition (n = 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>33.14 (14.71)</td>
<td>33.69 (13.64)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>52.70% / 47.30%</td>
<td>50.00% / 50.00%</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.80 (5.96)</td>
<td>27.09 (8.42)</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 MET-min/week</td>
<td>26.40%</td>
<td>23.10%</td>
</tr>
<tr>
<td>≥1500 MET-min/week</td>
<td>73.60%</td>
<td>76.90%</td>
</tr>
<tr>
<td>Cigarettes per day</td>
<td>15.35 (4.59)</td>
<td>15.94 (6.18)</td>
</tr>
<tr>
<td>Years smoking</td>
<td>15.64 (14.30)</td>
<td>16.49 (12.68)</td>
</tr>
<tr>
<td>Age of first cigarette</td>
<td>14.96 (2.93)</td>
<td>14.39 (4.94)</td>
</tr>
<tr>
<td>FTCD</td>
<td>4.18 (1.77)</td>
<td>5.06 (2.04)</td>
</tr>
<tr>
<td>Expired CO</td>
<td>19.36 (8.5)</td>
<td>23.39 (8.61)</td>
</tr>
<tr>
<td>Cravings</td>
<td>4.08 (1.76)</td>
<td>4.76 (1.60)</td>
</tr>
<tr>
<td>Cortisol (µg/dL)</td>
<td>0.46 (0.36)</td>
<td>0.51 (0.77)</td>
</tr>
<tr>
<td>Positive Affect</td>
<td>29.5 (8.26)</td>
<td>28.81 (8.09)</td>
</tr>
<tr>
<td>Negative Affect</td>
<td>14.41 (5.95)</td>
<td>14.58 (5.84)</td>
</tr>
<tr>
<td>Expired CO</td>
<td>6.57 (4.78)</td>
<td>8.52 (6.33)</td>
</tr>
<tr>
<td>Length of smoking abstinence (hours)</td>
<td>16.28 (3.77)</td>
<td>15.50 (4.10)</td>
</tr>
<tr>
<td>Cravings</td>
<td>5.82 (1.26)</td>
<td>6.25 (0.94)</td>
</tr>
<tr>
<td>Cortisol (µg/dL)</td>
<td>0.41 (0.30)</td>
<td>0.35 (0.49)</td>
</tr>
<tr>
<td>Positive Affect</td>
<td>27.12 (8.98)</td>
<td>26.75 (7.20)</td>
</tr>
<tr>
<td>Negative Affect</td>
<td>16.31 (5.79)</td>
<td>17.25 (5.69)</td>
</tr>
</tbody>
</table>

Note. Mean (SD). BMI = Body Mass Index; MET = Metabolic Equivalent Task; FTCD = Fagerström Test for Cigarette Dependence; CO = Carbon Monoxide.
Manipulation Check

Analyses confirmed that the smoking abstinence period had the anticipated effect (see Figure 3), as there were significant increases in cravings ($F [1, 95] = 62.82, p = 0.00, \eta^2 = 0.40$) and negative affect ($F [1, 87] = 17.99, p = 0.00, \eta^2 = 0.17$) and a significant decrease in positive affect ($F [1, 98] = 8.75, p = 0.00, \eta^2 = 0.08$). Trend effects for decreases in cortisol were also exhibited ($F [1, 86] = 3.31, p = 0.07, \eta^2 = 0.04$).

Among those randomized to the experimental group, 93.30% attained the calculated exercise prescription. Furthermore, a repeated measures ANOVA revealed that there was a significant interaction effect between groups from pre-condition to post-condition for desire to smoke ($F [2, 93] = 15.46, p = 0.00, \eta^2 = 0.25$; Figure 4).
Figure 3

*Changes in craving, cortisol, and affective measures between baseline and pre-condition*

Note. Error bars represent standard error. Solid square represents the exercise condition and the empty triangle represents the control condition.
Figure 4

*Change in cravings between pre-condition and post-condition*

Note. Error bars represent standard error.
Mediation Analyses

Sobel and bootstrapping tests are presented in Table 3.¹ None of the three models showed support for cortisol mediating the relationship between exercise and cravings. The results convey that mean scores of positive and negative affect significantly mediated the associations between mean scores of cravings and exercise in Model 1, residual change scores for positive affect significantly mediated the associations between mean scores of cravings and exercise in Model 2, and residual change scores of positive and negative affect significantly mediated the associations between residual change scores of cravings and exercise in Model 3.

¹ Mediation was also examined using the Baron and Kenny (1986) recommendation but the results are not presented here since this approach has low statistical power for small sample sizes, increased chance of a Type II error, and statistically tests for both direct and indirect effects.
### Table 3

Mediation analyses examining the indirect effect of cortisol and affect on cravings through exercise

<table>
<thead>
<tr>
<th>Model</th>
<th>Sobel test</th>
<th>Bootstrap estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>SE</td>
</tr>
<tr>
<td><strong>Model 1 (MS for M and DV)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise → Cortisol → Cravings</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>Exercise → Positive affect → Cravings</strong></td>
<td>-0.17</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Exercise → Negative affect → Cravings</strong></td>
<td>-0.22</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Model 2 (RCS for M and MS for DV)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise → Cortisol → Cravings</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Exercise → Positive affect → Cravings</strong></td>
<td>-0.22</td>
<td>0.14</td>
</tr>
<tr>
<td>Exercise → Negative affect → Cravings</td>
<td>-0.07</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Model 3 (RCS for M and DV)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exercise → Cortisol → Cravings</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>Exercise → Positive affect → Cravings</strong></td>
<td>-0.33</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Exercise → Negative affect → Cravings</strong></td>
<td>-0.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Note: MS = Mean scores at post-condition; M = Mediator; DV = Dependent variable (i.e. cravings); RCS = Residual change scores between pre- and post-condition. Boldface indicates a significant indirect effect.
Discussion

The objective of this study, one of the largest RCTs conducted in this area thus far, was to elucidate possible biological and affective processes that bring about craving reductions following exercise in abstinent smokers. This study replicated the consistent effects of an acute bout of moderate intensity exercise on desire to smoke, compared to a passive control group. Second, positive and negative affect, but not cortisol, were shown to be mechanistically involved in the exercise-craving reduction relationship using rigorous statistical mediation methods.

Cravings

The most consistent predictor of smoking relapse is desire to smoke (Doherty, Kinnunen, Militello, & Garvey, 1995; West, Hajek, & Belcher, 1989); thus, strategies and interventions to reduce these urges may improve smoking cessation rates. Numerous studies have revealed that exercise of various intensities (e.g. moderate, vigorous), durations (e.g. 5 to 30 minutes), and types (e.g. brisk walking, Hatha Yoga, isometric) are helpful for those attempting to quit smoking (Ussher, Taylor, & Faulkner, 2014).

Comparable to the current body of literature, a temporary period of abstinence and moderate intensity exercise resulted in the significant increase and attenuation of cigarette cravings, respectively, compared to the passive control group. There was a 1.46 point reduction in desire to smoke for the experimental condition between pre- and post-condition. Recent systematic reviews and meta-analyses have reported mean differences of 1.90 (Roberts et al., 2012) and 2.03 (or 30% reduction; Hassova et al., 2013) up to 30
minutes after a bout of exercise, with moderate and vigorous intensity yielding the greatest benefit (Haasova et al., 2014). The decrease in desire to smoke as a result of exercise is equivalent to the relief nicotine replacement therapy provides (Taylor et al., 2007). While there is strong evidence to support acute exercise as a craving management strategy during smoking abstinence, research conducted in ecologically valid settings is necessary.

**Cortisol**

It is widely accepted that smoking deprivation is associated with decreased cortisol levels (al’Absi, Hatsukami, Davis, & Wittmers, 2004; Wong, Pickworth, Waters, al’Absi, & Leventhal, 2014) while nicotine administration stimulates cortisol production (Dallman, 1993; Pomerleau & Pomerleau, 1991). Regardless of group allocation, all participants experienced a trend for reduction in cortisol levels from baseline to pre-condition, thereby supporting the effectiveness of the temporary period of abstinence. Although physical activity has been found to increase cortisol levels (Rahman, Abdullah, Singh, & Sosroseno, 2010; Rudolph & McAuley, 1998), this hormone further decreased from pre-condition to post-condition for both moderate intensity exercise and passive sitting conditions (analyses not presented here). Recent studies have demonstrated dissimilar patterns. To explain these differences, the dose-response relationship between exercise and cortisol must be taken into account.

Cortisol concentrations appear to be malleable under aerobic exercise conditions that are classified as vigorous intensity and longer durations. Jacks et al. (2002) found that high intensity (76.0% ± 6.0% VO$_{2\text{peak}}$) cycling impacted serum cortisol levels only
after 40 minutes of continuous exercise in a healthy, young, non-smoking sample. Along these same lines, Nieman et al. (2005) reported that 30 minutes of walking at 60% VO$_{2\text{max}}$ did not induce changes in cortisol levels compared to a passive control group.

Among temporarily abstaining smokers, Scerbo and colleagues (2010; 80-85% of HRR) and Janse Van Rensburg (2013; 75% of HRR) found that the vigorous exercise, but not light intensity exercise, attenuated changes in salivary cortisol levels after smoking abstinence. Roberts et al. (2015) also showed a reduction in cortisol pre- to post-exercise of various intensities (i.e. light, moderate, and vigorous), with a non-significant attenuation for vigorous exercise (70-85% of HRR). Against this background, it was improbable that the experimental condition in the current study – a short bout (10 minutes) of moderate intensity (40-68% of HRR), aerobic exercise – would alter cortisol concentrations. In addition, measuring cortisol is rife with challenges (i.e. impact of natural circadian rhythm) and may have implicated the results. Therefore, it is not surprising that cortisol did not surface as a biological mechanism in the study at hand.

Among earlier trials that explored potential mediators, the impact of exercise on cravings was shown not to operate through cortisol, despite significant interaction effects (Janse Van Rensburg et al., 2013, Roberts et al., 2015; Scerbo et al., 2010). The current data support previous patterns; there was no evidence for the indirect effects of cortisol on cravings through exercise across the three models, albeit the usage of an inappropriate exercise dose. In addition to the cited work, these findings suggest that cortisol is unlikely to be a key mechanism. That is to say, the effects of a short bout of light, moderate, or vigorous exercise on cravings is mediated by a factor besides cortisol.
Positive Affect

A meta-analysis found that acute aerobic exercise increased self-reported positive affect (Reed & Ones, 2006). What’s more, a bout of exercise has also produced increases in positive affect and decreases in negative affect among temporarily abstinent smokers (Arbour-Nicitopoulos et al., 2011; Bock, Marcus, King, Borrelli, & Roberts, 1999; Elibero et al., 2011; Everson et al., 2008; Haasova et al., 2014; Taylor et al., 2006; Thayer, Peters, Takahashi, & Birkhead-Flight, 1993; Williams et al., 2011). The manipulation check provided evidence that the simulated quit attempt had the anticipated impact on positive affect, as it significantly decreased from baseline to pre-condition. Furthermore, moderate intensity exercise increased positive affect by 2.55 points, compared to a 0.79 point decline in positive affect for the passive control condition (analyses not presented here). These findings mirror previous observations (Arbour-Nicitopoulos et al., 2011; Elibero et al., 2011; Janse Van Rensburg et al., 2013; Williams et al., 2011).

One study, however, discovered that compared to a bout of moderate intensity exercise, vigorous intensity exercise produced pronounced reductions in mood and happiness in temporarily abstaining young adults during the condition (Everson et al., 2008). This illustrates that for inactive smokers, a short bout of vigorous exercise may serve as a stressor. In fact, an intensity-dependent relationship has been established whereby greater intensity has been associated with diminished positive affect levels during exercise, particularly for unfit individuals (Ekkekakis & Petruzzello, 1999).

Acknowledging the equivalent proportion of active smokers in both conditions in the present study, the enhanced positivity of affect after a ten minute bout of moderate
intensity aerobic exercise may be attributed to exercise itself – the vigor, exhilaration, and revitalization typically experienced by individuals who are regularly active (Ekkekakis & Petruzello, 1999). The analyses reported here showed that positive affect was indirectly associated with cravings through its association with exercise, irrespective of mean or residual change scores. These results are in line with Janse Van Rensburg and colleagues (2013). They confirmed that positive affect mediated the effects of exercise on craving to smoke, which was measured with the Questionnaire for Smoking Urges. Exercise may influence cravings through positive affect in the following ways. According to the previously described Nesbitt’s paradox (Schachter, 1973) and the circumplex model of affect (Russell, 1980), exercise is capable of counteracting changes to affective states during nicotine deprivation (i.e. reduced arousal, valence), thereby subsiding one’s desire to smoke. Similarly, persistent evidence has shown that a disruption in dopamine in the pleasure and reward centers of the brain induces nicotine cravings, while exercise is known to mimic this key neurobiological cascade (Meeusen & De Meirleir, 1995; Ouchi et al., 2002), which appears to be associated with positive-activated affect (Depue & Collins, 1999). Another explanation rests with the limited strength model of self-regulation, which suggests that self-regulatory strength is a limited commodity and is necessary to inhibit urges and behaviours, such as the desire to smoke (Baumeister, 1998). Fong and colleagues (2014) revealed that, compared to a control group, a bout of aerobic exercise decreased psychological distress among smokers subjected to concurrent stressors (i.e., overnight abstinence, Stroop cognitive task, and cue-elicited smoking stimuli). This suggests that increased positive affect due to exercise may enhance self-regulatory strength to combat cravings.
Nevertheless, other research in this field has presented mixed findings regarding positive affect as a mediator. Following a one hour period of smoking deprivation, participants among the brisk walking and Hatha yoga conditions reported higher positive affect, relative to the control condition (Elibero et al., 2011). However, they did not find that positive affect mediated the relationship between exercise and craving reduction. They explained that the brief period of nicotine withdrawal (1 hour) may not have produced sufficiently intense cravings to detect associations between craving and affect. Combining individual participant data from 19 RCTs, Haasova et al. (2014) observed that reductions in desire to smoke after an acute session of exercise were not mediated by positive feelings (Feeling Scale) or level of arousal (Felt Arousal Scale). Although they expected positive affect to explain the benefit of exercise on cravings, they attributed different methodologies, populations, and affective inventories for impeding their ability to compare results.

**Negative Affect**

Just as with positive affect, there is a group of studies which have shown that physical activity favourably influences negative affect (Hassmen, Koivula, & Uutela, 2000; Penedo & Dahn, 2005; Reed & Ones, 2006; Schlicht, 1994). In specific, exercise has been associated with reduced levels of depression, anger, and stress (Hassmen et al., 2000). The link between negativity of affect and smoking has also been brought to light. Negative affect is a buttress for sustained smoking and smoking relapses (Piper et al., 2004; Shiffman, 2005; Shiffman & Waters, 2004; Zvolensky et al., 2008). In the same vein, a temporary period of nicotine deprivation significantly increased negative affect
from baseline to pre-condition in the current study. Findings also echo the relationship between negative affect and exercise. Negative affect decreased by 2.55 points for the moderate intensity exercise and increased 0.29 points for the passive control condition (analyses not presented here).

In summoning the literature, Roberts (2012) and Ussher (2014) and their respective colleagues concluded that acute bouts of light to moderate intensity activity (e.g. walking, cycling, yoga) after a period of smoking deprivation reduces negative affect, compared with a passive control group. Nevertheless, Everson et al. (2008) not only found that positive affect decreased, as previously mentioned, but that psychological distress increased during vigorous exercise, relative to control. As suggested by these investigators, the physiological demands of strenuous exercise may stymie the beneficial outcomes from physical exertion among inactive smokers. Given that the current participants are somewhat active individuals, as indicated by their physical activity levels, they were unlikely to experience heightened levels of negative affect due to any aversion or novelty of bodily movement.

As with positive affect, evidence for the indirect effects of negative affect which influenced cravings through exercise reached significance for most of the models. In the literature, negative affect has received little attention as a potential mediator concerning the exercise-craving relationship in the acute paradigm. Tart and colleagues (2010) provided early support for the possible mechanistic role of negative affect. Through a cross-sectional study, they revealed that negative affect (PANAS), mediated the relationship between vigorous-intensity exercise and smoking behaviour (Smoking History Questionnaire), which could be seen as a proxy measure of cravings. Exercise
may reduce cravings through negative affect in the same ways as positive affect.

Abstinence from smoking is characterized by heightened levels of emotional stress (i.e. Nesbitt’s paradox; Schachter, 1973) and lower arousal (circumplex model of affect; Russell, 1980), which can be attenuated by exercise through increased dopaminergic activity, thereby decreasing cravings. Similarly, exercise has been found to have a replenishing effect on the psychological distress levels of smokers experiencing concurrent stressors (Fong et al., 2014), which may reinforce their reservoir of self-regulatory strength to refrain from smoking.

While Elibero et al. (2011) demonstrated a reduction in negative affect following the brisk walking and Hatha yoga conditions, in contrast to the inactive control condition, after only one hour of smoking abstinence, they also found that negative mood did not mediate the treatment effect on changes in cravings. They believe that the short period of nicotine deprivation affected their ability to elucidate the craving and negative affect relationship. Janse Van Rensburg et al. (2013) also provided evidence to the contrary, in that, they did not find statistically significant differences in negative affect for both light and vigorous exercise conditions. As a result, meditational analyses were not conducted. They cautioned readers of these atypical negative affect patterns and attributed these findings to low baseline levels of negative affect. There may have been floor effects on negative affect (score can range from 10 to 50) prior to both light (mean 13.93) and vigorous (mean = 16.21) intensity exercise conditions. Given that the current literature remains mixed, further consideration and investigation of negative affect as a mediator is necessary.
Strengths and Limitations

There are several strengths of the current study that should be acknowledged. First, smoking abstinence and adherence to the exercise condition were objectively measured. Second, this was a rigorously designed study. That is, a between-subject, randomized controlled trial was implemented with an adequate period of smoking abstinence, baseline measure of salivary cortisol, and one of the largest sample sizes in this field to date. What’s more, mediation was tested using a superior method, as recommended by Preacher and Hayes (2004). By employing the Sobel and bootstrapping tests, the indirect effects, the true test for mediation, were examined with greater statistical power and minimal chances of a Type II error, as opposed to common but outdated methods (i.e. Baron & Kenny, 1986) which may have masked mediational outcomes. This concern was supported as a post-hoc mediation analysis using the Baron and Kenny approach attenuated several of the significant findings reported using the Preacher and Hayes approach. Mediation was also tested using three combinations of mean and residual change scores of potential mediators and cravings. While there is no universal practice on whether to use single time point assessments (mean scores) or standardized residual change scores (which reflect the degree of change occurring during treatment), both were included in analyses in order to account for the temporal sequence of the intervention as well as mediation and outcome measures. These approaches for testing for mediation should be considered by investigators. To control for diurnal variations in cravings and cortisol, baseline and follow-up appointments were scheduled at the same time of day. Lastly, this research study explored the complex relationships between biological and psychological patterns associated with smoking behaviour.
Limitations to the present study necessitate that the results be interpreted with caution. A temporary period of smoking abstinence is sufficiently different from engaging in a real quit attempt. Therefore, changes in primary outcome measures and the impact of each condition may vary in a more natural environment where individuals face multiple smoking-related cues, stressors, and unique craving patterns while quitting smoking. Also, these findings are only generalizable to smokers who have a similar demographic profile to the current sample. Finally, the short post-condition assessment period limited the examination of potential temporal effects of treatment, on cravings, cortisol, and affect, compared to control.

**Future Research**

In light of the limitations of this study, future work should enhance the external validity by recruiting individuals who are going through an actual quit attempt and implement an ecologically valid exercise treatment that is responsive to sporadic urges to smoke. Additional research is needed to examine other mediators for the exercise-cravings reduction relationship, such as noradrenaline and heart rate variability using the same powerful statistical methods for testing mediation in the present study.

**Conclusion**

Elucidating the mechanisms through which exercise is likely to attenuate cravings during smoking abstinence is critical for enhancing treatment impact and efficiency. The results of the present study corroborated the use of moderate intensity exercise to reduce cravings. The mechanistic role of cortisol for the well-established exercise-cravings
reduction relationship was discounted, while positive affect, and to a lesser extent negative affect, affected cravings through exercise. Investigators should seek opportunities to examine other possible interdisciplinary mediating variables using a pragmatic approach.
References


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Chapter Three: The Acute Effects of Exercise on Ad Libitum Smoking, Smoking Topography, Affect, and Withdrawal Symptoms

Introduction

Smoking tobacco is attributed to over $17 billion in direct health care costs and lost productivity in Canada alone each year (Rehm et al., 2006). This is not surprising since cigarette smoking impairs almost every organ of the human body (U.S. Department of Health and Human Services (USDHHS), 2004). Namely, this addictive behaviour has been linked to over ten types of cancers, cardiovascular and respiratory diseases, and reproduction issues, among other long-term health complications (USDHHS, 2004, 2010, 2014).

Although at any one time nearly two thirds of Canadians wish to quit (Reid, Hammond, Rynard, & Burkhalter, 2014), cigarette smokers are mired by interrelated physiological, environmental, and psychosocial factors. In particular, desire to smoke and tobacco withdrawal symptoms are cited as pitfalls in becoming nicotine-free (Aveyard & West, 2007; Hughes, 2007). As no two individuals are alike in their relationship to nicotine, an individualized treatment approach to smoking cessation should be adopted.

There are several smoking cessation-specific measures, each addressing potential physiological, environmental, and psychosocial reinforcers. For instance, individuals may try unassisted quitting, seek advice from a health care professional, engage in counselling, attempt cognitive behavioural therapy, and/or use pharmacotherapy (e.g. nicotine replacement therapy, varenicline, bupropion SR).
For those who are resistant to tobacco control policies, strategies, or interventions, a harm reduction approach may be better-suited. The primary objective of harm reduction is to reduce morbidity and mortality associated with tobacco use in individuals who are unable or unwilling to discontinue smoking (deRuiter & Faulkner, 2006). Harm reduction cannot eliminate all risks to the health or wellbeing from tobacco use, but, it does aim to diminish these risks. For an approach to be harm reducing, it should satisfy eight principles, some of which include: it must reduce the occurrence of disease and death associated with smoking; must not contribute to an individual’s nicotine dependence; and should not lure adolescents or lead to the misuse of tobacco by adolescents (deRuiter & Faulkner, 2006). Nicotine replacement therapy is upheld as a harm reduction strategy, but deRuiter and Faulkner (2006), among others, have made a case for the adoption of physical activity as another harm reduction strategy for nicotine dependency.

Over the past few decades, research has undoubtedly exhibited that exercise bouts of short (5 to 15 minutes) and longer (20 to 30 minutes) durations, ranging from light to moderate to vigorous aerobic intensity work-outs, to isometric exercises and yoga, produce moderate to large effects on reductions in cravings (Haasova et al., 2013, 2014; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012; Ussher, Taylor, & Faulkner, 2014). In the literature, there is also a pool of studies revealing that a single session of exercise mitigates tension, stress, affect (i.e. valence and arousal), and mood in temporarily abstaining smokers, compared to a passive control condition (Arbour-Nicitopoulos, Faulkner, Hsin, & Selby, 2011; Daniel, Cropley, Ussher, & West, 2004; Elibero, Janse Van Rensburg, & Drobes, 2011; Everson, Daley, & Ussher, 2008; Janse Van Rensburg, Elibero, Kilpatrick, & Drobes, 2013; Tart et al., 2010; Taylor, Katomeri, & Ussher, 2006; Ussher, Nunziata, Cropley, & West, 2001; Williams et al.,
2011). Furthermore, two meta-analyses (Haasova et al., 2014; Roberts et al., 2012) concluded that exercise, but not passive sitting, enhanced positive feelings (i.e. valence) among individuals who underwent a simulated quit attempt. What can be unmistakably understood from the studies reviewed here is the utility of physical activity as a potential harm reduction approach. Nevertheless, these well-documented outcomes attributable to short periods of exercise have mainly been psychological and emotional in nature. The ability of a short bout of exercise to change objectively measured smoking behaviour, such as *ad libitum* smoking and smoking topography, is less known. Nor have the relationships between these smoking-related exposure elements and tobacco withdrawal symptoms and affect been appraised. These matters are imperative to understanding exercise as a potential harm reduction strategy because one would expect concurrent behavioural and psychological (i.e. withdrawal symptoms and affect) gains to synergistically curtail the adverse consequences of smoking.

Early work in this area first explored the impact a single session of exercise on *ad libitum* smoking, or the latency to smoking a cigarette at one’s discretion. For his Master’s thesis, Reesor (1983) implemented a between-subject design which compared the effect of high-intensity cycling, low-intensity stretching and isometrics, and no-exercise control conditions on *ad libitum* smoking without a formal abstinence period. He discovered that there was an increased delay of time to first cigarette with exercise (high intensity: 14 minutes; low intensity: 31 minutes; and control: 7 minutes). In their natural environment, subjects self-reported their *ad libitum* smoking behaviour after 5 minutes of brisk walking or inactivity (Thayer et al., 1993). This study found that brisk walking significantly decreased the time until smoking by 50% (brisk walking: 17 minutes; inactivity: 9 minutes).
Some 15 years later, these findings were replicated using stronger research designs and a defined period of temporary smoking deprivation. Katomeri and Taylor (2006b) implemented a counterbalanced within-subject design, whereby subjects engaged in 15 minutes of walking or sitting after two hours of smoking abstinence. They found that time to first cigarette was significantly delayed by 66 and 31 minutes for the exercise and control conditions, respectively. Researchers further resolved that after two hours of abstinence, participants randomized to a 15 minute brisk walking condition smoked their first cigarette a net of 57 minutes later than those in the passive control condition (Taylor & Katomeri, 2007). The current literature remains mixed. Kurti and Dallery (2014) also found significantly longer delays to smoke between after a 20 minute period of moderate intensity exercise (21 minutes) than inactivity (4 minutes). These findings diverge from the results of Fong et al. (2014), who studied the effect of an acute bout of moderate intensity activity following concurrent stressors (i.e., overnight abstinence, Stroop cognitive task, and cue-elicited smoking stimuli) on desire to smoke and time to first puff using a between-subject design. Compared to the passive sitting condition, exercise significantly benefitted psychological withdrawal symptoms and cravings, but not ad libitum smoking, likely due to the impact of simultaneous stressors dampening any post-exercise craving reduction.

Only one study to date has explored possible mechanisms behind delayed ad libitum smoking following a bout of exercise. Kurti and Dallery (2014) discovered that the significant differences in latency to smoke between exercise and inactive conditions were mechanistically explained by the reward component of craving. Thus, their hypothesis of craving mediating the effects of exercise of smoking behaviour was only
partially supported. The researchers urged that future research further consider the mechanisms behind the harm reducing effects of acute exercise on ad libitum smoking.

While *ad libitum* smoking as an outcome measure hints at urges to smoke and rate of cigarette consumption, it is limited in providing a comprehensive profile of a smoker’s interaction with a cigarette. To this end, smoking topography affords a more complete representation of the physical attributes of smoking (De Jesus, Hsin, Faulkner, & Prapavessis, 2015). It can be subjectively or objectively measured through the quantification of variables such as interpuff interval, puff volume, and number of puffs per cigarette. Aside from elucidating precisely how an individual comes into contact with a cigarette, exposure to carbon monoxide (Zacny, Stitzer, Brown, Yingling, & Griffiths, 1987) and carcinogenic toxins (Djordjevic, Hoffmann, & Hoffman, 1997) can be inferred from smoking topography. Therefore, the study of smoking topographical indices is essential for a holistic understanding of this addictive behaviour and in ascertaining the harm from smoking – both of which have clinical implications (Perkins, Karelitz, Giedgowd, & Conklin, 2012).

Numerous subjective and objective modalities have been utilized to discern how an individual smokes a cigarette. Smoking topography has been subjectively and inadequately assessed through self-report (Shahab et al., 2008). More objective estimates of smoking topography include biomarkers such as carbon monoxide breath levels, observation in the lab or natural setting, and cigarette weighing. Smoking topography has been previously assessed using pneumotachographs (Zacny et al., 1987), pressure transducers (Ossip-Klein, Martin, Lomax, Prue, & Davis, 1983), portable recorders (Hatsukami, Morgan, Pickens, & Champagne, 1990), flowmeters (Ahijevych, Gillespie, Demirci, & Jagadeesh, 1996), and puff analysers (Sutton, Russell, Iyer, Feyerabend, &
Saloojee, 1982). Recently, smoking topography measurement has evolved into computer-based, hand-held, and portable versions.

Investigation of smoking topography as a primary outcome measure within the acute exercise paradigm remains in its infancy. Two Canadian graduate students first explored this area in the late twentieth century. Reesor (1983) randomized participants to three conditions: cycling (60% maximum heart rate); stretch and isometrics; and passive control. During the 30 minute observation period, Reesor visually noted that participants in both of the exercise arms smoked less than the passive control arm and that individuals in the stretching and isometric condition had an increased time to first cigarette (31 minutes after treatment) and took fewer puffs than the control condition (7 minutes after treatment). Participants who engaged in moderate intensity cycling smoked approximately 14 minutes following their condition. Mikhail (1983), on the other hand, implemented a within-subject experimental design through which moderate intensity cycling (66-69% maximum heart rate), vigorous intensity cycling (82-85% maximum heart rate), and passive conditions were compared. During the 60-minute observation period, Mikhail learned that exercise intensity was inversely correlated to smoking duration, the period of time between lighting and extinguishing the cigarette. Other indices of smoking topography, such as weight of cigarettes consumed and puff count (visually recorded), were not significantly affected by exercise.

More recently, Faulkner and colleagues (2010) were the first to utilize a handheld smoking topography device to measure ad libitum smoking behaviour in the context of exercise after a temporary period of abstinence. They found that brisk walking significantly delayed time to first puff by 72 minutes (compared to 57 minutes in passive sitting condition) and influenced an individual's smoking behaviour. In specific,
exercisers smoked less per puff and took shorter puff durations, compared to the passive sitting condition. However, this study was not without limitations. First, a within-subject study design was implemented which prevents the examination of causal effects. It was underpowered to demonstrate changes in most smoking topography variables and the sample was predominantly composed of active individuals. Also, a 10 minute bout of light intensity walking may have been inadequate to impact smoking topography variables in a fairly active sample. Similarly, participants temporarily abstained from smoking for 8.4 hours, which may be insufficient at eliciting cravings and tobacco withdrawal symptoms that resonate with a true quit attempt. It would appear that further research with improved external validity, a larger sample, and a more rigorous design is necessary.

In response to the caveats of the aforementioned study, Schneider and colleagues (2014) sought to replicate the research question posed by Faulkner et al. (2010) with a randomized controlled trial, the first of its kind in this area. Replication has been deemed “the cornerstone of science” (Moonesinghe, Khoury, & Janssens, 2007) as it provides cumulative evidence to confirm or dismiss research discoveries and make causal inferences (Ioannides, 2005; Moonesinghe et al., 2007). As such, 43 smokers were randomized to a moderate intensity exercise or passive sitting condition for ten minutes. Immediately afterwards, participants were asked to smoke a cigarette with a smoking topography device (i.e. not measured ad libitum). The outcome of this study supported the null hypothesis; an acute bout of exercise had a negligible impact on objectively measured smoking topography. Investigators acknowledged that the sample was predominantly female (79%) and the study had limited external validity. In particular, participants were invited to smoke a cigarette of their preferred brand immediately
following their respective condition. This procedural element may have inadvertently influenced smoking behaviour, as participants did not exercise their readiness to smoke, thereby reducing ecological validity. Although these results are incongruent with earlier findings, replication of research is warranted.

Recognizing these shortcomings, the objectives of the current study were to a) investigate the effects of a bout of moderate intensity exercise on *ad libitum* smoking and smoking topography (i.e. puff count, puff volume, average flow, puff duration, and interpuff interval) after a temporary period of abstinence compared to a control condition; b) examine the impact of exercise on cravings, affect, and tobacco withdrawal symptoms compared to passive sitting; c) examine the associations between the aforementioned smoking related variables; and d) assess whether the effects of moderate intensity exercise on *ad libitum* smoking were mediated through cravings, affect, or tobacco withdrawal symptoms. Based on the evidence to date, it was hypothesized that those in the moderate intensity exercise condition would delay the time to first cigarette compared to those in the passive control condition. It was further hypothesized that there would be no treatment effects for any of the smoking topography variables. It was also believed that cravings, affect, and tobacco withdrawal symptoms would be attenuated for the exercise but not passive conditions, and related to smoking behaviour. Lastly, it was expected that delays to ad libitum smoking would be mediated through cravings, affect, or tobacco withdrawal symptoms.

**Method**

**Design**
Using a two-arm randomized controlled trial, (see Figure 5 for flow diagram), participants were randomized to the moderate intensity exercise or passive sitting condition by way of a stratified randomization scheme for gender (male, female), age (18-30 years, 31-50 years, 51-64 years), nicotine dependence (moderate, severe), and physical activity level (active, inactive). Randomization was completed using a computer-generated randomized numbers table. Participants, but not researchers, were blind to group allocation (i.e. the existence of another condition).

**Participants**

One hundred and ten participants were recruited from places of employment, healthcare organizations, post-secondary institutions, and through advertisements placed in newspapers and online in London, Ontario. To be eligible to participate, individuals were required to satisfy the following inclusion criteria: be 18 to 64 years of age, smoke 10 cigarettes or more per day for more than two years, and be able to read and write in English. Individuals who had any medical condition that was contraindicative for exercise, answered “Yes” to one or more questions on the PAR-Q (Canadian Society for Exercise Physiology, 2002), had other substance dependency problems, was pregnant or intending on being pregnant over the course of the study, engaged in a serious quit attempt in the last six months, or was suffering from an illness (e.g. chest cold) that would affect their typical smoking behaviour were excluded from the study.

**Primary Outcome Measures**

*Ad libitum smoking.*
Ad libitum smoking was calculated by investigators as the difference in time from completing the condition to smoking the next cigarette.

**Smoking behaviour.**

Smoking topography was assessed using the Clinical Research Support System (CReSS) Pocket, a computer-based, battery-powered, hand-held unit by Plowshare Technologies® (Borgwalt, KC. Inc., Virginia). This device has an orifice flow meter mouthpiece, which produces a pressure drop when a puff is taken. This is converted to a flow velocity from which many of the topography indices are derived. The CReSS Pocket computes puff count (total number of puffs), puff volume (millilitres of tobacco smoke inhaled with each puff), average flow (i.e. velocity; puff volume with respect to puff duration), puff duration (period of time for each puff), and interpuff interval (amount of time between puffs).

To ensure proper functioning of the smoking topography apparatus, test puffs were performed whenever the mouthpiece was cleaned or changed (i.e. between each participant). An unlit cigarette was placed in the device mouthpiece, to which a sterile syringe was connected. Puffs were simulated by pulling the syringe plunger in a smooth fashion and ending abruptly. Syringe volume was then compared to the volume computed by the CReSS software. This process was repeated several times to ensure consistency and accuracy.

Prior to using the CReSS Pocket, participants were familiarized and instructed on the proper use of the device. They were directed to ignite a cigarette (of their preferred brand) before placing the cigarette into the CReSS Pocket and upon finishing smoking, to remove the cigarette from the device prior to extinguishing it. Use of the CReSS Pocket
took place outside as the laboratory was not adequately ventilated. Upon returning, the smoking topography data were immediately retrieved using a serial port linked with the CReSS computer software. Data were reduced by taking an average of all puffs except the first and last (De Jesus et al., 2015). The CReSS Pocket has demonstrated excellent test-retest reliability for puff duration ($\alpha \geq 0.75$) and acceptable reliability for puff volume and velocity ($0.4 > \alpha < 0.75$) (Lee et al., 2003).

**Secondary Outcome Measures**

**Cravings.**

Please refer to the Method section of Chapter Two for more information.

**Affect.**

Please refer to the Method section of Chapter Two for more information.

**Tobacco withdrawal symptoms.**

The strength and frequency of smoking abstinence symptomology was assessed using the Mood and Physical Symptoms Scale (MPSS; West & Hajek, 2004). Only the first seven core withdrawal symptoms (i.e. depression, anxiety, irritability, restlessness, hunger, poor concentration, and poor sleep at night), which were scored on a 5-point Likert scale (1 - *not at all*, 3 - *somewhat*, 5 - *extremely*), were used for the purpose of this study. The temporal component of the question stem for withdrawal symptoms was modified (from “over the past 24 hours” to “right now”). Raw scores were extracted for analyses, with higher scores reflecting greater severity. This questionnaire has been validated (West, Ussher, Evans, & Rashid, 2006) and shown to have moderate test-retest
reliability ($\alpha = 0.57$; West et al., 2006). In the current sample, the internal consistency was $\alpha = 0.87$ at baseline, $\alpha = 0.86$ pre-condition, and $\alpha = 0.88$ post-condition.

**Other Measures**

**Demographics and anthropometry.**

Please refer to the Method section of Chapter Two for more information.

**Smoking status and history.**

Please refer to the Method section of Chapter Two for more information.

**Cigarette dependency.**

Please refer to the Method section of Chapter Two for more information.

**Carbon monoxide.**

Please refer to the Method section of Chapter Two for more information.

**Physical activity behaviour.**

Please refer to the Method section of Chapter Two for more information.

**Acceptability questionnaire.**

In order to determine participants’ experiences with the CReSS Pocket and its perceived influence on smoking behaviour, a purpose-built inventory was developed. Items prompted participants to consider to what extent the device altered smoking topography (e.g. “how much I puffed” for puff volume”, “time between my puffs” for
interpuff interval, etc.), satisfaction (e.g. “made smoking less likely”, “affected the taste of the cigarettes), and cognitions (e.g. “increased my awareness of how much was smoked”). Eleven items were presented in a visual analogue scale format, ranging from 0 (strongly disagree) to 100 (strongly agree). This measure demonstrated excellent reliability at baseline ($\alpha = 0.91$) and post-condition ($\alpha = 0.95$).

**Intervention**

**Moderate intensity exercise.**

Participants randomized to the experimental condition were invited to engage in a single bout of moderate intensity exercise on a Woodway PPS treadmill (Woodway, Waukesha, WI). The session involved a warm-up period, 10 minutes of moderate intensity exercise, and a cool-down period. Moderate intensity was defined as 40-68% of the heart rate reserve (HRR; Karvonen, Kentala, & Mustala, 1957). Heart rate reserve was computed using the following formula: maximum heart rate ($HR_{\text{max}} = 220 – \text{age}$) – resting heart rate ($HR_{\text{rest}}$). Resting heart rate was recorded at baseline because research has demonstrated a reduction in HR in the order of 8.5 beats per minute after 11 to 15 hours of smoking abstinence (Perkins, Epstein, Stiller, Marks, & Jacob, 1989).

The lower bound of participants’ exercise prescriptions (40% HRR) was calculated accordingly: \[ ((HR_{\text{max}} – HR_{\text{rest}}) \times 0.4) + HR_{\text{rest}}. \] The upper bound of participants’ exercise prescriptions (68% HRR) was calculated accordingly: \[ ((HR_{\text{max}} – HR_{\text{rest}}) \times 0.68) + HR_{\text{rest}}. \] Compliance to the exercise prescription was monitored using a Polar RS100 Heart Rate monitor (Kempele, Finland), which consisted of an electrode strap, connector, and a watch. The heart rate transmitter was dampened for conductivity purposes and securely held in place under the participants’ bust line by an elastic strap. Heart rate feedback
served as a guide for participants to attain the appropriate intensity. Study investigators were in command of the treadmill incline and speed and manipulated these factors to meet the exercise prescription while respecting participants’ fitness capacity.

**Passive sitting.**

The passive sitting condition required that participants sit alone for 10 minutes in a quiet room. Contact with the study investigator was minimized and participants were not deterred from reading.

**Procedure**

Ethics approval was conferred by Western University’s Research Ethics Board (REB#18110, Appendix E) and was registered with Clinical Trials, a service of the United States National Institutes of Health (NCT01431365). This study was carried out in accordance with the ethical research principles outlined in the Declaration of Helsinki (World Medical Association, 2008) and the World Health Organization’s (WHO) Handbook for Good Clinical Research Practice (WHO, 2005). The design, conduct, and analysis of this study are reported in keeping with the CONSORT statement (Moher et al., 2010). A flow diagram of the study design and procedure can be seen in Figure 5.

Prior to the start of the study, individuals who expressed interest and contacted investigators were screened for eligibility criteria by telephone or e-mail. Eligible participants visited the Exercise and Health Psychology Laboratory (EHPL) at Western University (baseline), where eligibility criteria were confirmed. Smoking status was verified by breath analysis with the piCO+™ Smokerlyzer® (Bedfont Scientific Ltd., Kent, England). An exhaled CO cut-off of 10 ppm was required for study inclusion.
(Schneider et al., 2014). Participants reviewed the Letter of Information (Appendix A) and provided consent. Afterwards, the following baseline assessments were completed: demographics questionnaire, smoking status and history questionnaire, resting heart rate, IPAQ, FTCD, Cravings, PANAS, and MPSS. Participants were familiarized with the CReSS Pocket through verbal instruction and demonstration. Participants were invited to smoke a cigarette of their regular brand with the CReSS Pocket outside of the building. Upon returning, participants completed the Acceptability Questionnaire. Using a computer generated, stratified randomization scheme, participants were randomized into the moderate intensity exercise group (experimental condition) or the passive sitting group (control condition).

After one week, participants returned for their second visit, after abstaining from smoking cigarettes and/or using nicotine products for 18 hours. To minimize potential within-subject interference of diurnal variations in cravings, baseline and follow-up appointments were scheduled for the same time of the day.

First, smoking abstinence was validated from a breath CO sample of 6 ppm or less. For participants who were unsuccessful at refraining from smoking and/or nicotine products for 18 hours, another opportunity to do so was provided. Next, the following data were collected, pre-condition, from all participants: Cravings, PANAS, and MPSS.

Immediately after the completion of these measures, participants underwent ten minutes of moderate intensity exercise while wearing a Polar RS100 Heart Rate monitor (Kempele, Finland) or passive sitting. Post-condition, all participants worked on Cravings, PANAS, and MPSS inventories. Following the completion of these questionnaires, participants were invited to smoke a cigarette using the CReSS Pocket ad
libitum (at their own will). Upon returning, participants completed the Acceptability Questionnaire and were debriefed at the conclusion of the study.
Figure 5

*Flow diagram of study design and procedure*

Note. CO = Carbon monoxide; FTCD = Fagerström Test for Cigarette Dependence; IPAQ = International Physical Activity Questionnaire; PANAS = Positive and Negative Affect Scale; MPSS = Mood and Physical Symptoms Scale; HR = heart rate.
Power Calculation

Earlier research examining the effects of an acute bout of brisk walking on cigarette cravings and smoking topography revealed a 14.84 minute net difference between walking and passive conditions (Faulkner et al., 2010). As such, a priori sample size calculation projected that with a sample of 50 individuals per group, this study would be adequately powered (power of .84) to detect the aforementioned difference with an alpha level of 0.05 for a between-subject design (Cohen, 1992).

Statistical Analyses

Group equivalency.

Group equivalency for relevant demographic, smoking behaviour, as well as primary and secondary outcome variables was examined at baseline using one-way analyses of variance (ANOVAs) and chi-square tests. Pre-condition CO, number of hours abstained, and primary and secondary outcome variables were also assessed for variation between groups using ANOVAs.

Fidelity check.

In order to determine whether smoking a cigarette through a device altered smoking behaviour, and whether this influence varied between groups and across time, a group (exercise and passive) by time (pre-condition and post-condition) repeated measures ANOVA was completed for the Acceptability Questionnaire. Adherence to the exercise prescription was assessed descriptively using heart rate data. To verify treatment (i.e. moderate intensity exercise) effectiveness on attenuating cravings, a group (exercise
and passive) by time (pre-condition and post-condition) repeated measures ANOVA was carried out.

**Primary and secondary outcome analyses.**

A series of two-way repeated measures ANOVAs were used to test for differences in smoking behaviour (i.e. *ad libitum* time to first cigarette, flow rate, puff count, puff volume, etc.) between groups (exercise and control) and across time (baseline and post-condition). Supplementary ANOVAs were conducted for participants in the exercise condition who demonstrated a two-point or greater reduction in cravings from pre- to post-condition. Secondary outcome variables (i.e. MPSS and PANAS) were also analyzed for group (exercise and control) by time (pre- and post-condition) interaction effects. Lastly, bivariate correlations were performed to examine relationships among variables of interest at pre- and post-condition.

**Mediation analyses.**

To test the mediating effects of cravings, affect, and tobacco withdrawal symptoms on *ad libitum* smoking through exercise, the method recommended by Preacher and Hayes (2004) was implemented. This approach involves formally testing for indirect effects using Sobel and bootstrapping tests. To demonstrate mediation, a significant Sobel test (*p* < 0.05, two-tailed) was required. Seeing as though this test assumes normality, which is often not the case with the sampling distribution of products, the bootstrap test was also conducted. Bootstrapping also affords greater statistical power and minimizes Type I error, compared to more frequently used techniques (i.e. Baron & Kenny, 1986). The null hypothesis was rejected (i.e. the indirect effect is significant and
mediation is established) if the 95% confidence interval (CI), derived from 1,000 bootstrap resamples, did not include zero.

The level of significance was accepted at $p < 0.05$ for all statistical tests (Tabachnick & Fidell, 1996). In accordance with Cohen (1988), 0.01 constitutes a small effect size, 0.06 constitutes a moderate effect size, and 0.14 constitutes a large effect size ($\eta^2$). The aforementioned statistics were completed using IBM SPSS Statistics (Version 22).

Results

Group Equivalency

One hundred and ten participants were randomized in this study (see Figure 2 for the flow of participants throughout the study). One-way ANOVAs and chi-square tests were used to analyze parametric and non-parametric demographics variables, respectively, at baseline and pre-condition (see Table 4). Age ($F[1, 108] = 0.04, p = 0.84, \eta^2 = 0.00$), gender ($\chi^2 (1, n = 110) = 0.01, p = 0.09, \phi = 0.03$), and physical activity patterns ($\chi^2 (1, n = 105) = 0.03, p = 0.82, \phi = 0.04$) did not significantly differ between groups, however, BMI did ($F[1, 103] = 5.41, p = 0.02, \eta^2 = 0.05$).

Concerning smoking related characteristics, participants across conditions did not differ in number of years smoking ($F[1, 106] = 0.11, p = 0.75, \eta^2 = 0.00$), number of cigarettes smoked per day ($F[1, 107] = 0.32, p = 0.57, \eta^2 = 0.00$), age of first cigarette ($F[1, 107] = 0.53, p = 0.47, \eta^2 = 0.01$), smoking cessation readiness (i.e. Smoking Ladder; $F[1, 99] = 0.68, p = 0.41, \eta^2 = 0.01$), and acceptability of the CReSS Pocket ($F[1, 106] = \ldots$)
0.98, \( p = 0.32, \eta^2 = 0.01 \)). Significant differences did exist between exercise and control conditions for cigarette dependency (FTCD; \( F [1, 108] = 5.81, p = 0.02, \eta^2 = 0.05 \)).

Group differences were also examined for primary and secondary outcome measures at baseline. Puff count (\( F [1, 106] = 0.18, p = 0.67, \eta^2 = 0.00 \)), puff volume (\( F [1, 106] = 0.02, p = 0.89, \eta^2 = 0.00 \)), average flow (\( F [1, 106] = 1.23, p = 0.27, \eta^2 = 0.01 \)), puff duration (\( F [1, 106] = 0.22, p = 0.64, \eta^2 = 0.00 \)), interpuff interval (\( F [1, 106] = 0.15, p = 0.70, \eta^2 = 0.00 \)), positive affect subscale (\( F [1, 108] = 0.19, p = 0.66, \eta^2 = 0.00 \)), negative affect subscale (\( F [1, 97] = 0.02, p = 0.89, \eta^2 = 0.00 \)), depression (\( F [1, 108] = 0.80, p = 0.37, \eta^2 = 0.01 \)), anxiety (\( F [1, 108] = 0.92, p = 0.34, \eta^2 = 0.01 \)), irritability (\( F [1, 108] = 0.01, p = 0.92, \eta^2 = 0.00 \)), restlessness (\( F [1, 108] = 0.11, p = 0.74, \eta^2 = 0.00 \)), hunger (\( F [1, 107] = 0.57, p = 0.45, \eta^2 = 0.01 \)), poor concentration (\( F [1, 108] = 0.59, p = 0.44, \eta^2 = 0.01 \)), and poor sleep (\( F [1, 108] = 1.11, p = 0.29, \eta^2 = 0.01 \)) were comparable between groups. Cravings (\( F [1, 107] = 4.49, p = 0.04, \eta^2 = 0.04 \)) and CO breath levels (\( F [1, 108] = 6.08, p = 0.02, \eta^2 = 0.05 \)), on the other hand, significantly differed between treatment arms.

Finally, variability between groups was examined following overnight nicotine deprivation, but prior to enduring the respective condition. The experimental and passive conditions were equivalent in terms of CO levels (\( F [1, 97] = 3.02, p = 0.09, \eta^2 = 0.03 \)), number of hours abstained (\( F [1, 97] = 0.97, p = 0.33, \eta^2 = 0.01 \)), cravings (\( F [1, 94] = 3.57, p = 0.06, \eta^2 = 0.04 \)), positive affect subscale (\( F [1, 97] = 0.05, p = 0.82, \eta^2 = 0.00 \)), negative affect subscale (\( F [1, 97] = 0.66, p = 0.42, \eta^2 = 0.01 \)), depression (\( F [1, 97] = 0.70, p = 0.41, \eta^2 = 0.01 \)), anxiety (\( F [1, 97] = 1.84, p = 0.18, \eta^2 = 0.02 \)), irritability (\( F [1, 97] = 2.16, p = 0.15, \eta^2 = 0.02 \)), restlessness (\( F [1, 97] = 0.49, p = 0.49, \eta^2 = 0.01 \)),
hunger ($F_{[1, 97]} = 0.49, p = 0.48, \eta^2 = 0.01$), poor concentration ($F_{[1, 97]} = 0.60, p = 0.44, \eta^2 = 0.01$), and poor sleep ($F_{[1, 97]} = 0.92, p = 0.34, \eta^2 = 0.01$).
Table 4

Demographic and smoking related characteristics of participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Exercise Condition (n = 56)</th>
<th>Passive Condition (n = 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>33.14 (14.71)</td>
<td>33.69 (13.64)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>52.70% / 47.30%</td>
<td>50.00% / 50.00%</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.80 (5.96)</td>
<td>27.09 (8.42)</td>
</tr>
<tr>
<td>Physical activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1500 MET-min/week</td>
<td>26.40%</td>
<td>23.10%</td>
</tr>
<tr>
<td>≥1500 MET-min/week</td>
<td>73.60%</td>
<td>76.90%</td>
</tr>
<tr>
<td>Cigarettes per day</td>
<td>15.35 (4.59)</td>
<td>15.94 (6.18)</td>
</tr>
<tr>
<td>Years smoking</td>
<td>15.64 (14.30)</td>
<td>16.49 (12.68)</td>
</tr>
<tr>
<td>Age of first cigarette</td>
<td>14.96 (2.93)</td>
<td>14.39 (4.94)</td>
</tr>
<tr>
<td>FTCD</td>
<td>4.18 (1.77)</td>
<td>5.06 (2.04)</td>
</tr>
<tr>
<td>Smoking Ladder</td>
<td>5.62 (1.54)</td>
<td>5.88 (1.65)</td>
</tr>
<tr>
<td>Expired CO</td>
<td>19.36 (8.50)</td>
<td>23.39 (8.61)</td>
</tr>
<tr>
<td>Cravings</td>
<td>4.08 (1.76)</td>
<td>4.76 (1.60)</td>
</tr>
<tr>
<td>Acceptability of CReSS Pocket</td>
<td>51.50 (19.39)</td>
<td>47.72 (20.23)</td>
</tr>
</tbody>
</table>

Pre-condition

<table>
<thead>
<tr>
<th></th>
<th>Exercise Condition (n = 56)</th>
<th>Passive Condition (n = 54)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expired CO</td>
<td>6.57 (4.78)</td>
<td>8.52 (6.33)</td>
</tr>
<tr>
<td>Length of smoking abstinence (hours)</td>
<td>16.28 (3.77)</td>
<td>15.50 (4.10)</td>
</tr>
<tr>
<td>Cravings</td>
<td>5.82 (1.26)</td>
<td>6.25 (0.94)</td>
</tr>
</tbody>
</table>

Note. Mean (SD). BMI = Body Mass Index; MET = Metabolic Equivalent Task; FTCD = Fagerström Test for Cigarette Dependence; CO = Carbon Monoxide; mL = millilitre; sec = second; MPSS = Mood and Physical Symptoms Scale.
**Fidelity Check**

There were no significant differences between groups and across time for subjects’ perceived interference of the CReSS Pocket in their smoking behaviour ($F[1, 95] = 0.363, p = 0.55, \eta^2 = 0.00$). Nearly all participants (93.30%) met their calculated exercise prescription. Finally, the treatment (i.e. moderate intensity exercise) was effective at attenuating cravings from pre-condition to post-condition compared to the passive condition ($F[2, 93] = 15.46, p = 0.00, \eta^2 = 0.25$; Figure 4).

**Primary Outcome Analyses**

*Ad libitum and smoking topography behaviour.*

A one-way ANOVA revealed a significant difference for *ad libitum* time to first cigarette ($F[1, 87] = 8.64, p = 0.00, \eta^2 = 0.09$) whereby the moderate intensity exercise condition had a greater delay (M = 7.82 minutes, SD = 9.23) than the passive condition control (M = 1.88 minutes, SD = 9.65).

Results showed no significant group by time interaction effects for puff count ($F[1, 96] = 2.71, p = 0.10, \eta^2 = 0.03$), puff volume ($F[1, 96] = 1.05, p = 0.31, \eta^2 = 0.01$), average flow ($F[1, 96] = 0.14, p = 0.71, \eta^2 = 0.00$), puff duration ($F[1, 96] = 0.80, p = 0.37, \eta^2 = 0.01$), and interpuff interval ($F[1, 95] = 0.29, p = 0.60, \eta^2 = 0.00$) (see Table 6).

**Ancillary analysis for craving reduction.**

Paired-samples t-tests were completed solely on exercisers who reported a craving reduction of two points or greater between pre- to post-condition (see Table 6). The analyses suggest non-significant changes across time for puff count ($t(26) = 0.30, p =$
between time. Puff duration significantly decreased from baseline to post-condition \( t \) (26) = 2.21, \( p = 0.04, \eta^2 = 0.16 \).
Table 5

Means and standard deviations for smoking topography variables between groups across time

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercise</td>
<td>Control</td>
<td>Exercise</td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Puff Count</td>
<td>13.69 (4.12)</td>
<td>13.43 (4.60)</td>
<td>13.16 (5.31)</td>
<td>14.38 (4.42)</td>
<td></td>
</tr>
<tr>
<td>Puff Volume (mL)</td>
<td>60.68 (19.48)</td>
<td>59.00 (22.22)</td>
<td>58.08 (16.70)</td>
<td>59.06 (19.06)</td>
<td></td>
</tr>
<tr>
<td>Average Flow (mL/sec)</td>
<td>37.81 (11.79)</td>
<td>34.87 (8.98)</td>
<td>39.06 (10.98)</td>
<td>36.75 (10.04)</td>
<td></td>
</tr>
<tr>
<td>Puff Duration (sec)</td>
<td>1.72 (0.56)</td>
<td>1.77 (0.61)</td>
<td>1.59 (0.54)</td>
<td>1.71 (0.60)</td>
<td></td>
</tr>
<tr>
<td>Interpuff Interval (sec)</td>
<td>17.71 (7.10)</td>
<td>16.01 (8.38)</td>
<td>19.04 (9.19)</td>
<td>18.13 (9.34)</td>
<td></td>
</tr>
</tbody>
</table>
Table 6

*Means and standard deviations for smoking topographical variables among participants with further craving reduction across time*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>Post-condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puff Count</td>
<td>13.26 (4.03)</td>
<td>13.00 (5.43)</td>
</tr>
<tr>
<td>Puff Volume (mL)</td>
<td>58.50 (23.39)</td>
<td>55.57 (17.11)</td>
</tr>
<tr>
<td>Average Flow (mL/sec)</td>
<td>38.36 (12.08)</td>
<td>40.02 (10.22)</td>
</tr>
<tr>
<td>Puff Duration (sec)</td>
<td>1.59 (0.52)</td>
<td>1.44 (0.42)</td>
</tr>
<tr>
<td>Interpuff Interval (sec)</td>
<td>18.62 (7.88)</td>
<td>19.48 (9.17)</td>
</tr>
</tbody>
</table>
**Affect and tobacco withdrawal symptoms.**

Repeated measures ANOVAs (see Table 7) revealed a significant difference between groups from baseline, pre-, and post-condition for positive affect ($F[2, 95] = 5.56, p = 0.01, \eta^2 = 0.11$; see Figure 5), negative affect ($F[2, 84] = 11.20, p = 0.00, \eta^2 = 0.21$; see Figure 6), anxiety ($F[2, 95] = 5.31, p = 0.01, \eta^2 = 0.10$), irritability ($F[2, 95] = 4.56, p = 0.01, \eta^2 = 0.09$), and restlessness ($F[2, 95] = 3.63, p = 0.03, \eta^2 = 0.07$). Group by time interaction effects did not reach significance for depression ($F[2, 95] = 1.54, p = 0.22, \eta^2 = 0.03$), hunger ($F[2, 94] = 0.14, p = 0.87, \eta^2 = 0.00$), poor concentration ($F[2, 95] = 0.95, p = 0.39, \eta^2 = 0.02$), and poor sleep ($F[2, 95] = 0.09, p = 0.92, \eta^2 = 0.00$).
### Table 7

*Means and standard deviations for affect and tobacco withdrawal symptoms between groups and across time*

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Baseline</th>
<th>Pre-Condition</th>
<th>Post-Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercise</td>
<td>Control</td>
<td>Exercise</td>
</tr>
<tr>
<td></td>
<td>(n = 56)</td>
<td>(n = 54)</td>
<td>(n = 56)</td>
</tr>
<tr>
<td>Positive affect</td>
<td>29.75</td>
<td>28.49</td>
<td>27.12</td>
</tr>
<tr>
<td></td>
<td>(8.27)</td>
<td>(8.00)</td>
<td>(8.98)</td>
</tr>
<tr>
<td>Negative affect</td>
<td>14.36</td>
<td>13.98</td>
<td>16.45</td>
</tr>
<tr>
<td></td>
<td>(6.13)</td>
<td>(4.52)</td>
<td>(5.54)</td>
</tr>
<tr>
<td>Depression</td>
<td>1.55</td>
<td>1.51</td>
<td>1.71</td>
</tr>
<tr>
<td></td>
<td>(0.86)</td>
<td>(0.72)</td>
<td>(1.01)</td>
</tr>
<tr>
<td>Anxiety</td>
<td>1.90</td>
<td>2.19</td>
<td>2.45</td>
</tr>
<tr>
<td></td>
<td>(1.20)</td>
<td>(1.01)</td>
<td>(1.24)</td>
</tr>
<tr>
<td>Irritability</td>
<td>1.41</td>
<td>1.45</td>
<td>2.27</td>
</tr>
<tr>
<td></td>
<td>(0.80)</td>
<td>(0.86)</td>
<td>(1.33)</td>
</tr>
<tr>
<td>Restlessness</td>
<td>1.80</td>
<td>1.83</td>
<td>2.51</td>
</tr>
<tr>
<td></td>
<td>(0.92)</td>
<td>(1.11)</td>
<td>(1.21)</td>
</tr>
<tr>
<td>Hunger</td>
<td>2.08</td>
<td>2.13</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td>(1.12)</td>
<td>(1.12)</td>
<td>(1.30)</td>
</tr>
<tr>
<td>Poor concentration</td>
<td>1.63</td>
<td>1.81</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td>(0.96)</td>
<td>(1.04)</td>
<td>(1.13)</td>
</tr>
<tr>
<td>Poor sleep</td>
<td>2.78</td>
<td>2.45</td>
<td>2.55</td>
</tr>
<tr>
<td></td>
<td>(1.55)</td>
<td>(1.44)</td>
<td>(1.50)</td>
</tr>
</tbody>
</table>
Correlations

Pearson’s product-moment correlation coefficients for relationships between primary and secondary outcome variables are presented in Table 8. At baseline, there were small to moderate size significant relationships among smoking behaviours. There was a small, positive relationship between cravings and puff count. Puff volume was moderately and strongly related to average flow and puff duration, respectively, in the positive direction. Small to moderate, negative relationships existed between puff count and both puff volume and puff duration. Average flow and puff duration as well as puff count and interpuff interval were moderately related in the positive direction. Smoking behaviour variables were unrelated to affect and tobacco withdrawal symptoms, except for puff volume and irritability, for which there was a small, negative correlation. Nearly all affect and tobacco withdrawal symptoms correlated in a positive manner at baseline.

Relationships between smoking behaviour variables post-condition were maintained. In addition, there was a strong, positive correlation between ad libitum time to first cigarette and cravings. Cravings were also positively and negatively related to puff duration and interpuff interval, respectively. Contrary to baseline, relationships among smoking behaviour, affect, and tobacco withdrawal symptoms surfaced post-condition. Cravings were negatively related to positive affect. Furthermore, positive relationships were found between cravings and negative affect, depression, anxiety, irritability, restlessness, and poor concentration. A small, negative correlation existed between anxiety and ad libitum smoking. Finally, irritability and restlessness were positively related to puff count. Similar significant relationships were present post-condition among most affective and tobacco withdrawal symptoms variables.
### Table 8

**Relationships between primary and secondary outcome variables at baseline and follow-up**

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cravings</td>
<td>–</td>
<td>–</td>
<td>0.19*</td>
<td>-0.08</td>
<td>-0.05</td>
<td>-0.05</td>
<td>-0.18</td>
<td>0.02</td>
<td>0.16</td>
<td>0.04</td>
<td>0.04</td>
<td>0.08</td>
<td>0.06</td>
<td>0.17</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>2. Ad libitum</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>3. Puff count</td>
<td>0.15</td>
<td>0.01</td>
<td>–</td>
<td>-0.22*</td>
<td>0.13</td>
<td>–</td>
<td>–</td>
<td>-0.01</td>
<td>0.06</td>
<td>0.11</td>
<td>0.07</td>
<td>0.05</td>
<td>-0.03</td>
<td>0.17</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>4. Puff volume</td>
<td>0.17</td>
<td>0.00</td>
<td>-0.17</td>
<td>–</td>
<td>0.44**</td>
<td>0.62**</td>
<td>0.04</td>
<td>0.13</td>
<td>0.10</td>
<td>-0.11</td>
<td>-0.05</td>
<td>-0.22*</td>
<td>0.07</td>
<td>-0.12</td>
<td>-0.13</td>
<td>-0.06</td>
</tr>
<tr>
<td>5. Average flow</td>
<td>-0.04</td>
<td>0.05</td>
<td>0.08</td>
<td>0.29**</td>
<td>–</td>
<td>–</td>
<td>-0.03</td>
<td>0.03</td>
<td>0.11</td>
<td>-0.06</td>
<td>-0.09</td>
<td>-0.08</td>
<td>0.04</td>
<td>0.08</td>
<td>0.07</td>
<td>0.09</td>
</tr>
<tr>
<td>6. Puff duration</td>
<td>0.20*</td>
<td>-0.06</td>
<td>-0.18</td>
<td>0.62**</td>
<td>-0.52</td>
<td>–</td>
<td>0.05</td>
<td>0.12</td>
<td>-0.04</td>
<td>-0.09</td>
<td>-0.01</td>
<td>-0.15</td>
<td>0.02</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.14</td>
</tr>
<tr>
<td>7. Interpuff interval</td>
<td>-0.23*</td>
<td>0.02</td>
<td>–</td>
<td>-0.10</td>
<td>-0.09</td>
<td>0.04</td>
<td>–</td>
<td>-0.01</td>
<td>-0.07</td>
<td>-0.14</td>
<td>-0.18</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.07</td>
<td>-0.18</td>
<td>-0.04</td>
</tr>
<tr>
<td>8. Positive affect</td>
<td>-</td>
<td>0.24</td>
<td>0.00</td>
<td>0.12</td>
<td>0.06</td>
<td>0.03</td>
<td>0.02</td>
<td>–</td>
<td>0.12</td>
<td>-0.13</td>
<td>0.01</td>
<td>-0.11</td>
<td>-0.15</td>
<td>-0.05</td>
<td>-0.24*</td>
<td>-0.17</td>
</tr>
<tr>
<td>9. Negative affect</td>
<td>0.35**</td>
<td>-0.11</td>
<td>0.13</td>
<td>0.07</td>
<td>0.09</td>
<td>-0.02</td>
<td>-0.21*</td>
<td>–</td>
<td>–</td>
<td>0.41**</td>
<td>0.56**</td>
<td>0.35**</td>
<td>0.42**</td>
<td>0.08</td>
<td>0.35**</td>
<td>0.38**</td>
</tr>
<tr>
<td>10. Depression</td>
<td>0.26*</td>
<td>-0.12</td>
<td>0.24*</td>
<td>-0.10</td>
<td>-0.06</td>
<td>-0.04</td>
<td>-0.17</td>
<td>–</td>
<td>0.51**</td>
<td>–</td>
<td>0.60**</td>
<td>0.42**</td>
<td>0.36**</td>
<td>0.16</td>
<td>0.42**</td>
<td>0.33**</td>
</tr>
<tr>
<td>11. Anxiety</td>
<td>0.54**</td>
<td>-</td>
<td>0.15</td>
<td>-0.02</td>
<td>0.02</td>
<td>-0.02</td>
<td>-0.10</td>
<td>–</td>
<td>0.70**</td>
<td>0.39**</td>
<td>–</td>
<td>0.38**</td>
<td>0.52**</td>
<td>0.12</td>
<td>0.54**</td>
<td>0.41**</td>
</tr>
<tr>
<td>12. Irritability</td>
<td>0.47**</td>
<td>-0.08</td>
<td>0.26*</td>
<td>0.00</td>
<td>-0.03</td>
<td>0.02</td>
<td>-0.24</td>
<td>–</td>
<td>0.75**</td>
<td>0.43**</td>
<td>0.68**</td>
<td>–</td>
<td>0.57**</td>
<td>0.26**</td>
<td>0.41**</td>
<td>0.31**</td>
</tr>
<tr>
<td>13. Restlessness</td>
<td>0.45**</td>
<td>-0.14</td>
<td>0.22*</td>
<td>-0.05</td>
<td>-0.01</td>
<td>-0.04</td>
<td>-0.16</td>
<td>–</td>
<td>0.65**</td>
<td>0.31**</td>
<td>0.72**</td>
<td>0.70**</td>
<td>–</td>
<td>0.25**</td>
<td>0.42**</td>
<td>0.41**</td>
</tr>
<tr>
<td>14. Hunger</td>
<td>0.14</td>
<td>0.09</td>
<td>-0.03</td>
<td>-0.09</td>
<td>-0.05</td>
<td>-0.07</td>
<td>0.00</td>
<td>-0.18</td>
<td>0.15</td>
<td>0.05</td>
<td>0.20*</td>
<td>0.13</td>
<td>0.25*</td>
<td>–</td>
<td>0.36**</td>
<td>0.24*</td>
</tr>
<tr>
<td>15. Poor concentration</td>
<td>0.39**</td>
<td>-0.22</td>
<td>0.04</td>
<td>-0.18</td>
<td>0.06</td>
<td>-0.18</td>
<td>-0.06</td>
<td>–</td>
<td>0.52**</td>
<td>0.35**</td>
<td>0.55**</td>
<td>0.45</td>
<td>0.62**</td>
<td>0.35**</td>
<td>–</td>
<td>0.47**</td>
</tr>
<tr>
<td>16. Poor sleep</td>
<td>0.16</td>
<td>-0.11</td>
<td>0.20*</td>
<td>0.08</td>
<td>0.18</td>
<td>-0.07</td>
<td>-0.14</td>
<td>-0.08</td>
<td>0.16</td>
<td>0.18</td>
<td>0.19</td>
<td>0.14</td>
<td>0.20*</td>
<td>0.25*</td>
<td>0.27**</td>
<td>–</td>
</tr>
</tbody>
</table>

*Note. Each cell above the diagonal indicates relationships at baseline. Each cell below the diagonal indicates relationships at follow-up. *p < .05, **p < .01 for significant group differences.*
Mediation Analyses

Sobel and bootstrapping tests are presented in Table 9.\textsuperscript{1} The results convey that cravings and anxiety significantly mediated the associations between delay to smoke and exercise.

\textsuperscript{1} Mediation was also examined using the Baron and Kenny (1986) recommendation but the results are not presented here since this approach has low statistical power for small sample sizes, increased chance of a Type II error, and statistically tests for both direct and indirect effects.
Table 9

Mediation analyses examining the indirect effect of cravings, affect, and tobacco withdrawal symptoms on ad libitum smoking through exercise

<table>
<thead>
<tr>
<th>Model</th>
<th>Value</th>
<th>SE</th>
<th>z</th>
<th>p</th>
<th>Mean</th>
<th>SE</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cravings → Exercise → Ad libitum smoking</td>
<td>-5.78</td>
<td>1.54</td>
<td>-3.75</td>
<td>0.00</td>
<td>-5.64</td>
<td>2.19</td>
<td>-10.35, -1.60</td>
</tr>
<tr>
<td>Positive affect → Exercise → Ad libitum smoking</td>
<td>-0.58</td>
<td>0.55</td>
<td>-1.06</td>
<td>0.29</td>
<td>-0.56</td>
<td>0.61</td>
<td>-2.14, 0.31</td>
</tr>
<tr>
<td>Negative affect → Exercise → Ad libitum smoking</td>
<td>-0.13</td>
<td>0.62</td>
<td>-0.21</td>
<td>0.83</td>
<td>-0.10</td>
<td>0.40</td>
<td>-0.80, 0.86</td>
</tr>
<tr>
<td>Depression → Exercise → Ad libitum smoking</td>
<td>-0.08</td>
<td>0.32</td>
<td>-0.25</td>
<td>0.80</td>
<td>-0.06</td>
<td>0.26</td>
<td>-0.65, 0.45</td>
</tr>
<tr>
<td>Anxiety → Exercise → Ad libitum smoking</td>
<td>-1.26</td>
<td>1.04</td>
<td>-1.22</td>
<td>0.22</td>
<td>-1.29</td>
<td>0.75</td>
<td>-3.16, -0.18</td>
</tr>
<tr>
<td>Irritability → Exercise → Ad libitum smoking</td>
<td>0.08</td>
<td>0.70</td>
<td>0.12</td>
<td>0.91</td>
<td>0.16</td>
<td>0.74</td>
<td>-0.86, 2.04</td>
</tr>
<tr>
<td>Restlessness → Exercise → Ad libitum smoking</td>
<td>-0.34</td>
<td>0.64</td>
<td>-0.52</td>
<td>0.60</td>
<td>-0.31</td>
<td>0.38</td>
<td>-1.12, 0.44</td>
</tr>
<tr>
<td>Hunger → Exercise → Ad libitum smoking</td>
<td>0.05</td>
<td>0.30</td>
<td>0.18</td>
<td>0.86</td>
<td>0.06</td>
<td>0.27</td>
<td>-0.56, 0.68</td>
</tr>
<tr>
<td>Poor concentration → Exercise → Ad libitum smoking</td>
<td>-0.68</td>
<td>0.59</td>
<td>-1.16</td>
<td>0.24</td>
<td>-0.62</td>
<td>0.57</td>
<td>-0.21, 0.16</td>
</tr>
<tr>
<td>Poor sleep → Exercise → Ad libitum smoking</td>
<td>0.19</td>
<td>0.38</td>
<td>0.51</td>
<td>0.61</td>
<td>0.19</td>
<td>0.38</td>
<td>-0.42, 1.12</td>
</tr>
</tbody>
</table>

Note: Boldface indicates a significant indirect effect.
Discussion

This study sought to understand the effects of an acute bout of moderate intensity exercise on objectively measured *ad libitum* smoking, smoking topography, as well as cravings, affect, and tobacco withdrawal symptoms. Moreover, this study investigated the mechanistic role of cravings, affect, and tobacco withdrawal symptoms in the attenuating effects of exercise on latency to smoke. While the exercise condition was associated with delayed time to first cigarette, it had a minimal impact on objectively measured smoking topography variables compared to the passive control group. In accordance with previous observations (Haasova et al., 2013, 2014; Roberts et al., 2012), exercise was also found to attenuate cravings, affect, and tobacco withdrawal symptoms in temporarily abstinent smokers. Lastly, cravings and anxiety were shown to be mechanistically involved in the exercise and time to first cigarette relationship using rigorous statistical mediation methods.

Smoking Behaviour

Tobacco control has typically focused on eliminating tobacco uptake and exposure. However, reducing tobacco use also reduces health risks, for which a dose-response relationship has been established (National Cancer Institute, 2001). This study maintains that a short period of exercise significantly delayed time before smoking the next cigarette by a multiple of four. That is, nicotine deprived individuals randomized to the exercise condition waited approximately eight minutes before smoking their first cigarette compared to two minutes for those who were in the control condition. Previous research has documented similar patterns but extended delays, ranging from 14 to 72
minutes (Faulkner et al., 2010; Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Reesor, 1983; Taylor & Katomeri, 2007; Thayer, 1993).

The pronounced variability in participant characteristics, abstinence period, study design, exercise dose, and environment forbids a comparison between studies. Earlier studies (Reesor, 1983; Thayer, 1993) recruited individuals who smoked heavily (i.e. 22.8 cigarettes per day, 1-2 packs per day) and were not required to temporarily abstain. Participants from other studies (Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Taylor & Katomeri, 2007) were regular smokers (smoked 13 to 15 cigarettes per day) but abstained from smoking for only one to two hours, with a third study involving an eight hour period of nicotine deprivation (Faulkner et al., 2010). More than half of these studies implemented a within-subject design (Faulkner et al., 2010; Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Thayer, 1993) and only one relied on self-reporting of ad libitum smoking behaviour through text messaging (Taylor & Katomeri, 2007). Finally, the bout of exercise differed in length, type, and intensity. It could be argued that the experimental environment (e.g. lab setting or natural setting) could have presented different stressors and interfered with self-determined smoking. Although drawing conclusions across these six studies is complicated by the aforementioned dissimilarities, it is undeniable that prolonging the period between cigarettes results in fewer cigarettes smoked per day, thereby corresponding to risk reduction (deRuiter & Faulkner, 2006; Godtfredsen, Prescott, & Osler, 2005).

As previously described, a group of studies have shown that acute bouts of exercise delays time to first cigarette between 14 to 72 minutes (Faulkner et al., 2010; Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Reesor, 1983; Taylor & Katomeri, 2007; Thayer, 1993). Despite this accumulating evidence, only one study to date has
investigated the role of craving in mediating the relationship between exercise and ad libitum smoking (Kurti & Dallery, 2014). They found that the smoking delay afforded by moderate-intensity exercise was mediated through the reward component of cravings in specific. Nevertheless, additional research to substantiate this breakthrough and consideration of other potential mechanisms are necessary. Consequently, the present study sought to elucidate the mechanistic role of cravings, affect, and tobacco withdrawal symptoms. Subsequent mediation analysis extends the work by Kurti and Dallery (2014) by revealing that exercise influences ad libitum smoking through craving and anxiety. These findings are supported by previous work indicating that craving is a powerful predictor of ad libitum smoking (Kurti & Dallery, 2014; Shiffman et al., 2002; Shiffman, Paty, Gwaltney, & Dang, 2004) and that negative affective states, which could be likened to anxiety, increases latency to smoke (Heckman et al., 2015).

Paying heed to the nicotine dependence properties of tobacco, curbing cigarette consumption (i.e. delaying time to next cigarette) may be coupled with compensatory behaviour. Smokers may attempt to extract more nicotine and associated toxins by taking more, deeper, slower, and longer puffs from each cigarette, thereby offsetting the potentially harm reducing benefits of acute exercise and reduced cigarette consumption. Therefore, a more accurate index of the impact of harm reduction strategies is smoking topography, as it provides an exhaustive profile of the interface between smoker and cigarette.

The current randomized controlled trial revealed that an acute moderate intensity exercise intervention did not produce statistically significant changes to smoking topography, compared to passive sitting. Upon visual inspection of the data, trends were evident. From baseline to post-condition, puff count, puff volume, and puff duration
decreased while average flow and interpuff interval increased for the exercise group versus the control group. These patterns are indicative of harm reduction as exercisers took fewer, shallower, shorter, and quicker puffs which were parceled by longer breaks. With the exception of puff duration and average flow, the passive sitting condition produced opposite effects on smoking topography variables. Recent research findings (Faulkner et al., 2010; Schneider et al., 2014) were replicated here, in that, they also found identical non-significant trends. Earlier work in this area demonstrated inverse relationship between cigarette duration and exercise intensity (Mikhail, 1983), and that, compared to a control group, non-abstaining participants in the stretching and isometric exercise condition smoked fewer puffs (Reesor, 1983).

Among individuals in the exercise condition who reported at least a 2-point cravings reduction, ancillary analyses upheld aforementioned trends except for puff duration, which significantly decreased over time. Schneider and colleagues (2014) also found no significant differences from baseline to follow-up for smoking topography (with the exception of IPI) of exercisers who experienced a similar diminution in cravings.

**Cravings**

Desire to smoke is a powerful predictor of smoking relapse (Doherty, Kinnunen, Militello, & Garvey, 1995; West, Hajek, & Belcher, 1989) and the impact of short bouts of exercise on cravings has been undisputed (Haasova et al., 2013, 2014; Roberts et al., 2012; Taylor, Ussher, & Faulkner, 2007; Ussher et al., 2014). Our study sample supports these observations as there was a 1.46 point reduction in desire to smoke for the experimental condition between pre- and post-condition, compared to 0.13 point reduction for the control condition. A greater desire to smoke was related to lower levels
of positive affect, and increased negative affect, depression, anxiety, irritability, restlessness, and poor concentration. Furthermore, stronger cravings post-condition was associated with shorter delays to *ad libitum* smoking, longer puff durations, and shorter interpuff intervals. This is in line with other research that has illustrated that heightened cravings amplify smoking intensity (Arndt et al., 2013). Given the existing body of knowledge, it was hypothesized that craving reductions following exercise would be manifested in objectively measured smoking behaviour, but this was not corroborated.

**Positive and Negative Affect**

Previous research has contended that an acute bout of exercise boosts positive affect and alleviates negative affect (Haasova et al., 2014; Roberts et al., 2012; Taylor et al., 2007) among nicotine deprived smokers. The present data are consistent with these findings, as exercisers experienced gains in positive affect of 2.55 points, whereas those who sat for an equal period of time experienced a 0.79 point decline in positive affect. As expected, there was a decline in negative affect by 2.55 points for the moderate intensity exercise condition and an increase by 0.29 points for the passive control condition. These affective changes may have crucial health implications in regards to smoking behaviour.

Namely, affect levels, particularly negative affect, are foretelling of sustained smoking and smoking relapses (Piper et al., 2004; Shiffman, 2005; Shiffman & Waters, 2004; Zvolensky et al., 2008). It has also been suggested that mood shapes smoking topography. Negative affect has been associated with shorter time to next cigarette, increased puff volume and puff count, and sustained puff duration (Conklin & Perkins, 2005; Payne, Schare, Levis, & Colletti, 1991; Weinberger & McKee, 2012). Positive and negative affect were unrelated to cravings and smoking behaviour at baseline. However,
post-condition, heightened levels of positive affect corresponded to a reduced desire to smoke, whereas increases in negative affect was related to more pronounced cigarette cravings. Higher negative affect was associated with shorter interpuff intervals as well, which corroborates the affective and smoking behaviour relationship.

**Tobacco Withdrawal Symptoms**

From a systematic review of 32 studies, all but six concluded that an acute bout of exercise significantly reduced withdrawal symptoms among temporarily deprived smokers, in contrast to a control group (Ussher et al., 2014). The results of the present investigation support these findings. Compared to passive sitting, a short bout of moderate intensity exercise significantly attenuated the following abstinence-induced tobacco withdrawal symptoms: anxiety (0.82 and 0.26 point reduction for exercise and control groups, respectively), irritability (0.70 vs. 0.30 point reduction), and restlessness (0.63 vs. 0.12 point reduction). Group by time interaction effects were not found for depression (0.36 vs. 0.12 point reduction), hunger (0.02 vs. 0.06 point reduction), poor concentration (0.28 vs. 0.04 point reduction), and poor sleep (0.20 vs 0.15 point reduction).

In much the same way that affective changes were related to smoking topography, so were tobacco withdrawal symptoms. At baseline, only puff volume and irritability were related. Following the respective conditions, those with stronger cravings also experienced higher levels of depression, anxiety, irritability, restlessness, and poor concentration. Shortened latency to *ad libitum* smoking was associated with increased anxiety levels. Finally, greater smoking delivery (i.e. puff count) was related to higher levels of depression, irritability, restlessness, and poor sleep. The present results
demonstrate that tobacco withdrawal symptoms are related to exacerbative smoking behaviour.

Research has documented that following stress and anxiety inducing situations, smoking topography patterns were altered, denotative of increased smoking delivery from increased puff count, puff volume, puff duration, and decreased interpuff interval (McClernon et al., 2005; McKee et al., 2011; Payne et al., 1991; Pomerleau & Pomerleau, 1987; Rose, Ananda, & Jarvik, 1983). Another study has indicated that smokers living with depression smoke cigarettes more intensely than those without a history of depression (i.e. increased total puff volume; Perkins, Karelitz, & Giedgowd, 2010). To our knowledge, this is the first time relationships between tobacco withdrawal symptoms, affect, and smoking behaviour were explored in an acute exercise paradigm with a non-clinical sample.

In marshalling this evidence about smoking behaviour in relation to affect and tobacco withdrawal symptoms, the negligible impact of acute exercise on smoking topography merits further explanation. As predicted, a ten minute bout of moderate intensity exercise abated changes in cravings, affect, and tobacco withdrawal symptoms associated with a temporary period of nicotine deprivation compared to passive sitting. In spite of these significant findings, a disconnect exists, in that, the benefits garnered from the acute exercise paradigm were not coupled with sweeping behavioural manifestations. Prolonged latency to first cigarette was observed, but physical engagement with the cigarette was unaffected.
This disconnect is not explained by the mere act of using a smoking topography device, as supported by the acceptability data of the present study. Lee and colleagues also reported that smoking behaviour was not influenced by smoking through a mouthpiece and that the CReSS system provides a valid and reliable measure of topography (Lee, Malson, Waters, Moolchan, & Pickworth, 2003). Perhaps for a fairly active sample to exhibit discernible differences in smoking behaviour, a more taxing bout of exercise is necessary. Above all, is it plausible to expect that smoking administration would digress when one has the freedom to smoke (i.e. *ad libitum*) following exercise? It may be that when an individual returns to cigarettes at their own will or degree of readiness, irrespective of treatment, habitual smoking behaviours are restored. Therefore, these non-significant smoking topography results are not due to insufficient power, but a reflexive interaction with a harmful, but violently addictive substance.

**Strengths and Limitations**

A few notable strengths of this research included that the hypotheses were tested using a between-subject, randomized controlled trial study design; smoking topography was objectively assessed at each participant’s self-determined readiness, which enhanced the ecological validity of the relationship they had with the first cigarette smoked after their respective condition; and an adequate abstinence period was implemented. The acute bout of exercise was individually prescribed based on each participant’s pre-abstinence resting heart rate. Most of all, this study partially replicated extant work. It sought to understand the acute effects of exercise on *ad libitum* smoking behaviour, which was comparable to the work of Faulkner et al. (2010), by using a randomized controlled trial design, which paralleled the study by Schneider et al. (2014). In doing so, it confirmed
previous research by demonstrating the harm reducing effectiveness of exercise on time to smoke, but not smoking topography.

A potential source of bias in interpreting the findings is the limited generalizability. To illustrate, a temporary period of nicotine deprivation may not emulate the physical and psychological experiences associated with a real quit attempt in one’s natural environment. Second, the current sample may not be representative of other smokers, as participants were somewhat active and were low to moderately dependent on nicotine. Also, the post-condition assessment period was not sufficient in duration. As a result, any residual, temporal impact of treatment on smoking behaviour, affect, and tobacco withdrawal symptoms, compared to control condition, could not be investigated.

**Future Research**

In addition to addressing the aforementioned limitations, future research should examine under what, if any, exercise conditions is smoking topography malleable. For instance, would increasing the duration or modifying the intensity or type of physical exertion yield statistically significant harm reducing effects on smoking topography? Or does exercise truly have a null effect on the physical attributes of smoking administration? Furthermore, the effects of exercise on smoking behaviour may hinge on other underlying factors such as the motives, rewards, and satisfaction associated with this addiction.

**Conclusion**

This study aimed to adequately and rigorously examine the effects of exercise on smoking behaviour during a temporary period of abstinence. Changes in *ad libitum*
smoking, but not changes in smoking topography, were found between exercise and passive sitting conditions during a simulated quit attempt. Specifically, this study demonstrated that an acute bout of exercise prolonged time to first cigarette and blunted changes in cravings, affect, and tobacco withdrawal symptoms. Relationships in the expected direction also were observed between time to first cigarette and cravings, withdrawal, and affect. Changes in ad libitum smoking following exercise were mediated by cravings and anxiety. Based on this evidence, acute bouts of moderate intensity exercise have utility as a harm reduction strategy for delaying latency to smoke but not when cigarette is in hand.
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Chapter Four: Smoking Behaviour and Sensations during the Pre-Quit Period of an Exercise-aided Smoking Cessation Intervention

Introduction

Tobacco is the foremost contributing agent to non-communicable diseases and preventable cause of death in the world, killing approximately 6 million individuals each year (World Health Organization, 2013). Considering the delay between cigarette smoking initiation and disease onset, this behaviour poses a significant threat to public health and necessitates the continued development of effective programs and policies to hinder tobacco consumption.

In Canada, upwards of two thirds of smokers genuinely plan to quit smoking (Reid, Hammond, Rynard, & Burkhalter, 2014). These intentions are met by a cluster of physiological, environmental, and psychosocial factors that dampen quit rates. Not surprisingly, only 13% of individuals who made a quit attempt were abstinent one year later (Reid et al., 2014), likely attributable to insurmountable cravings and tobacco withdrawal symptoms which are cited as pitfalls in becoming nicotine-free (Aveyard & West, 2007; Hughes, 2007).

A number of individual-based smoking cessation methods exist to blunt the addictive nicotinic properties of tobacco. These include unassisted quitting, advice from a health care professional, counselling, cognitive behavioural therapy, nicotine replacement therapy, varenicline, and bupropion. Six month abstinence rates for these interventions range from 4 to 28% (Hughes, 2003; U.S. Department of Health and Human Services,
One novel adjunct to improve traditional therapies is exercise, in the form of incidental or structured physical activity.

Recently, Ussher and colleagues (2014) sought to examine whether exercise-aided interventions either alone or in combination with a smoking cessation component were more effective than traditional smoking cessation interventions at improving quit rates. Twenty randomized controlled trials with at least a six month follow-up period were identified for the systematic review. Just four studies demonstrated significantly higher abstinence for the exercise condition, compared to control, following treatment (Bock et al., 2012; Marcus, Albrecht, Niaura, Abrams, & Thompson, 1991; Marcus et al., 1999; Martin, Kalfas, & Patten, 1997). Of these studies, only one revealed the continued benefit of exercise versus control on quit rates at three and 12-month follow-up (Marcus et al., 1999). Overall, Ussher et al. found unreliable evidence to support exercise-based smoking cessation interventions for long-term abstinence.

Although smoking cessation rates marginally improved with regular physical activity, individuals engaged in a quit attempt garner other physical and psychological health benefits, some of which may prevent smoking relapse. Among females participating in an exercise-aided smoking cessation intervention, vascular health (e.g., peripheral resistance, compliance, inertia, brachial velocity) and lung function ameliorated (Fitzgeorge, Harper, & Prapavessis, 2011; Nielson et al., 2014). Other physical activity based smoking cessation programs have shown significant improvements in cardiovascular disease biomarkers, Type 2 diabetes, systemic inflammation, exercise performance, and high-density lipoprotein for quitters (Albrecht, Marcus, Roberts, Forman, & Parisi, 1998; Korhonen, Goodwin, Miesmaa, Dupuis, & Kinnunen, 2011; Linke, Ciccolo, Ussher, & Marcus, 2013; Niaura, Marcus, Albrecht,
Thompson, & Abrams, 1998), and risk reductions in cardiovascular mortality and colorectal cancer (Colbert et al., 2001; Hedblad, Ogren, Isacsson, & Janzo, 1997) for continued smokers. In addition, there were significant gains in perceived coping ability (Steptoe, Edwards, Moses, & Mattews, 1989) and quality of life (Bloom et al., 2013) as well as lower levels of mood and sleep disturbances, stress, and anxiety (Abrantes et al., 2014; Stathopoulou, Power, Berry, Smits, & Otto, 2006; Taylor, 2000; Taylor & Faulkner, 2008) among physically active individuals attempting to quit.

In sum, from the studies conveyed above, regular physical activity is associated with numerous physiological and psychological benefits among quitters and current smokers. Nevertheless, the role of habitual exercise on smoking behaviour is less known. A handful of studies have observed a decrease in the number of cigarettes smoked for the physical activity treatment arm compared to the control arm (Leelarungrayub et al., 2010; Maddison et al., 2014; Taylor, Houston-Miller, Haskell, & Debrusk, 1988; Taylor et al., 2014). In a single group community-based exercise program, there was also a significant decline in cigarette consumption (Whiteley et al., 2007). Recently, Thompson et al. (2015) showed that a smoking reduction intervention for economically disadvantaged smokers which focused on support to increase physical activity was more effective than standard care in reducing cigarette consumption. In fact, a meta-analysis by Lindson-Hawley and colleagues (2012) concluded that tapering cigarette use was equally effective to the conventional abrupt approach to smoking cessation and hence, a viable alternative. Evidently, long-term exercise-aided interventions for smoking cessation may have a harm reduction effect on smoking behaviour.

It is quite possible that the effects of exercise as an adjunctive quit smoking therapy on cigarette consumption is further evidence of the incompatibility of these two
behaviours. Cross-sectional research has suggested that physically active smokers are more confident that they can refrain from smoking (King, Marcus, Pinto, Emmon, & Abrams, 1996), less nicotine dependent (deRuiter, Faulkner, Cairney, & Veldhuizen, 2008; Ward et al., 2003), make more cessation attempts (deRuiter et al., 2008), and are more successful at quitting smoking (Marcus et al., 1991; Ward et al., 2003) than physically inactive smokers. As such, most well-designed exercise-aided smoking cessation trials introduce exercise to participants prior to the quit attempt. In light of previous findings, this sequential approach is considered more advantageous than introducing exercise and cessation concurrently or cessation prior to exercise. The concurrent approach may be taxing as participants are enduring multiple behaviour change; while exercise is considered a gateway behaviour to cessation, cessation is not considered a gateway behaviour to exercise. This is underscored by the aforementioned trials (Leelarunggrayub et al., 2010; Maddison et al., 2014; Prapavessis et al., 2007; Taylor et al., 2014) which did not provide a reduction intervention and yet smokers who exercised leading up to the targeted quit date (usually 3-4 weeks away) curbed their cigarette consumption. Against this background, exercise and smoking are not compatible behaviours and exercise may indeed be the conduit to smoking reduction.

With most addictions, individuals may consciously or unconsciously adjust their smoking behaviour, or compensate, to achieve a desired effect. Nicotine titration can take the form of changing the number of cigarettes smoked per day, cigarette brand selection, smoking topography, and manual manipulation of the cigarette. Objective indicators of compensation include nicotine, cotinine, exhaled carbon monoxide, and thiocyanate levels as well as smoking topography. A review of the smoking and compensation literature has conveyed that smoking intensity is greater for low (nicotine)-yield cigarettes
compared to high-yield cigarettes (Scherer, 1999). Moreover, smoking topography
appeared to be the likely means of compensational smoking, over altering cigarette
consumption and vent blocking (Scherer, 1999). These patterns were consistent with
previous studies (Cinciripini et al., 1989; Hammond, Fong, Cummings, & Hyland, 2005;
Karanci, 1985). Behavioural (i.e. number of cigarettes smoked) and biochemical (i.e.
carbon monoxide) compensation also appeared in a qualitative systematic review
conducted by Hughes and Carpenter (2005) when participants were undergoing
behavioural treatment, nicotine replacement therapy, or bupropion. What remains to be
elucidated is whether smoking topography compensation (i.e., intensity of cigarette
smoking changes) occurs in light of cigarette reduction during the pre-quit period of an
exercise-aided smoking cessation program.

What also remains unknown is the impact of regular physical activity on the
reinforcing, subjective sensations that individuals experience when smoking. These
reinforcing sensory experiences include smoking satisfaction, psychological reward,
enjoyment of respiratory tract sensations, aversion, and craving reduction. Such sensory
factors have mainly been examined in experiments related to nicotine manipulation,
satiation, pharmacotherapy (i.e. varenicline, bupropion SR), or were descriptive in nature.
Only one previous study has examined changes in cigarette-related sensations with
respect to physical activity. Using a pilot randomized controlled trial that involved an 8-
week physical activity and smoking reduction counselling intervention for disadvantaged
smokers, Taylor and colleagues (2014) learned that the previously mentioned sensory
experiences decreased with increased physical activity levels.

In addressing these matters, investigators and healthcare professionals alike will
gain deeper insight into a smoker’s profile as they approach their quit date and
implications for the quit attempt. In particular, if topography and sensations associated with smoking intensify ahead of the quit date, despite a reduction in cigarette consumption, complete abstinence may be more difficult to achieve, putting smokers at a disadvantage compared to quitting abruptly. On the other hand, it is conceivable that if harm reduction behaviour and psyche (i.e. diminished or no change in smoking intensity and sensory experiences) followed cigarette reduction, smokers may be better positioned to achieve smoking cessation and do so with greater ease. With this knowledge, stakeholders can tailor interventions and circumstances surrounding the quit attempt to optimize success, which would enhance the proportion of individuals in pursuit of and realize cessation.

Therefore, the purpose of this study was to investigate the changes and interrelatedness of cigarette consumption, expired carbon monoxide levels, smoking topography, and cigarette-related sensations during the first three-weeks (i.e., pre-quit period) of a supervised, laboratory-based exercise-aided smoking cessation program. It was hypothesized that during this pre-quit period cigarette consumption, carbon monoxide, smoking topography, and sensory factors would positively change (i.e., fewer cigarettes smoked, reduction in puff duration, inter puff interval, and puff count as well as less satisfaction and reward associated with smoking). It was further hypothesized that changes in cigarette consumption and carbon monoxide would either mirror or be unrelated to changes in smoking topography and cigarette-related sensations, indicating no compensation.

Method
Design

The current study was part of a large-scale study (Getting Physical on Cigarettes) wherein the effect of an exercise-aided smoking cessation intervention on post-intervention cessation rates compared to contact controls was examined (Jung et al., 2010). Data for the current study were collected prior to the start (i.e. baseline) and during the first three weeks of the exercise intervention. A targeted quit date was set for the beginning of week 4, at which point, participants concurrently followed the exercise and Nicoderm® three step, 10-week program.

Participants

The Getting Physical on Cigarettes trial recruited approximately 400 participants (over seven cohorts) from local businesses, health care and academic institutions, organizations, and through advertisements placed in newspapers, radio stations, and public transit in London, Ontario. Only subjects involved with the last four cohorts were invited to participate in this study.

To be eligible to participate in Getting Physical on Cigarettes, women were required to be between the ages of 18 and 65, smoke 10 cigarettes or more per day for the last two years, wish to quit smoking, engage in two or fewer 30-minute bouts of moderate-to-vigorous intensity exercise per week over the past six months, able to read and write in English, and have access to a telephone or e-mail account for communication purposes. Women were excluded from participating if they were pregnant or were intending to become pregnant during the next year, had other substance dependency issues (e.g. alcohol), prescribed medication for physical and/or mental health reasons that would comprise compliance with the study protocol, or presented with medical conditions
that were contraindicative for regular exercise or the use of transdermal nicotine replacement therapy.

**Primary Outcome Measures**

**Smoking behaviour.**

*Cigarette consumption.*

Total number of cigarettes smoked per day was recorded through self-report.

*Carbon monoxide.*

Expired carbon monoxide levels were measured with the piCO+™ Smokerlyzer® (Bedfont Scientific Ltd., Kent, England). The recommended calibration procedure was performed every day the CO monitor was being utilized.

**Smoking topography.**

Smoking topography was assessed using the Clinical Research Support System (CReSS) Pocket, a computer-based, battery-powered, hand-held unit by Plowshare Technologies® (Borgwalt, KC. Inc., Virginia). This device has an orifice flow meter mouthpiece, which produces a pressure drop when a puff is taken. This is converted to a flow velocity from which many of the topography indices are derived. The CReSS Pocket computes puff count (total number of puffs), puff volume (millilitres of tobacco smoke inhaled with each puff), average flow (i.e. velocity; puff volume with respect to puff duration), puff duration (period of time for each puff), and interpuff interval (length of time between puffs).
To ensure proper functioning of the smoking topography apparatus, test puffs were performed whenever the mouthpiece was cleaned or changed (i.e. between each participant). An unlit cigarette was placed in the device mouthpiece, to which a sterile syringe was connected. Puffs were simulated by pulling the syringe plunger in a smooth fashion and ending abruptly. Syringe volume was then compared to the volume computed by the CReSS software. This process was repeated several times to ensure consistency and accuracy.

Prior to using the CReSS Pocket, participants were familiarized and instructed on the proper use of the device. They were directed to ignite a cigarette (of their preferred brand) before placing the cigarette into the CReSS Pocket and upon finishing smoking, to remove the cigarette from the device prior to extinguishing it. Use of the CReSS Pocket took place outside as the laboratory was not adequately ventilated. Upon returning, the smoking topography data were immediately retrieved using a serial port linked with the CReSS computer software. Data were reduced by taking an average of all puffs except the first and last (De Jesus, Hsin, Faulkner, & Prapavessis, 2015). The CReSS Pocket has demonstrated excellent test-retest reliability for puff duration ($\alpha \geq 0.75$) and acceptable reliability for puff volume and velocity ($0.4 > \alpha < 0.75$) (Lee, Malson, Waters, Moolchan, & Pickworth, 2003).

**Sensory factors.**

The reinforcing sensory effects of cigarettes were subjectively determined using the modified Cigarette Evaluation Questionnaire (mCEQ; Cappelleri et al., 2007). This inventory involved rating 12 items on a seven-point scale (1- *not at all*, 4 - *moderately*, 7 - *extremely*), in which higher values denoted a stronger intensity of smoking-related
experiences. These items corresponded to the following five subscales: smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, craving reduction, and aversion. This inventory has demonstrated acceptable reliability across all five domains and good internal consistency for smoking satisfaction (α = 0.84) and psychological reward (α = 0.83), but low consistency for aversion (α = 0.54; Cappelleri et al., 2007). Across the data collection period, consistency was found to be good for smoking satisfaction (α ranging from 0.82 to 0.90) and psychological reward (α ranging from 0.81 to 0.90), but acceptable for aversion (α ranging from 0.49 to 0.87).

Other Measures

Demographics and anthropometry.

Demographic measures, such as age, marital status, level of education, employment status, and annual household income, were collected using self-report. Anthropometric data (i.e. height and weight) were noted in order to calculate Body Mass Index (BMI; kg/m²).

Cigarette dependency.

Please refer to the Method section of Chapter Two for more information.

Acceptability questionnaire.

Please refer to the Method section of Chapter Three for more information.

Program adherence.
Adherence to the first three weeks of the supervised, aerobic exercise regimen was calculated from the number of exercise sessions attended by the participant compared to the total number of exercise sessions offered. This was converted into a percentage.

**Intervention**

In groups of 10-15, female smokers participated in an aerobic, supervised exercise program in a laboratory facility. Participants had access to equipment such as treadmills, rowing machines, stair climbers, and stationary bicycles. The exercise program involved three exercise sessions per week during weeks 1 to 8, two exercise sessions per week during weeks 9 to 11, and one exercise session per week during weeks 12 to 14. Throughout this tapering period, participants were expected to supplement with home-based physical activity, thereby enhancing exercise independence. Each exercise session was approximately 45 minutes in duration and consisted of a warm-up, 20-35 minutes of aerobic exercise, and a cool-down. Participants' workload (intensity and duration) progressively increased to 70-75% of their maximum heart rate over the 14-week period. Individualized exercise prescriptions were determined from maximum heart rate attained during the baseline cardiorespiratory fitness assessment and were monitored during exercise sessions using Polar RS100 Heart Rate monitor (Kempele, Finland). Regarding the transdermal nicotine replacement therapy, this trial employed the NicoDerm® 10-week transdermal patch program. A targeted quit date was established for the start of week 4, when participants were provided NicoDerm® patches on a weekly basis for ten weeks. For the purpose of this study, only data collected between baseline and week 3 were of interest.
Procedure

Ethics approval was provided by Western University’s Research Ethics Board (REB#16306, Appendix H) and was registered with Clinical Trials, a service of the United States National Institutes of Health (NCT1305447). This study was carried out in accordance with the ethical research principles outlined in the Declaration of Helsinki (World Medical Association, 2008) and the World Health Organization’s (WHO) Handbook for Good Clinical Research Practice (WHO, 2005).

Prior to enrolling in the trial, eligible female smokers provided written informed consent (see Appendix F) and approval from their family physician to engage in an exercise program and use of the NicoDerm® product. Next participants completed their baseline assessments, which involved demographic, cigarette dependency, and cigarette consumption questionnaires. Anthropometric variables and an exhaled carbon monoxide reading were taken. Next, participants were familiarized with the CReSS Pocket through verbal instruction and demonstration and invited to smoke a cigarette of their regular brand with the CReSS Pocket outside of the building. Upon returning, participants completed the Acceptability Questionnaire. Thereafter, cigarette consumption was documented by participants on a daily basis, whereas carbon monoxide, smoking topography, and CReSS Pocket acceptability were assessed following one and three weeks of completing the exercise program. Participants were encouraged to self-administer the modified Cigarette Evaluation Questionnaire on a daily basis, immediately after the first cigarette of the day, during the 14 days leading up to the targeted quit date. A timeline of the collection of primary outcome and other measures is presented in Table 9.
Table 10

*Timeline of the assessment of primary outcome and other measures*

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>D1 to D6</th>
<th>D7</th>
<th>D8 to D20</th>
<th>D21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Questionnaire</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthropometry</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FTCD</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cigarette consumption</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>CO</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Smoking Topography</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Acceptability Questionnaire</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>mCEQ</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

*Note.* FTCD = Fagerström Test for Cigarette Dependence; CO = Carbon monoxide; mCEQ = modified Cigarette Evaluation Questionnaire; B = Baseline; D = Day of program.
Power Calculation

No power calculation was computed given the novelty of this study and since the sample size was derived from the parent study.

Statistical Analyses

Descriptive statistics were computed for the entire sample for demographic and smoking related factors.

Adherence to the exercise program, by way of attendance, was examined with descriptive statistics. Participants’ acceptability of the CReSS Pocket was tested using a repeated measures analysis of variance (ANOVA) across time (baseline, week 1, week 3).

For the primary outcome measures, repeated measures ANOVAs were used to test for temporal differences in cigarette consumption, carbon monoxide levels, smoking topography, and sensory factors. Finally, bivariate correlations were performed to examine relationships among the residual change scores of these variables.

The level of significance was accepted at $p < 0.05$ for all statistical tests (Tabachnick & Fidell, 1996). In accordance with Cohen (1988), 0.01 constitutes a small effect size, 0.06 constitutes a moderate effect size, and 0.14 constitutes a large effect size ($\eta^2$). The aforementioned statistics were completed using IBM SPSS Statistics (Version 22).

Results

Females participating in this exercise-aided smoking cessation program were middle-aged smokers who were moderately dependent on cigarettes (Table 10).
Table 11

Demographic and smoking related characteristics of participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N</strong></td>
<td>236</td>
</tr>
<tr>
<td>Age (years)</td>
<td>43.34 (12.46)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.57 (6.22)</td>
</tr>
<tr>
<td>Marital status (N, %)</td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>70 (29.90%)</td>
</tr>
<tr>
<td>Married</td>
<td>71 (30.30%)</td>
</tr>
<tr>
<td>Divorced/separated</td>
<td>53 (22.70%)</td>
</tr>
<tr>
<td>Education (years)</td>
<td>13.57 (2.48)</td>
</tr>
<tr>
<td>Employment status</td>
<td></td>
</tr>
<tr>
<td>Employed</td>
<td>150 (64.10%)</td>
</tr>
<tr>
<td>Unemployed</td>
<td>28 (12.00%)</td>
</tr>
<tr>
<td>Student</td>
<td>23 (9.80%)</td>
</tr>
<tr>
<td>Annual household income (N, %)</td>
<td></td>
</tr>
<tr>
<td>&lt; $50,000</td>
<td>103 (44.78%)</td>
</tr>
<tr>
<td>$50,000 – $75,000</td>
<td>53 (23.04%)</td>
</tr>
<tr>
<td>&gt; $75,000</td>
<td>51 (22.17%)</td>
</tr>
<tr>
<td>METs</td>
<td>5.74 (6.29)</td>
</tr>
<tr>
<td>Years smoking</td>
<td>23.86 (12.27)</td>
</tr>
<tr>
<td>FTCD</td>
<td>5.32 (1.93)</td>
</tr>
<tr>
<td>Cigarettes per day</td>
<td>16.97 (6.19)</td>
</tr>
<tr>
<td>Expired CO (ppm)</td>
<td>22.89 (12.20)</td>
</tr>
<tr>
<td>Percent adherence to exercise (%)</td>
<td>79.57 (27.50)</td>
</tr>
</tbody>
</table>

Note. BMI = Body Mass Index; MET = Metabolic Equivalent Task; FTCD = Fagerström Test for Cigarette Dependence; CO = Carbon Monoxide; ppm = parts per million.
**Fidelity Check**

Overall, participants completed 79.57% (SD = 27.50) of their supervised exercise sessions. There were significant differences across time for subjects’ perceived interference of the CReSS Pocket in their smoking behaviour ($F [2, 174] = 8.76, p = 0.00$, $\eta^2 = 0.09$; Figure 6).
Figure 6

*Change in CReSS Pocket acceptability at baseline, week 1, and week 3*

Note. Error bars represent standard error.
Primary and Secondary Outcome Analyses

Smoking behaviour.

There was a significant reduction in daily cigarette consumption \( F[2, 122] = 29.19, p = 0.00, \eta^2 = 0.32 \) and carbon monoxide levels \( F[2, 188] = 15.14, p = 0.00, \eta^2 = 0.14 \) (see Table 11).

Puff duration \( F[2, 165] = 4.74, p = 0.01, \eta^2 = 0.05 \) significantly decreased whereas average puff flow \( F[2, 165] = 4.73, p = 0.01, \eta^2 = 0.05 \) significantly increased across time (see Table YY). There were non-significant changes in puff count \( F[2, 165] = 1.02, p = 0.36, \eta^2 = 0.01 \), puff volume \( F[2, 165] = 1.20, p = 0.30, \eta^2 = 0.01 \), and interpuff interval \( F[2, 164] = 2.14, p = 0.12, \eta^2 = 0.03 \) (see Table 11).^1

^1 Ancillary analyses were conducted to examine the impact of program adherence on smoking behaviour on the primary outcome variables over time. Participants were categorized according to their level of involvement: those who completed all (i.e. 100%) of the exercise sessions and those who did not (i.e. <100%). Interaction effects for group by time ancillary analyses did not surface for cigarettes per day, carbon monoxide levels or any smoking topography variable, except for puff volume which significantly decreased for participants with perfect attendance compared to those without.
Table 12

*Means and standard deviations for smoking behaviour over time*

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Week 1</th>
<th>Week 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarettes per day</td>
<td>16.98 (6.15)</td>
<td>14.68 (5.18)</td>
<td>13.62 (5.04)</td>
</tr>
<tr>
<td>Carbon monoxide (ppm)</td>
<td>23.44 (12.09)</td>
<td>20.94 (10.95)</td>
<td>19.46 (10.22)</td>
</tr>
<tr>
<td>Puff Count</td>
<td>14.58 (5.39)</td>
<td>14.13 (5.63)</td>
<td>14.10 (4.53)</td>
</tr>
<tr>
<td>Puff Volume (mL)</td>
<td>58.48 (21.14)</td>
<td>56.51 (18.75)</td>
<td>56.46 (17.80)</td>
</tr>
<tr>
<td>Average Flow (mL/sec)</td>
<td>37.03 (9.71)</td>
<td>38.08 (9.73)</td>
<td>39.38 (10.37)</td>
</tr>
<tr>
<td>Puff Duration (sec)</td>
<td>1.69 (0.64)</td>
<td>1.66 (1.02)</td>
<td>1.53 (0.59)</td>
</tr>
<tr>
<td>Interpuff Interval (sec)</td>
<td>16.45 (6.77)</td>
<td>17.46 (7.60)</td>
<td>16.65 (6.62)</td>
</tr>
</tbody>
</table>
Smoking sensations.

A significant decrease over time was found for smoking satisfaction ($F_{13, 124} = 4.95, p = 0.00, \eta^2 = 0.34$), psychological reward ($F_{13, 124} = 7.32, p = 0.00, \eta^2 = 0.43$), enjoyment of respiratory tract sensations ($F_{13, 123} = 3.89, p = 0.00, \eta^2 = 0.29$), and craving reduction ($F_{13, 124} = 6.16, p = 0.00, \eta^2 = 0.39$). There were non-significant changes in aversion ($F_{13, 124} = 1.49, p = 0.13, \eta^2 = 0.14$) (see Figure 7).²

² Ancillary analyses were conducted to examine the impact of program adherence on smoking sensations over time. Participants were categorized according to their level of involvement: those who completed all (i.e. 100%) of the exercise sessions and those who did not (i.e. <100%). Interaction effects for group by time ancillary analyses did not surface for any sensory factor.
Figure 7

*Change in smoking sensations over a two week period*
Correlations

Pearson’s bivariate correlation coefficients between the residual change scores for smoking behaviour and cigarette evaluation variables are displayed in Table 12. Residual change scores for puff volume were positively related to average flow and puff duration. There were moderate, negative relationships between the residual change scores for average flow and puff duration as well as between puff count and interpuff interval. There were small to moderate positive relationships between smoking satisfaction residual change scores and psychological reward, enjoyment of respiratory tract sensations, and craving reduction. There was a small, negative relationship between residual change scores for smoking satisfaction and aversion. Residual change scores for psychological reward were also positively related to enjoyment of respiratory tract sensations and craving reduction. Residual change scores for craving reduction were positively correlated to enjoyment of respiratory tract sensations and aversion. Finally, the sole significant relationship between smoking behaviour and cigarette evaluation was between the residual change scores of cigarette consumption and smoking satisfaction.
Table 13

*Relationships between residual change scores for smoking behaviour and cigarette evaluation*

<table>
<thead>
<tr>
<th></th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
<th>12.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cigarette consumption</td>
<td>1</td>
<td>.050</td>
<td>-.052</td>
<td>-.046</td>
<td>-.044</td>
<td>-.115</td>
<td>.004</td>
<td>.237**</td>
<td>.137</td>
<td>-.049</td>
<td>.141</td>
<td>.068</td>
</tr>
<tr>
<td>2. CO</td>
<td>.050</td>
<td>1</td>
<td>.087</td>
<td>.013</td>
<td>-.044</td>
<td>.029</td>
<td>-.002</td>
<td>.154</td>
<td>.077</td>
<td>.053</td>
<td>.145</td>
<td>.086</td>
</tr>
<tr>
<td>3. Puff Count</td>
<td>-.052</td>
<td>.087</td>
<td>1</td>
<td>-.113</td>
<td>-.054</td>
<td>-.048</td>
<td>.468**</td>
<td>-.031</td>
<td>.026</td>
<td>.001</td>
<td>-.012</td>
<td>-.039</td>
</tr>
<tr>
<td>4. Puff Volume</td>
<td>-.046</td>
<td>.013</td>
<td>-.113</td>
<td>1</td>
<td>.202**</td>
<td>.659**</td>
<td>-.059</td>
<td>.031</td>
<td>-.070</td>
<td>.086</td>
<td>-.082</td>
<td>.094</td>
</tr>
<tr>
<td>5. Average Flow</td>
<td>-.044</td>
<td>-.054</td>
<td>.202**</td>
<td>1</td>
<td>.464**</td>
<td>.028</td>
<td>.067</td>
<td>-.016</td>
<td>-.001</td>
<td>.000</td>
<td>.059</td>
<td></td>
</tr>
<tr>
<td>6. Puff Duration</td>
<td>-.115</td>
<td>.029</td>
<td>-.048</td>
<td>.659**</td>
<td>-.464**</td>
<td>1</td>
<td>-.111</td>
<td>-.061</td>
<td>-.055</td>
<td>.039</td>
<td>-.019</td>
<td>.037</td>
</tr>
<tr>
<td>7. Interpuff Interval</td>
<td>.004</td>
<td>.002</td>
<td>.468**</td>
<td>-.059</td>
<td>.028</td>
<td>-.111</td>
<td>1</td>
<td>.150</td>
<td>.133</td>
<td>-.127</td>
<td>.102</td>
<td>.090</td>
</tr>
<tr>
<td>8. Smoking Satisfaction</td>
<td>.237**</td>
<td>.154</td>
<td>-.031</td>
<td>.031</td>
<td>.067</td>
<td>-.061</td>
<td>.150</td>
<td>1</td>
<td>.333**</td>
<td>-.106</td>
<td>.294*</td>
<td>.205*</td>
</tr>
<tr>
<td>9. Psychological Reward</td>
<td>.137</td>
<td>.077</td>
<td>.026</td>
<td>-.070</td>
<td>-.016</td>
<td>-.055</td>
<td>.133</td>
<td>.333**</td>
<td>1</td>
<td>-.106</td>
<td>.294*</td>
<td>.205*</td>
</tr>
<tr>
<td>10. Aversion</td>
<td>-.049</td>
<td>.053</td>
<td>.001</td>
<td>.086</td>
<td>-.001</td>
<td>.039</td>
<td>-.127</td>
<td>.275**</td>
<td>-.106</td>
<td>1</td>
<td>-.120</td>
<td>.193*</td>
</tr>
<tr>
<td>11. Enjoyment of Respiratory Tract Sensations</td>
<td>.141</td>
<td>.145</td>
<td>-.012</td>
<td>-.082</td>
<td>.000</td>
<td>-.019</td>
<td>.102</td>
<td>.586**</td>
<td>.294*</td>
<td>-.120</td>
<td>1</td>
<td>.289*</td>
</tr>
<tr>
<td>12. Craving Reduction</td>
<td>.068</td>
<td>.086</td>
<td>-.039</td>
<td>.094</td>
<td>.059</td>
<td>.037</td>
<td>.090</td>
<td>.237**</td>
<td>.203*</td>
<td>.193*</td>
<td>.289*</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note. *p < .05, **p < .01.*
Discussion

The ambition of the present study was to understand the impact of structured aerobic exercise during the pre-quit period of an exercise-aided smoking cessation program on cigarette consumption, expired carbon monoxide levels, smoking topography, and cigarette-related sensory factors. Over a three-week pre-quit period of exercise, there was a significant reduction in the number of cigarettes smoked, carbon monoxide levels and puff duration, as well as a significant increase in average puff flow. None of the other smoking topography variables (i.e., puff count, puff volume, or inter puff interval) significantly changed. Nearly all of the sensory variables (i.e., satisfaction, reward, respiratory tract sensation, and craving) significantly decreased. Furthermore, with the exception of a mild positive association shown between cigarette consumption and satisfaction, there was no evidence that cigarette consumption and carbon monoxide were related to either smoking topography or sensations. Potential explanations and implications for the observed findings in this study are considered below.

Smoking Behaviour

An important tactic to facilitate cessation is the gradual reduction method, as opposed to abrupt cessation on a designated quit day. In fact, over half of daily smokers surveyed in the United Kingdom and the United States described that they planned to quit smoking using the former method (Hughes, Callas, & Peters, 2006; West & Brown, 2012). Women attempting to quit smoking through this exercise-based smoking cessation intervention also reduced the number of cigarettes smoked by 3.36 cigarettes over the three weeks prior to their quit date. Hesitation over accepting these results owing merely
to exercise, without direct comparison to a non-active control group, is justifiable. To this end, one should note that other randomized controlled trials of various program durations and design revealed that participants randomized to physical activity gradually decreased the amount of cigarettes smoked versus the non-exercising control group (Leelarungrayub et al., 2010; Maddison et al., 2014; Prapavessis et al., 2007; Taylor, et al., 1988; Taylor et al., 2014). Furthermore, the current exercise-aided smoking cessation intervention did not comprise of a gradual reduction method, nor were participants encouraged to do so. In light of these findings, the gradual reduction demonstrated in the current study may be a reflection of the incompatibility of regular physical activity and cigarette consumption. Namely, these patterns may be attributed to smokers’ enhanced ability to refrain from smoking (King et al., 1996), compared to leading a sedentary lifestyle. Cigarette reduction may also be driven by the craving and withdrawal symptom relief exercise provides, albeit in an acute paradigm, but could extrapolate to individual, but repetitive, 30-minute sessions of moderate-to-vigorous exercise.

Besides self-report, another notable method of determining smoking behaviour is expired carbon monoxide. Termed the “stethoscope of smoking cessation” (Bittoun, 2008), carbon monoxide levels provide an immediate and non-invasive estimate using a relatively economical instrument. Expired carbon monoxide breath levels of female smokers significantly dropped during the first few weeks of the exercise-aided smoking cessation intervention. This finding is not surprising. A number of previous studies have shown that expired carbon monoxide is related to the number of cigarettes smoked during the preceding 24 hours (Cunnington & Hormbrey, 2002; Deveci, Deveci, Acik, & Ozan, 2004; Low, Ong, & Tan, 2004; Pearce & Hayes, 2005). Data not presented here support this relationship, as a significant positive relationship was found between cigarette
consumption and expired carbon monoxide levels at baseline \((r = 0.44, p = 0.00)\), week 1 \((r = 0.42, p = 0.00)\), and week 3 \((r = 0.25, p = 0.00)\) with the current sample. Furthermore, two randomized controlled trials, which also reported cigarette reductions, also revealed significant decreases in carbon monoxide levels from baseline to post-intervention for the exercise treatment arm in contrast to the control group (Leelarungrayub et al. 2010; Taylor et al., 2014).

Literature has suggested that smokers who are physically active benefit from improved physical and mental health, as well as, a stronger propensity to attain cessation (deRuiter & Faulkner, 2006; deRuiter et al., 2008; Ward et al., 2003). Despite this emerging evidence, this is the first study to our knowledge which has investigated the effects of an aerobic exercise quit smoking program on smoking topography. The results showed a significant decline in puff duration and significant rise in average puff flow. Although puff count, puff volume, and interpuff interval did not statistically differ over time, diminutions were visible. Changes in carbon monoxide may echo smoking topography patterns, as previous research has found a dose response between smoking intensity and carbon monoxide (Ahijevych & Parsley, 1999; Lee et al., 2003). These positive changes to smoking topography may be a manifestation of exercise-related benefits for smokers. In particular, long-term exercise has been found to mitigate mood disturbances, stress, and anxiety (Abrantes et al., 2014; Stathopoulou et al., 2006; Taylor, 2000; Taylor & Faulkner, 2008). These poor psychoemotional states have been linked to higher smoking intensity (Conklin & Perkins, 2005; McClernon et al., 2005; McKee et al., 2011; Payne, Schare, Levis, & Colletti, 1991; Pomerleau & Pomerleau, 1987; Rose et al., 1983; Weinberger & McKee, 2012;). The current data partially corroborate the harm
reducing effect of physical activity in anticipation of a quit attempt and closes a gap in the existing smoking cessation literature.

It is widely accepted that nicotine is the highly addictive component of tobacco and stimulates a cascade of neurological and hormonal messages within seconds of use (Benowitz, Hukkanen, & Jacob III, 2009; National Institute of Drug Abuse, 2012; Pomerleau & Pomerleau, 1984). Granted there was a decrease in the number of cigarettes smoked, corresponding to reduced nicotine exposure, concern for compensational smoking patterns is warranted. The first indicator for compensatory behaviour was carbon monoxide levels. Although carbon monoxide breath levels can be confounded by its short half-life, environmental pollution, diet, physical activity, and inflammatory lung diseases (Christenhusz et al., 2007; Deller, Stenz, Forstner, & Konrad, 1992; Hovarth et al., 1998; Joumard, Chiron, Vidon, Maurin, & Rouzioux, 1981; Middleton & Morice, 2000), changes in cigarette consumption paralleled changes in expired carbon monoxide, thereby providing preliminary grounds for refuting smoking compensation. The second indicator for compensatory behaviour is objectively measured smoking topography. Smoking topography is a highly elastic trait, as smokers are able to modify their interactions with a cigarette in order to titrate nicotine delivery (Bittoun, 2008; Hammond et al., 2005). In concert with expired carbon monoxide, smoking topography variables decreased over time, albeit some changes were statistically non-significant. Overall, this study provides early evidence for the harm reducing properties of regular physical activity on the objectively measured smoking behaviour profile of female smokers leading up to their quit date.

**Sensory Factors**
Although addictive constituents, such as nicotine, are fundamental to the maintenance of smoking behaviour, the role of non-nicotine effects warrant attention. Research suggests that smoking behaviour (i.e. cigarette consumption and smoking topography) is reinforced by a host of physical, cognitive, and affective sensations (Rees et al., 2012; Rose, Behm, Westman, Bates, & Salley, 2003; Rose, 2006; Shiffman & Kirchner 2009). Only one study to date has explored subjective smoking experience in light of exercise, however, the main purpose of this pilot randomized controlled trial was to assess the feasibility and acceptability of a pragmatic physical activity and smoking reduction counselling intervention (8 weeks in duration; Taylor et al., 2014). As Taylor and colleagues expected, satisfaction, reward, enjoyment of respiratory sensations, and cravings decreased more in the intervention arm, in contrast to the control arm, from baseline to 16 weeks. This finding was also confirmed by the current data. In specific, significant declines were noted for smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, and craving reduction over the three weeks prior to the scheduled quit day of the exercise-aided smoking cessation program. This can be justified by a case study from Taylor and colleagues (2014) whereby increased physical activity levels bolstered a stronger positive health identity as cigarette consumption was reduced. This change in identity may also mitigate cigarette-related sensory factors.

Based on the existing body of literature, correlations between smoking behaviour (i.e. cigarette consumption, carbon monoxide levels, smoking topography) and sensory factors were anticipated but only cigarette consumption was related to smoking satisfaction. The data revealed that decreased cigarette consumption was associated with less satisfaction. This contradicts the nicotine addiction theory, which assumes that
smokers will find each remaining cigarette during the reduction process to be more rewarding and more difficult to avoid (Lindson-Hawley et al., 2012). This divergence may allude to the role of physical activity in the current study, which has been found to attenuate cravings and withdrawal symptoms, thereby refuting the nicotine addiction theory under these circumstances. Regarding the remaining negligible relationships it is possible that an increased dose of physical activity would generate a greater net difference in smoking behaviour and discernible relationships with psychological reward, enjoyment of respiratory tract sensations, craving reduction, and aversion. Equally important is explicating possible mechanisms responsible for the effects of physical activity on these non-nicotinic factors. According to Dunbar and colleagues (2010), for every 1-point increase in preceding craving, smoking satisfaction increased by approximately one quarter of a point. Craving relief was also found to be the strongest predictor of smoking satisfaction (Dunbar, Scharf, Kirchner, & Shiffman, 2010). Given the overwhelming evidence that exercise is associated with craving reduction (Haasova et al., 2013 and 2014; Roberts et al., 2012; Ussher, Taylor, & Faulkner, 2014) and findings from Dunbar et al., (2010), future research should explore craving as a potential mediator of the effects of physical activity on cigarette-related sensory factors.

In marshalling this evidence, the principal finding in the present study was that regular physical activity served as a conduit for facilitating harm reducing interactions with cigarettes. More specifically, cigarette consumption, smoking intensity, and sensations subsided in the weeks preceding a quit attempt during an exercise-aided smoking cessation intervention. Hence, these female smokers stood to benefit from these behavioural and sensory changes, as they exhibited a profile suggestive of indifference
towards cigarettes. These participants were in the most favourable state for their quit date. Physical activity may induce smoking reduction through the short-lived attenuation of cravings and tobacco withdrawal symptoms (Haasova et al., 2013 and 2014; Roberts et al., 2012), development of a positive health identity (Taylor et al., 2014), and reducing post-cessation weight gain (Aubin, Farley, Lycett, Lahmek, & Aveyard, 2012). Above all, these results communicate the role of physical activity as a catalyst to reduction, and ultimately in confronting and overcoming tobacco use disorder.

Strengths and Limitations

A primary strength of this novel study is the holistic approach to understanding the effects of sustained physical activity on multiple smoking-related dimensions during the pre-quit period. Specifically, the interface between exercise, cigarette consumption, carbon monoxide, smoking topography, and sensory smoking experiences were examined among women engaged in an exercise-aided smoking cessation program. Secondly, the aforementioned outcome variables were evaluated using objective, reliable, and validated tools. There were also satisfactory adherence rates to the first three weeks of the exercise program and completion of assessments.

A systemic limitation with this research is the inability to separate the effects of the physical activity intervention and approaching a targeted quit date on smoking behaviour and experiences. There is ample evidence to support the beneficial impact of a long-term exercise program on cigarette and carbon monoxide reduction, in contrast to a control group, whereas additional research is necessary to compare its impact on smoking topography and cigarette-related sensory factors. Second, cigarette consumption was measured through self-report which can be influenced by social desirability and recall
bias. Finally, generalizability is narrow as this intervention recruited female smokers to participate in a supervised exercise program that took place in a university laboratory.

**Future Research**

Considering these limitations, it follows that prospective experiments include a control group and broadened eligibility criteria. The dose response between physical activity and beneficial smoking-related outcomes should be further explored. Equally important is the consideration of potential mechanisms in explaining such relationships. Future research should also examine the combined impact of pharmacotherapy, such as nicotine replacement or varenicline, with an exercise intervention on smoking topography and associated physical, cognitive, and affective sensations.

**Conclusion**

A challenge surrounding smoking cessation is the potency and addictive properties of nicotine. This is the first study to concurrently identify the harm reducing effects of an exercise-aided smoking cessation program on cigarette consumption, carbon monoxide, as well as some smoking topography and cigarette-related sensations leading up to a quit attempt. Thus, engaging in physical activity may reduce the risks and reinforcing sensory effects associated with continued tobacco use but may also serve as a means for positioning smokers in the most advantageous state to approach quitting smoking.
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doi:10.1037/a0015620


doi:10.1111/j.1468-2850.2006.00021.x


Chapter Five: Dissertation Conclusions

The halcyon days of scientific and public ignorance to the harms of tobacco have vanished. The catastrophic pandemic spun by the tobacco industry has been described as “the deadliest artifact in the history of human civilization” and “the golden holocaust,” owing to the tobacco curing process (Proctor, 2011). This tenacious addiction has prompted robust, evidence-based strategies to stymie its lethality, and even still, smoking prevalence has plateaued across the country (Reid, Hammond, Rynard, & Burkhalter, 2014).

Research has repeatedly demonstrated that exercise, in acute or chronic form, is beneficial for quitters and continued tobacco users regarding craving, tobacco withdrawal symptoms, psychological well-being, and physical health. In its entirety, the objective of this dissertation was to add to the existing smoking and exercise literature by exploring potential mechanisms as well as short and long-term relief of this adjunctive therapy.

Cravings, substantial evidence now tells us, is attenuated by a single bout of exercise. Knowledge of the underlying mechanism(s) behind this relationship is essential to developing interventions that can effectively manipulate smoking cessation strategies and improve quit rates. From a two-arm randomized controlled trial design, the indirect effects of biological (i.e. cortisol) and affective variables on cravings through exercise were tested using rigorous mediation techniques. In line with other research (Janse Van Rensburg, Elibero, Kilpatrick, & Drobes, 2013; Roberts et al., 2015; Scerbo, Faulkner, Taylor, & Thomas, 2010), results in Chapter 2 revealed that cortisol did not surface as a biological mechanism. It may be that cortisol is resistant to the acute exercise paradigm,
extended physical activity may be necessary, or there may be more salient biomarkers for explaining the acute exercise and craving relationship. On the other hand, positive and negative affect were shown to be mechanistically involved in craving reductions following exercise, which has been suggested elsewhere (Janse Van Rensburg et al., 2013; Tart et al., 2010). These affective states may play a mediating role through the Nesbitt’s Paradox, circumplex model, and limited strength model of self-regulation.

Unlike the extensive literature on the effects of acute exercise on cravings, smoking behaviour as a primary outcome is less understood. As such, a two-arm randomized controlled trial design was implemented to examine the effects of a bout of moderate intensity exercise on ad libitum smoking and smoking topography, in addition to cravings, affect, and tobacco withdrawal symptoms, after a temporary period of abstinence. The evidence presented in Chapter 3 demonstrated that exercise delayed the latency to smoke but had marginal effects on smoking topography. Changes in ad libitum smoking following exercise were mediated by cravings and anxiety. This study replicated earlier findings regarding ad libitum smoking (Faulkner, Arbour-Nicitopoulos, & Hsin, 2010; Katomeri & Taylor, 2006b; Kurti & Dallery, 2014; Reesor, 1983; Taylor & Katomeri, 2007; Thayer, 1993) and unwaveringly reflexive smoking topography (Schneider, De Jesus, & Prapavessis, 2014). As demonstrated in previous research (Haasova et al., 2013, 2014; Roberts, Maddison, Simpson, Bullen, & Prapavessis, 2012), exercise also alleviated cravings, affect, and tobacco withdrawal symptoms in temporarily abstinent smokers. Compelling relationships between these variables and ad libitum smoking behaviour (i.e. time to smoke and topography) were also elucidated.
There is a paucity of literature that explores the incompatibility between objectively measured smoking behaviour, sensory experiences, and long-term exercise. Hence, in Chapter 4, the effects and interrelatedness of cigarette consumption, expired carbon monoxide levels, smoking topography, and cigarette-related sensations during the three weeks prior to a quit attempt of an exercise-aided smoking cessation program were investigated. Smokers intending to quit may be at an advantage in realizing cessation if cigarette consumption, smoking intensity, and sensory factors (e.g. reward and satisfaction from cigarettes) decrease. Findings showed a significant decrease in cigarette consumption, expired carbon monoxide, and puff duration and an increase in average puff flow. Similarly, reductions in smoking satisfaction, psychological reward, enjoyment of respiratory tract sensations, and cravings were also visible. There were marginal relationships between cigarette consumption and smoking topography and sensation. Taken together these findings provide no evidence for compensation. This study offers a seminal contribution to the smoking cessation field. The findings are also in line with research that observed reductions in the number of cigarettes smoked, carbon monoxide, and cigarette-related sensory factors as a result of physical activity interventions for smoking cessation and reduction (Leelarunggrayub et al., 2010; Maddison et al., 2014; Prapavessis et al., 2007; Taylor, Houston-Miller, Haskell, & Debusk, 1988; Taylor et al., 2014).

Collectively, these three studies provide further credence to the dividends afforded by acute and chronic exercise for individuals who wish to minimize the physical and psychological burden of achieving complete abstinence. The next section of this
chapter will consider the limitations of these studies and future directions for this area of research.

**Limitations**

A number of limitations should be mentioned concerning the execution of this dissertation. First, a quit attempt was simulated for Studies 1 and 2 through a temporary period of nicotine deprivation. Compared to a genuine quit attempt, smokers may not experience the same degree of physical and psychological withdrawal during a simulated quit attempt, as this hardship is for a predefined, impermanent period. Furthermore, data collection did not occur in a smoker’s natural environment, where they are exposed to multiple smoking-related cues, stressors, and unique craving patterns. By extension, this expectation of participants may have introduced selection bias during the recruitment process. For example, there were four individuals who specifically identified the period of temporary abstinence as grounds for declining to participate. Participants, therefore, may not be representative of the overall smoking population. The sample for Studies 1 and 2 was fairly active and low to moderately dependent on nicotine, whereas in Study 3, the sample consisted of only female smokers who were willing to partake in a smoking cessation program in an academic setting, which may be unfamiliar and overwhelming to some.

There were also a few limitations within the experimental context. The inadequate post-condition assessment period seriously limited the ability to make comparisons with similar studies and examine any residual impact of exercise on cravings, affect, and tobacco withdrawal symptoms. Finally, a control group was not implemented in the
parent study pertaining to Study 3. Therefore, the impact of exercise and an impending quit date cannot be teased and causative statements cannot be made.

**Future Directions**

There are multiple areas of interest that arise from this research. The precise mechanisms responsible for the exercise-craving relationship are currently not well understood and have not been substantiated. Based on the findings of Study 1, other potential mediators (e.g. noradrenaline and heart rate variability) should be explored and tested using robust statistical methods. Forthcoming research can also look into whether mediators and outcome variables, particularly smoking behaviour, are responsive to varying doses of exercise. These relationships may also depend on, perhaps partially, smoking motives, rewards, and satisfaction. While the smoking behaviour literature is in its infancy, future investigations can probe for mediators of significant exercise-induced changes. In light of the additive benefit of combining behavioural and pharmacological methods, another line of research can examine whether exercise has equivalent or superior effects on smoking behaviour and sensory factors under combined therapies. Lastly, future research should aim to minimize threats to internal and external validity. Studies similar to Study 3 would benefit from the inclusion of a control group. Smokers who are motivated to undergo a real quit attempt should be recruited and researchers should use more inclusive eligibility criteria and strive to develop and test a pragmatic exercise intervention.
It is unlikely in our lifetime that we will witness the abolition of tobacco related suffering and death. Considering this fate, strengthening the effectiveness of evidence-based tobacco control methods is key to mollifying the ebbs and flows of cravings, tobacco withdrawal symptoms, and affect that all smokers endure during a quit attempt. Exercise has been championed as a successful and accessible tactic. While exercise cannot account for failed quit attempts and recalcitrant smokers, this thesis demonstrated that it can, in acute and chronic doses, serve as a gateway to harm reduction and smoking cessation, albeit the mechanisms by which it exerts these effects have not been conclusively resolved. Ultimately, exercise is a critical weapon in our arsenal against the reinforcing effects of nicotine.
References


Appendix A: Letters of Information and Consent Form (Study 1 and Study 2)
LETTER OF INFORMATION

Study Title: Does an acute bout of exercise affect smoking topography?

Principal Study Investigator:
Harry Prapavessis, Ph.D. (School of Kinesiology, The University of Western Ontario)

Co-Investigator:
Stefanie De Jesus, B.Sc., M.A. (School of Kinesiology, The University of Western Ontario).

You are being invited to participate in a research study looking at the effects of a short period of exercise on smoking behaviour. This is a randomized control trial (a type of research study), which includes eligible volunteers who choose to take part. Please take your time to make a decision, and discuss this proposal with your personal doctor, family members and friends as you feel inclined. The purpose of this letter is to provide you with the information you require to make an informed decision on participating in this. This letter contains information to help you decide whether or not to participate in this research study. It is important for you to know why the study is being conducted and what it will involve. Please take the time to read this carefully and feel free to ask questions if anything is unclear or there are words or phrases you do not understand. We are asking you to take part because you are an adult between 18 and 64 years of age who smokes.

Purpose of the study
Exercise has been shown to help with traditional cessation strategies. A single bout of exercise, low to moderate in intensity, can help regulate cravings, withdrawal symptoms and smoking topography. Smoking topography refers to the measurement of smoking behaviour, which includes puff volume, maximum puff velocity, interpuff interval, puff duration, number of puffs per cigarette, and the time to smoke a single cigarette.

The primary objective of this study is to examine the effects of an acute bout of moderate intensity exercise on smoking behaviour (smoking topography) following a period of smoking abstinence. The second purpose of this study is to assess the influence of nicotine metabolism rate (how quickly your body breaks down nicotine) on smoking topography. Lastly, this study seeks to understand the role of cortisol, a stress hormone produced in your body, in diminishing cravings following a period of smoking abstinence.

Participants
One hundred and twenty five participants will be asked to take part in this research. To be eligible to participate, you must be between 18 and 64 years of age, smoke 10 or more cigarettes per day, have been smoking for more than 2 years, have not been engaged in a serious quit attempt in the last six months, must not be suffering from an illness (e.g. cold) that would affect your typical smoking behaviour, do not have a medical condition that prevents you from exercising, not be pregnant or intending on being pregnant, are
able to read and write in English and have a telephone or an email account that we investigators can contact you at.

Research Procedure
If you choose to take part in this study, you will be asked to complete three study components: A) the first laboratory session, B) abstain from smoking, C) the second laboratory session.

The laboratory sessions will be held at the Exercise and Health Psychology Laboratory (EHPL) at the University of Western Ontario (UWO). Prior to the first meeting you will be asked to complete the Physical Activity Readiness Questionnaire (PAR-Q). The prescreening period will require approximately 20 minutes, completing the PAR-Q will take approximately 15 minutes. Each laboratory meeting will take approximately 75 minutes.

A) First laboratory session
During your first laboratory session, you will complete a questionnaire package (see item 1) and the following information will be collected: resting heart rate (see item 2), weight, height, breath carbon monoxide levels (see item 3) and saliva samples (see item 4) for nicotine metabolism analysis. Afterwards, you will be asked to familiarize yourself with the CReSS Pocket (see item 5) by taking a few puffs of an electronic cigarette (see item 6). Following this, you will be asked to smoke a cigarette (of your regular brand) with the CReSS Pocket, at a minimum of 10 meters away from any building entrance of the Labatt Health Sciences Building. It is within your rights to refuse to smoke during this research study and we will honour your rights. At the end of your first laboratory session, we will schedule your second laboratory session within seven days of your first laboratory session.

B) Abstain from smoking
You will be asked to abstain from smoking for at least 18 hours prior to your second laboratory visit (see item 7). We will confirm that you have not smoked in the last 18 hours by getting you to complete a second carbon monoxide test (see item 3).

C) Second laboratory session
During your second laboratory session, a saliva sample and smoking abstinence will first be completed, the latter by breath carbon monoxide levels (see item 3). You will then be asked to exercise at a moderate intensity on a treadmill for 10 minutes, which will be followed by the collection of another saliva sample. Afterwards, you will smoke a cigarette using the CReSS Pocket (see item 5) (at your own will) and complete a questionnaire package (see item 1). You will be invited to smoke outside the Labatt Health Sciences Building, at a minimum of 10 meters away from any building entrance. It is within your rights to refuse to smoke during this research study and we will honour your rights.

Experimental descriptions (items 1-10)
Item 1: Questionnaire package
Time Involvement: 30 minutes
The questionnaire package will include: demographic questionnaire, Dependence on nicotine questionnaire, physical activity questionnaire, stage of change questionnaire, smoking motives questionnaire, smoking withdrawal questionnaire, subjective exercise experiences scale, and questions about your cravings and comfort using the CReSS device.

**Item 2: Measuring Resting Heart Rate**  
**Time Involvement: 5 minutes**  
Heart rate will be measured by a Polar heart rate transmitter, which consists of a watch and a strap held in place under your bust line by an elastic strap.

**Item 3: Carbon monoxide assessments**  
**Time Involvement: 15 seconds each**  
We will measure your smoking status using a breath carbon monoxide analyzer twice: once at each laboratory session. We will ask you to breathe into a machine called the Bedfont Smokerlyzer. This machine measures the amount of carbon monoxide (CO) as you breathe out. It does not cause any harm or discomfort to you. This smokerlyzer measures how much you have smoked in the past several hours. The second test (just prior to treatment at the second laboratory session) will be done to verify that you have abstained from smoking for at least 18 hours.

**Item 4: Provide saliva sample on cotton swab**  
**Time Involvement: 3 minutes**  
From this saliva sample we will measure 3-hydroxycotinine and cotinine within your body to determine a 3-hydroxycotinine/cotinine ratio. This ratio tells us about the rate at which your body metabolizes (breaks down) nicotine. We will also measure cortisol within your body from this saliva sample. Cortisol is a hormone that is produced within your body.

**Item 5: CReSS Pocket Device**  
**Time Involvement: 15 minutes**  
We will measure your smoking topography using the CReSS Pocket. This hand-held, computer-based machine measures how you smoke a cigarette (puff count, puff volume, puff duration, inter-puff interval and time to first puff) by placing your cigarette in the device and breathing through the sterilized orifice of the device. The CReSS Pocket does not cause any harm or discomfort to you.

**Item 6: Electronic Cigarette**  
**Time Involvement: 5 minutes**  
Electronic cigarettes, also known as e-cigarettes, are electrical devices that attempt to simulate the act of tobacco smoking. This e-cigarette may mimic an actual cigarette except it does not contain nicotine (0mmg of nicotine). When a smoker draws air through the e-cigarette, an airflow sensor activates the battery that turns the tip of the cigarette red to simulate smoking and heats the atomizer to vaporize the propylene glycol into a mist. The vapour is odorless and vanishes quickly. Propylene glycol is an FDA- and Health
Canada-approved approved compound that is used in many food products, cosmetics, and toothpaste. Upon inhalation, the aerosol vapor evaporates and vanishes

**Item 7: Abstain from smoking for 18-24 hours**
We ask that prior to your second laboratory session you abstain from smoking for at least 18 hours (18-24 hours).

**Risks**
While in the study, you may experience side effects. Known side effects are listed below, but other effects may occur that we cannot predict. If you are or become pregnant you must notify the investigator as smoking involves risks to the foetus.

**Exercise:** There are some inherent risks of injury associated with exercise participation, particularly among people who are not used to exercising. You may, for example, feel mild muscle “tightness” or soreness that lasts for a couple of days. The possible benefits associated with exercise may outweigh the potential minor discomfort of beginning a supervised, laboratory-based exercise program. To minimize the physical risks of exercise, proper warm-up/cool-down and stretching protocols will be performed by a trained exercise counsellor. Additionally, the exercise program delivered will be tailored to your individual fitness level, and modified according to your comfort level. Furthermore, you will only be allowed to participate in this exercise program if you complete the PAR-Q (Physical Activity Readiness Questionnaire) forms to ensure that it is safe for you to begin an exercise program. The exercise facilitator will be both CPR and First Aid trained, and experienced in working with previously inactive populations. If any physical or mental risks arise during treatment, The Student Emergency Response Team (SERT) will be available to provide immediate assistance. SERT will assist the exercise supervisor until the 911 emergency services arrive. Should you have a minor injury while exercising you will receive medical treatment onsite as necessary. A first aid kit and ice packs will be available for minor injuries.

**Temporary Smoking Abstinence:** You may experience withdrawal symptoms during the time you are abstaining from cigarettes. Such symptoms may include feeling edgy and nervous, dizzy, sweaty, having trouble concentrating, headaches, insomnia, increased appetite and weight gain, muscular pain, constipation, fatigue, or having an upset stomach. All of these symptoms are common for those who quit smoking so you should not be alarmed, as these symptoms will go away within a few days. Moderate intensity exercise has been shown to reduce smoking withdrawal symptoms, so it could be that those in the moderate intensity exercise treatment condition experience relief from some of these symptoms. Another common side effect of quitting smoking is that your “smoker’s cough” gets worse for the first few days after you quit. This is your body’s way of attempting to rid the lungs of excess toxins. Your smoker’s cough will improve to a great extent after you have become smoke-free for a number of days.

**Benefits**
Involvement in this study could assist you in becoming smoke free. You may not get a personal benefit from participating in this study but your participation may help us get knowledge to shape the development of future exercise and smoking cessation programs.

**Participation**
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your academic or employment status. If you decide to take part you will be given this Letter of Information to keep and be asked to sign the consent form. If you withdraw from the study, you maintain the right to request that any data collected from you not be used in the study. If you make such a request, all of the data collected from you will be destroyed. Please contact the study coordinator, Stefanie De Jesus, if you wish to withdraw from the study. If you are participating in another study at this time, please inform the study researchers right away to determine if it is appropriate for you to participate in this study.

As a participant in this study, you will be asked to bring two cigarettes of your own regular brand, for the purpose of assessing your smoking behaviour.

**Biological Specimens**
The sample we are asking of you during the course of this study is saliva. This saliva sample will be used for the current study only. The saliva sample will be frozen in our laboratory freezer, then shipped and analyzed at the University of Toronto in Canada for an indication of how quickly you metabolize (break down) nicotine in your body (3-hydroxycotinine: cotinine ratio) and at Salimetrics (101 Innovation Blvd. Suite #302 State College, PA, USA) for an analysis of cortisol levels. Bar codes will be used to label your saliva samples, so the laboratory technicians analyzing your saliva will have no information as to who provided the saliva sample. The samples will be stored for a minimum of 3 years. Usage and potential research value will be reviewed annually thereafter. It is typical to keep the samples collected from a research study for 6 years after the study has been conducted. Once the research value is deemed lower than sufficient to justify storage costs, the samples will be destroyed by standard disposal of biohazardous waste laboratory policies and procedures. If we would like to use your saliva for a different study or for a different purpose in this study, we will send you a new letter of information and ask your permission.

Any specimen(s) obtained for the purposes of this study will become the property of the study researchers and once you have provided the specimens you will not have access to them. The specimen(s) will be discarded or destroyed once they have been used for the purposes described in the protocol. The specimen(s) will be used for research and such use may result in inventions or discoveries that could become the basis for new products or diagnostic or therapeutic agents. In some instances, these inventions and discoveries may be of potential commercial value and may be patented and licensed by the researcher. It is not the purpose of this study to use specimens for any inventions or patents, so it is very unlikely that this will occur as an outcome of a sample you provide us with. You will not receive any money or other benefits derived from any commercial or other products that may be developed from use of the specimens.
New Findings
If, during the course of this study, new information becomes available that may relate to your willingness to continue to participate, this information will be provided to you by the investigator.

Confidentiality
We will be collecting information from 125 participants for this study. All the information you provide to the researcher will be kept in the strictest confidence. You will be assigned an identification number and all data collected from you will be recorded and stored under this number only. All data will be stored in coded form on computers accessible only to research staff in a secure office. You will not be identified in any documents relating to the research. No information obtained during the study will be discussed with anyone outside of the research team. If the results of the study are published, your name will not be used.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board and regulatory bodies (Health Canada) may contact you or require access to your study-related records to monitor the conduct of the research. If we find information we are required by law to disclose, we cannot guarantee confidentiality. We will strive to ensure the confidentiality of your research-related records. Absolute confidentiality cannot be guaranteed as we may have to disclose certain information under certain laws.

Compensation
You will be compensated $10.00 upon arrival at your first visit, and $10.00 upon arrival at your second visit. You will be provided with free parking for your visits to the laboratory. If you are traveling by public transport, you will be reimbursed up to $10.00 (to cover two return trips for the two appointments).

If you have private medical or life insurance, you should check with your insurance company before you agree to take part in the study to confirm your participation in this study will not affect your insurance coverage and/or access to benefits.

This study is covered by an insurance policy and if during the course of the study any injury should occur to you, not due to your fault or negligence, all medical expenses necessary to treat such injury will be paid provided: a) you comply at all times with the study researcher’s instructions b) you promptly report any such injury to the study researchers conducting the study, and c) the expenses are not otherwise covered by your provincial health care. Financial compensation for such things as lost wages, disability or discomfort due to this type of injury is not routinely available. You do not waive any legal rights by signing the consent form.

Alternative treatments
If you decide not to participate or if you withdraw from the study before it is completed, the alternative course of treatment could be to see your family physician for advice on how to quit smoking. Another alternative to the procedures described above is not to participate in the study and continue on just as you do now.
Optional Follow-Up Telephone Interviews
At the completion of the study, you will be given the option of participating in the follow-up phase of this study, consisting of a yearly update of your health and/or the re-use of your smoking behaviour information. This will consist of a short telephone interview (less than 15 minutes) conducted once a year, for twenty years, where we will ask you if you have had any major health complications in the past year, such as heart disease or cancer. This research has the same purpose as the original study with a focus on comparing these issues between males and females and identifying potential contributors to future health status. If you choose to provide consent to the use of your data, your smoking topography, nicotine metabolism, and questionnaire data will be used in future smoking-related research. Your confidentiality will be protected as outlined above (please refer to page 5).

If you would like to have your name and contact information kept on file, we can ask you about the possibility of participating in future studies. If you agree to participate in the study follow-up and/or be contacted for participation in other studies, you may refuse to answer any questions or withdraw your consent at any time by informing a member of the research team. Your name and contact information will not be shared with anyone outside our Research Team. The potential risks and discomfort, benefits and confidentiality and privacy issues are identical to those outlined in the confidentiality section of this letter of information. You will not be compensated financially for participation in the follow-up phase of this study. If you have any questions or concerns about this research, you should contact study investigators.

Contact person(s)
If you have any questions about your rights as a research participant or the conduct of the study you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute. If you have any questions about the study, please contact the study coordinator, Stefanie De Jesus.

This letter is for you to keep. You will be given a copy of this letter of information and consent form once it has been signed. If you have any concerns, please feel free to contact one of the researchers below. You may request the general findings of this research study from the researchers after the study is complete. You do not waive any legal rights by signing the consent form.

Stefanie De Jesus  Dr. Harry Prapavessis
Graduate Student  Professor
School of Kinesiology, UWO  School of Kinesiology, UWO
INFORMED CONSENT

Study Title: Does an acute bout of exercise affect smoking topography?

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Please send me the overall conclusions from this trial: Yes □ No □

I consent to the use of my study-related data in future studies: Yes □ No □

I would like to be contacted for other research studies: Yes □ No □

I would like to participate in the follow-up phase of the study: Yes □ No □

Consenting Signature:

Participant: ________________________________________________________ Please Print Name

Participant: ________________________________________________________ Please Sign Name

Date: _________________

Researcher Signature:

Person obtaining informed consent: ____________________________________________ Please Print Name

Person obtaining informed consent: ____________________________________________ Please Sign Name

Date: _________________
LETTER OF INFORMATION

Study Title: Does an acute bout of exercise affect smoking topography?

Principal Study Investigator:
Harry Prapavessis, Ph.D. (School of Kinesiology, The University of Western Ontario)

Co-Investigator:
Stefanie De Jesus, B.Sc., M.A. (School of Kinesiology, The University of Western Ontario).

You are being invited to participate in a research study looking at the effects of a short period of exercise on smoking behaviour. This is a randomized control trial (a type of research study), which includes eligible volunteers who choose to take part. Please take your time to make a decision, and discuss this proposal with your personal doctor, family members and friends as you feel inclined. The purpose of this letter is to provide you with the information you require to make an informed decision on participating in this research. This letter contains information to help you decide whether or not to participate in this research study. It is important for you to know why the study is being conducted and what it will involve. Please take the time to read this carefully and feel free to ask questions if anything is unclear or there are words or phrases you do not understand. We are asking you to take part because you are an adult between 18 and 64 years of age who smokes.

Purpose of the study
Exercise has been shown to help with traditional cessation strategies. A single bout of exercise, low to moderate in intensity, can help regulate cravings, withdrawal symptoms and smoking topography. Smoking topography refers to the measurement of smoking behaviour, which includes puff volume, maximum puff velocity, interpuff interval, puff duration, number of puffs per cigarette, and the time to smoke a single cigarette.

The primary objective of this study is to examine the effects of cravings and withdrawal symptoms on smoking behaviour (smoking topography) following a period of smoking abstinence. The second purpose of this study is to assess the influence of nicotine metabolism rate (how quickly your body breaks down nicotine) on smoking topography. Lastly, this study seeks to understand the role of cortisol, a stress hormone produced in your body, in diminishing cravings following a period of smoking abstinence.

Participants
One hundred and twenty five participants will be asked to take part in this research. To be eligible to participate, you must be between 18 and 64 years of age, smoke 10 or more cigarettes per day, have been smoking for more than 2 years, have not been engaged in a serious quit attempt in the last six months, must not be suffering from an illness (e.g. cold) that would affect your typical smoking behaviour, do not have a medical condition that prevents you from exercising, not be pregnant or intending on being pregnant, are able to read and write in English and have a telephone or an email account that we investigators can contact you at.
Research Procedure
If you choose to take part in this study, you will be asked to complete three study components: A) the first laboratory session, B) abstain from smoking, C) the second laboratory session.

The laboratory sessions will be held at the Exercise and Health Psychology Laboratory (EHPL) at the University of Western Ontario (UWO). Prior to the first meeting you will be asked to complete the Physical Activity Readiness Questionnaire (PAR-Q). The prescreening period will require approximately 20 minutes, completing the PAR-Q will take approximately 15 minutes. Each laboratory meeting will take approximately 75 minutes.

A) First laboratory session
During your first laboratory session, you will complete a questionnaire package (see item 1) and the following information will be collected: resting heart rate (see item 2), weight, height, breath carbon monoxide levels (see item 3) and saliva samples (see item 4) for nicotine metabolism analysis. Afterwards, you will be asked to familiarize yourself with the CReSS Pocket (see item 5) by taking a few puffs of an electronic cigarette (see item 6). Following this, you will be asked to smoke a cigarette (of your regular brand) with the CReSS Pocket, at a minimum of 10 meters away from any building entrance of the Labatt Health Sciences Building. It is within your rights to refuse to smoke during this research study and we will honour your rights. At the end of your first laboratory session, we will schedule your second laboratory session within seven days of your first laboratory session.

B) Abstain from smoking
You will be asked to abstain from smoking for at least 18 hours prior to your second laboratory visit (see item 7). We will confirm that you have not smoked in the last 18 hours by getting you to complete a second carbon monoxide test (see item 3).

C) Second laboratory session
During your second laboratory session, a saliva sample and smoking abstinence will first be completed, the latter by breath carbon monoxide levels (see item 3). You will then be asked to passively sit on a chair for 10 minutes, which will be followed by the collection of another saliva sample. Afterwards, you will smoke a cigarette using the CReSS Pocket (see item 5) (at your own will) and complete a questionnaire package (see item 1). You will be invited to smoke outside the Labatt Health Sciences Building, at a minimum of 10 meters away from any building entrance. It is within your rights to refuse to smoke during this research study and we will honour your rights.

Experimental descriptions (items 1-10)
Item 1: Questionnaire package
Time Involvement: 30 minutes
The questionnaire package will include: demographic questionnaire, dependence on nicotine questionnaire, physical activity questionnaire, stage of change questionnaire, smoking motives questionnaire, smoking withdrawal questionnaire, subjective exercise
experiences scale, and questions about your cravings and comfort using the CReSS device.

**Item 2: Measuring Resting Heart Rate**  
**Time Involvement: 5 minutes**  
Heart rate will be measured by a Polar heart rate transmitter, which consists of a watch and a strap held in place under your bust line by an elastic strap.

**Item 3: Carbon monoxide assessments**  
**Time Involvement: 15 seconds each**  
We will measure your smoking status using a breath carbon monoxide analyzer twice: once at each laboratory session. We will ask you to breathe into a machine called the Bedfont Smokerlyzer. This machine measures the amount of carbon monoxide (CO) as you breathe out. It does not cause any harm or discomfort to you. This smokerlyzer measures how much you have smoked in the past several hours. The second test (just prior to treatment at the second laboratory session) will be done to verify that you have abstained from smoking for at least 18 hours.

**Item 4: Provide saliva sample on cotton swab**  
**Time Involvement: 3 minutes**  
From this saliva sample we will measure 3-hydroryptotine and cotinine within your body to determine a 3-hydroryptotine/cotinine ratio. This ratio tells us about the rate at which your body metabolizes (breaks down) nicotine. We will also measure cortisol within your body from this saliva sample. Cortisol is a hormone that is produced within your body.

**Item 5: CReSS Pocket Device**  
**Time Involvement: 15 minutes**  
We will measure your smoking topography using the CReSS Pocket. This hand-held, computer-based machine measures how you smoke a cigarette (puff count, puff volume, puff duration, inter-puff interval and time to first puff) by placing your cigarette in the device and breathing through the sterilized orifice of the device. The CReSS Pocket does not cause any harm or discomfort to you.

**Item 6: Electronic Cigarette**  
**Time Involvement: 10 minutes**  
Electronic cigarettes, also known as e-cigarettes, are electrical devices that attempt to simulate the act of tobacco smoking. This e-cigarette may mimic an actual cigarette except it does not contain nicotine (0mmg of nicotine). When a smoker draws air through the e-cigarette, an airflow sensor activates the battery that turns the tip of the cigarette red to simulate smoking and heats the atomizer to vaporize the propylene glycol into a mist. The vapour is odorless and vanishes quickly. Propylene glycol is an FDA- and Health Canada-approved compound that is used in many food products, cosmetics, and toothpaste. Upon inhalation, the aerosol vapor evaporates and vanishes.

**Item 7: Abstain from smoking for 18-24 hours**
We ask that prior to your second laboratory session you abstain from smoking for at least 18 hours (18-24 hours).

**Risks**
While in the study, you may experience side effects. Known side effects are listed below, but other effects may occur that we cannot predict. If you are or become pregnant you must notify the investigator as smoking involves risks to the foetus.

**Temporary Smoking Abstinence:** You may experience withdrawal symptoms during the time you are abstaining from cigarettes. Such symptoms may include feeling edgy and nervous, dizzy, sweaty, having trouble concentrating, headaches, insomnia, increased appetite and weight gain, muscular pain, constipation, fatigue, or having an upset stomach. All of these symptoms are common for those who quit smoking so you should not be alarmed, as these symptoms will go away within a few days. Another common side effect of quitting smoking is that your "smoker’s cough” gets worse for the first few days after you quit. This is your body’s way of attempting to rid the lungs of excess toxins. Your smoker’s cough will improve to a great extent after you have become smoke-free for a number of days.

**Benefits**
Involvement in this study could assist you in becoming smoke free. You may not get a personal benefit from participating in this study but your participation may help us get knowledge to shape the development of future exercise and smoking cessation programs.

**Participation**
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your academic or employment status. If you decide to take part you will be given this Letter of Information to keep and be asked to sign the consent form. If you withdraw from the study, you maintain the right to request that any data collected from you not be used in the study. If you make such a request, all of the data collected from you will be destroyed. Please contact the study coordinator, Stefanie De Jesus, if you wish to withdraw from the study. If you are participating in another study at this time, please inform the study researchers right away to determine if it is appropriate for you to participate in this study.

As a participant in this study, you will be asked to bring two cigarettes of your own regular brand, for the purpose of assessing your smoking behaviour.

**Biological Specimens**
The sample we are asking of you during the course of this study is saliva. This saliva sample will be used for the current study only. The saliva sample will be frozen in our laboratory freezer, then shipped and analyzed at the University of Toronto in Canada for an indication of how quickly you metabolize (break down) nicotine in your body (3-hydroxycotinine: cotinine ratio) and at Salimetrics (101 Innovation Blvd. Suite #302 State College, PA, USA) for an analysis of cortisol levels. Bar codes will be used to label your saliva samples, so the laboratory technicians analyzing your saliva will have no information as to who provided the saliva sample. The samples will be stored for a
minimum of 3 years. Usage and potential research value will be reviewed annually thereafter. It is typical to keep the samples collected from a research study for 6 years after the study has been conducted. Once the research value is deemed lower than sufficient to justify storage costs, the samples will be destroyed by standard disposal of biohazardous waste laboratory policies and procedures. If we would like to use your saliva for a different study or for a different purpose in this study, we will send you a new letter of information and ask your permission.

Any specimen(s) obtained for the purposes of this study will become the property of the study researchers and once you have provided the specimens you will not have access to them. The specimen(s) will be discarded or destroyed once they have been used for the purposes described in the protocol. The specimen(s) will be used for research and such use may result in inventions or discoveries that could become the basis for new products or diagnostic or therapeutic agents. In some instances, these inventions and discoveries may be of potential commercial value and may be patented and licensed by the researcher. It is not the purpose of this study to use specimens for any inventions or patents, so it is very unlikely that this will occur as an outcome of a sample you provide us with. You will not receive any money or other benefits derived from any commercial or other products that may be developed from use of the specimens.

**New Findings**
If, during the course of this study, new information becomes available that may relate to your willingness to continue to participate, this information will be provided to you by the investigator.

**Confidentiality**
We will be collecting information from 125 participants for this study. All the information you provide to the researcher will be kept in the strictest confidence. You will be assigned an identification number and all data collected from you will be recorded and stored under this number only. All data will be stored in coded form on computers accessible only to research staff in a secure office. You will not be identified in any documents relating to the research. No information obtained during the study will be discussed with anyone outside of the research team. If the results of the study are published, your name will not be used.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board and regulatory bodies (Health Canada) may contact you or require access to your study-related records to monitor the conduct of the research. If we find information we are required by law to disclose, we cannot guarantee confidentiality. We will strive to ensure the confidentiality of your research-related records. Absolute confidentiality cannot be guaranteed as we may have to disclose certain information under certain laws.

**Compensation**
You will be compensated $10.00 upon arrival at your first visit, and $10.00 upon arrival at your second visit. In addition, you will be provided with free parking for your visits to the laboratory. You will be provided with free parking for your visits to the laboratory.
you are traveling by public transport, you will be reimbursed up to $10.00 (to cover two return trips for the two appointments).

If you have private medical or life insurance, you should check with your insurance company before you agree to take part in the study to confirm your participation in this study will not affect your insurance coverage and/or access to benefits.

This study is covered by an insurance policy and if during the course of the study any injury should occur to you, not due to your fault or negligence, all medical expenses necessary to treat such injury will be paid provided: a) you comply at all times with the study researcher’s instructions b) you promptly report any such injury to the study researchers conducting the study, and c) the expenses are not otherwise covered by your provincial health care. Financial compensation for such things as lost wages, disability or discomfort due to this type of injury is not routinely available. You do not waive any legal rights by signing the consent form.

**Alternative treatments**

If you decide not to participate or if you withdraw from the study before it is completed, the alternative course of treatment could be to see your family physician for advice on how to quit smoking. Another alternative to the procedures described above is not to participate in the study and continue on just as you do now.

**Optional Follow-Up Telephone Interviews**

At the completion of the study, you will be given the option of participating in the follow-up phase of this study, consisting of a yearly update of your health and/or the reuse of your smoking behaviour information. This will consist of a short telephone interview (less than 15 minutes) conducted once a year, for twenty years, where we will ask you if you have had any major health complications in the past year, such as heart disease or cancer. This research has the same purpose as the original study with a focus on comparing these issues between males and females and identifying potential contributors to future health status. If you choose to provide consent to the use of your data, your smoking topography, nicotine metabolism, and questionnaire data will be used in future smoking-related research. Your confidentiality will be protected as outlined above (please refer to page 5).

If you would like to have your name and contact information kept on file, we can ask you about the possibility of participating in future studies. If you agree to participate in the study follow-up and/or be contacted for participation in other studies, you may refuse to answer any questions or withdraw your consent at any time by informing a member of the research team. Your name and contact information will not be shared with anyone outside our Research Team. The potential risks and discomfort, benefits and confidentiality and privacy issues are identical to those outlined in the confidentiality section of this letter of information. You will not be compensated financially for participation in the follow-up phase of this study. If you have any questions or concerns about this research, you should contact study investigators.
**Contact person(s)**

If you have any questions about your rights as a research participant or the conduct of the study you may contact Dr. David Hill, Scientific Director, Lawson Health Research Institute. If you have any questions about the study, please contact the study coordinator, Stefanie De Jesus.

This letter is for you to keep. You will be given a copy of this letter of information and consent form once it has been signed. If you have any concerns, please feel free to contact one of the researchers below. You may request the general findings of this research study from the researchers after the study is complete. You do not waive any legal rights by signing the consent form.

Stefanie De Jesus  
Graduate Student  
School of Kinesiology, UWO

Dr. Harry Prapavessis  
Professor  
School of Kinesiology, UWO
INFORMED CONSENT

Study Title: Does an acute bout of exercise affect smoking topography?

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Please send me the overall conclusions from this trial: Yes ☐ No ☐

I consent to the use of my study-related data in future studies: Yes ☐ No ☐

I would like to be contacted for other research studies: Yes ☐ No ☐

I would like to participate in the follow-up phase of the study: Yes ☐ No ☐

Consenting Signature:

Participant: ________________________________________________________

Please Print Name

Participant: ________________________________________________________

Please Sign Name

Date: _________________

Researcher Signature:

Person obtaining informed consent: __________________________________________

Please Print Name

Person obtaining informed consent: __________________________________________

Please Sign Name

Date: _________________
Appendix B: Questionnaires for Study 1
PHYSIOLOGICAL DATA

Carbon Monoxide
HR Visit 2: ______
Visit 1 Micro Smokerlyzer: ________
Visit 2 Micro Smokerlyzer: ________

Visit 2 Number of hours abstained: ________

Ad libitum time to first cigarette: ________

Exercise Prescription
HR_rest: ______
Age: ______

HR_max: 220bpm - _____ (age) = ______

HRR: ______ (HR_max) - ______ (HR_rest) = ______

45% of HRR is calculated as follows:
[(HR_max - HR_rest) x %] + HR_rest

[(____) – (_____) x 0.45] + _____ = ______

68% of HRR is calculated as follows:
[(HR_max - HR_rest) x %] + HR_rest

[(____) – (_____) x 0.68] + _____ = ______

Exercise session:
Warm up Length: __________
Total duration: __________ Speed: _______ Incline: _______ HR: ______

Nicotine Metabolism
Saliva sample taken: □ Yes □ No

CYP2A6 genotype (polymorphism): ______

CYP2A6 phenotype: □ High metabolism
□ Intermediate metabolism
□ Slow metabolism

Cortisol
Visit 1 ________ □
Visit 2a_______ □
Visit 2b_______ □
DEMOGRAPHIC QUESTIONNAIRE

First Name:_______________________ Last Name:________________________ ID: _______

Address:__________________________________________________________________________
                  STREET ADDRESS, CITY, POSTAL CODE

Home Phone: _______ - _______ - _______

Email Address: __________________________________________@_____________________

Date of Birth: _______/_____/___________                  Age: _________

Gender:□ Male    □ Female                        If female, day of menstrual cycle: _________

Height: __________                  Weight: __________    BMI: __________

SMOKING STATUS AND HISTORY

Please indicate the length of time you have smoked: ________________________

On average, how many cigarettes do you smoke per day? : ___________________

Do you currently smoke any other substance besides cigarettes?           □ Yes
                        □ No

If yes, please specify (e.g. marijuana, cigar, pipe, cigarello, waterpipe tobacco/hookah):
________________________________________________________________________

Have you ever smoked any other substance besides cigarettes?           □ Yes
                        □ No

Does anyone in your household currently smoke? □ Yes □ No

Do you drink Alcohol?       □ Yes □ No

If yes, number of drinks per week? __________

What is the approximate date and time of the last cigarette you have smoked?

                      Date: ______________ Time: ______________

At what age did you smoke your first cigarette? __________
What brand of cigarette do you smoke most of the time?  
________________________________

Do you smoke  □ Filter cigarettes  □ Non-filter cigarettes

Do you smoke  □ regular  □ king size  □ extra large cigarettes

Do you smoke your cigarette about  □ 1/4 of the length  
□ 1/2 of the length  
□ 3/4 of the length  
□ all the way to the end (the filter)

Do you simply puff your cigarette without inhaling the smoke?  □ Yes  □ No

Do you inhale the smoke  □ seldom  
□ occasional  
□ often  
□ always

How long have you been smoking regularly? ________
FAGERSTROM TEST FOR NICOTINE DEPENDENCE

1. How soon after you wake up do you smoke your first cigarette?
   a) After 60 minutes
   b) 31-60 minutes
   c) 6-30 minutes
   d) Within 5 minutes

2. Do you find it difficult to refrain from smoking in places where it is forbidden?
   a) No
   b) Yes

3. Which cigarette would you most hate to give up?
   a) The first in the morning
   b) Any other

4. How many cigarettes per day do you smoke?
   a) 10 or less
   b) 11-20
   c) 21-30
   d) 30 or more

5. Do you smoke more frequently during the first hours after awakening than during the rest of the day?
   a) No
   b) Yes

6. Do you smoke even if you are so ill that you are in bed most of the day?
   a) No
   b) Yes
INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

1. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?
   _____ days per week

   [ ] No vigorous physical activities  ➔ Skip to question 3

2. How much time did you usually spend doing vigorous physical activities on one of those days?
   _____ hours per day
   _____ minutes per day

   [ ] Don’t know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.
   _____ days per week

   [ ] No moderate physical activities  ➔ Skip to question 5
4. How much time did you usually spend doing moderate physical activities on one of those days?

   _____ hours per day
   _____ minutes per day

   [ ] Don’t know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

   _____ days per week

   [ ] No walking → Skip to question 7

6. How much time did you usually spend walking on one of those days?

   _____ hours per day
   _____ minutes per day

   [ ] Don’t know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the last 7 days, how much time did you spend sitting on a week day?

   _____ hours per day
   _____ minutes per day

   [ ] Don’t know/Not sure

This is the end of the questionnaire, thank you for participating.
CRAVINGS

Using a seven-point scale, please respond to the following statement: *'I have a desire to smoke'*

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>Neither agree nor disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
POSITIVE AND NEGATIVE AFFECT SCALE (PANAS)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you feel this way right now, that is, at the present moment.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Interested</td>
<td>11. Irritable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Distressed</td>
<td>12. Alert</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Excited</td>
<td>13. Ashamed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Strong</td>
<td>15. Nervous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Scared</td>
<td>17. Attentive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Hostile</td>
<td>18. Jittery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Enthusiastic</td>
<td>19. Active</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Ethics Approval Notice for Study 1
Principal Investigator: Prof. Harry Papavassiliou
File Number: 109873
Review Level: Delegated
Approved Local Adult Participants: 160
Approved Local Minor Participants: 0
Protocol Title: Does an acute bout of exercise affect smoking topography? (REB 18110)
Department & Institution: Health Sciences/Kinesiology/Western University
Sponsor:
Ethics Approval Date: June 12, 2012 Expiry Date: August 31, 2012
Documents Reviewed & Approved & Documents Received for Information:

<table>
<thead>
<tr>
<th>Document Name</th>
<th>Comments</th>
<th>Version Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revised Letter of Information &amp; Consent</td>
<td>Exercise</td>
<td>2012/05/31</td>
</tr>
<tr>
<td>Revised Letter of Information &amp; Consent</td>
<td>Control</td>
<td>2012/05/31</td>
</tr>
<tr>
<td>Revised Western University Protocol</td>
<td>Revised study objectives, methodology, study procedures, study instruments and compensation</td>
<td></td>
</tr>
<tr>
<td>Advertisement</td>
<td>Poster</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>SEES Questionnaire</td>
<td></td>
</tr>
</tbody>
</table>

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REB's as defined in Division 6 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval report prior to that time you must request it using the University of Western Ontario Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000040.

[Signature]

Ethics Office to Contact for Further Information

This is an official document. Please retain the original in your files.

The University of Western Ontario
Research Development & Services
Support Services Building Suite 5150 • London, Ontario • CANADA • N6A 3K7
PH: 519-661-2161 • F: 519-661-3907 • www.uwo.ca/research
Appendix D: Questionnaires for Study 2
PHYSIOLOGICAL DATA

Carbon Monoxide

<table>
<thead>
<tr>
<th>Visit 1 Micro Smokerlyzer:</th>
<th>Visit 2 Micro Smokerlyzer:</th>
</tr>
</thead>
</table>

Visit 2 Number of hours abstained: _______

Ad libitum time to first cigarette: _______

Exercise Prescription

HR rest: ______ Age: ______

HR max: 220bpm - _____ (age) = ______

HRR: _____ (HR max) - _____ (HR rest) = ______

45% of HRR is calculated as follows:

\[(\text{HR max} - \text{HR rest}) \times 0.45\] + HR rest

68% of HRR is calculated as follows:

\[(\text{HR max} - \text{HR rest}) \times 0.68\] + HR rest

Exercise session:

Warm up Length: __________

Total duration: __________ Speed: _______ Incline: _______ HR: _____

Nicotine Metabolism

Saliva sample taken: Yes No

CYP2A6 genotype (polymorphism): _______

CYP2A6 phenotype:

☐ High metabolism
☐ Intermediate metabolism
☐ Slow metabolism

Cortisol

Visit 1 _______ □

Visit 2a _______ □

Visit 2b _______ □
DEMOGRAPHIC QUESTIONNAIRE

First Name:_______________________ Last Name:________________________ ID: _______

Address:______________________________________________________________________

STREET ADDRESS, CITY, POSTAL CODE

Home Phone: _______ - _______ - _______

Email Address: __________________________________________@_____________________

Date of Birth: _______/_______/___________ Age: _________

Gender:□ Male □ Female If female, day of menstrual cycle: _________

Height: __________ Weight: __________ BMI: __________

SMOKING STATUS AND HISTORY

Please indicate the length of time you have smoked: ________________________

On average, how many cigarettes do you smoke per day? : ___________________

Do you currently smoke any other substance besides cigarettes? □ Yes □ No

If yes, please specify (e.g. marijuana, cigar, pipe, cigarello, waterpipe tobacco/hookah):

________________________________________________________________________

Have you ever smoked any other substance besides cigarettes? □ Yes □ No

Does anyone in your household currently smoke? □ Yes □ No

Do you drink Alcohol? □ Yes □ No

If yes, number of drinks per week? ____________

What is the approximate date and time of the last cigarette you have smoked?

Date: ____________ Time: ____________

At what age did you smoke your first cigarette? ________
What brand of cigarette do you smoke most of the time?
________________________________

Do you smoke ☐ Filter cigarettes ☐ Non-filter cigarettes

Do you smoke ☐ regular ☐ king size ☐ extra large cigarettes

Do you smoke your cigarette about ☐ 1/4 of the length ☐ 1/2 of the length ☐ 3/4 of the length ☐ all the way to the end (the filter)

Do you simply puff your cigarette without inhaling the smoke? ☐ Yes ☐ No

Do you inhale the smoke ☐ seldom ☐ occasional ☐ often ☐ always

How long have you been smoking regularly? ________
FAGERSTROM TEST FOR NICOTINE DEPENDENCE

1. How soon after you wake up do you smoke your first cigarette?
   e)  After 60 minutes
   f)  31-60 minutes
   g)  6-30 minutes
   h)  Within 5 minutes

2. Do you find it difficult to refrain from smoking in places where it is forbidden?
   c)  No
   d)  Yes

3. Which cigarette would you most hate to give up?
   c)  The first in the morning
   d)  Any other

4. How many cigarettes per day do you smoke?
   e)  10 or less
   f)  11-20
   g)  21-30
   h)  30 or more

5. Do you smoke more frequently during the first hours after awakening than during the rest of the day?
   c)  No
   d)  Yes

6. Do you smoke even if you are so ill that you are in bed most of the day?
   c)  No
   d)  Yes
INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

5. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?

____ days per week

☐ No vigorous physical activities ➔ Skip to question 3

6. How much time did you usually spend doing vigorous physical activities on one of those days?

____ hours per day

____ minutes per day

☐ Don’t know/Not sure

Think about all the moderate activities that you did in the last 7 days. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

7. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

____ days per week

☐ No moderate physical activities ➔ Skip to question 5
8. How much time did you usually spend doing moderate physical activities on one of those days?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

Think about the time you spent walking in the last 7 days. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the last 7 days, on how many days did you walk for at least 10 minutes at a time?

____ days per week

☐ No walking ➔ Skip to question 7

8. How much time did you usually spend walking on one of those days?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

9. During the last 7 days, how much time did you spend sitting on a week day?

____ hours per day
____ minutes per day

☐ Don’t know/Not sure

This is the end of the questionnaire, thank you for participating.
CRAVINGS

Using a seven-point scale, please respond to the following statement: ‘I have a desire to smoke’

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly disagree</td>
<td>Neither agree nor disagree</td>
<td>Strongly agree</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The table above shows the seven-point scale for responding to the statement. The scale ranges from 1 (Strongly disagree) to 7 (Strongly agree).
POSITIVE AND NEGATIVE AFFECT SCALE (PANAS)

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. Indicate to what extent you feel this way right now, that is, at the present moment.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very Slightly or Not at All</td>
<td>A Little</td>
<td>Moderately</td>
<td>Quite a Bit</td>
<td>Extremely</td>
</tr>
</tbody>
</table>

|   | 1. Interested |   |   |   |   |
|   | 2. Distressed |   |   |   |   |
|   | 3. Excited |   |   |   |   |
|   | 4. Upset |   |   |   |   |
|   | 5. Strong |   |   |   |   |
|   | 6. Guilty |   |   |   |   |
|   | 7. Scared |   |   |   |   |
|   | 8. Hostile |   |   |   |   |
|   | 9. Enthusiastic |   |   |   |   |
|   | 10. Proud |   |   |   |   |
|   | 11. Irritable |   |   |   |   |
|   | 12. Alert |   |   |   |   |
|   | 13. Ashamed |   |   |   |   |
|   | 14. Inspired |   |   |   |   |
|   | 15. Nervous |   |   |   |   |
|   | 16. Determined |   |   |   |   |
|   | 17. Attentive |   |   |   |   |
|   | 18. Jittery |   |   |   |   |
|   | 19. Active |   |   |   |   |
|   | 20. Afraid |   |   |   |   |
MOOD AND PHYSICAL SYMPTOMS SCALE (MPSS)

Please show for each of the items below how you have been feeling right now. *(Circle one number for each item).*

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Slightly</th>
<th>Somewhat</th>
<th>Very</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depressed</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Anxious</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. Irritable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Restless</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. Hungry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Poor concentration</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. Poor sleep at night</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

8. How much of the time have you felt the urge to smoke recently? *(Circle one number)*

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>A little of the time</th>
<th>Some of the time</th>
<th>A lot of the time</th>
<th>Almost all the time</th>
<th>All the time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

9. How strong have the urges been? *(Circle one number)*

<table>
<thead>
<tr>
<th></th>
<th>No urges</th>
<th>Slight</th>
<th>Moderate</th>
<th>Strong</th>
<th>Very strong</th>
<th>Extremely strong</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Have you experienced any of the following over the past 24 hours? *(Circle one number for each item).*

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Slight</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very severe</th>
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</thead>
<tbody>
<tr>
<td>10. Sores in the mouth</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<tr>
<td>11. Constipation</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>12. Cough/sore throat</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
**ACCEPTABILITY QUESTIONNAIRE**

Please put a mark on the line that best describes the question being asked in regards to your experience with the Portable Smoking Topography Measurement Device (CReSS Pocket) that used during your laboratory visits compared to smoking a cigarette without the CReSS Pocket.

The CReSS Pocket altered how *much* I puffed (i.e. puff volume)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
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<tbody>
<tr>
<td></td>
<td>STRONGLY DISAGREE</td>
<td>NEUTRAL</td>
<td>STRONGLY AGREE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The CReSS Pocket altered how *fast* I puffed (i.e. puff velocity)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>STRONGLY DISAGREE</td>
<td>NEUTRAL</td>
<td>STRONGLY AGREE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The CReSS Pocket altered the *time* between my puffs

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>STRONGLY DISAGREE</td>
<td>NEUTRAL</td>
<td>STRONGLY AGREE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The CReSS Pocket altered how *long* I puffed (i.e. puff duration)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>10</th>
<th>20</th>
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The CReSS Pocket altered the time to smoke my single cigarette

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The CReSS Pocket reduced smoking enjoyment

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The CReSS Pocket affected the taste of the cigarettes

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The CReSS Pocket made smoking more difficult

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The CReSS Pocket increased my awareness of how much was smoked

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Appendix E: Ethics Approval Notice for Study 2
Use of Human Participants - Ethics Approval Notice

Western

Principal Investigator: Prof. Harry Trappenseis
Review Number: 1110
Review Level: Full Board
Approved Local Adult Participants: 100
Approved Local Minor Participants: 0
Protocol Title: Does acute heat of exercise affect smoking topography?
Department & Institution: Kinesiology, University of Western Ontario
Sponsor:
Ethics Approval Date: July 21, 2011
Expiry Date: August 31, 2012

Documents Reviewed & Approved & Documents Received for Information:

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This is to notify you that the University of Western Ontario Health Sciences Research Ethics Board (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The membership of this HSREB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request form.

Member of the HSREB that are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

Signatures:

Ethics Officer to Contact for Further Information

This is an official document. Please retain the original in your files.

The University of Western Ontario
Office of Research Ethics
Support Services Building Room 5156 • London, Ontario • CANADA • N6A 3K7
PH: 519-661-3036 • F: 519-850-2466 • ethics@uwo.ca • www.uwo.ca/research/ethics
Appendix F: Letter of Information and Consent Form (Study 3)
Letter of Information

Study Title: Getting Physical on Cigarettes

Principal Study Investigator:
Harry Prapavessis, Ph.D. (School of Kinesiology, The University of Western Ontario)

Co-Investigators:
Guy Faulkner, Ph.D. (Faculty of Physical Education and Health, University of Toronto)
Ralph Maddison, Ph.D. (Clinical Trials Research Unit, University of Auckland)
Lyndsay Fitzgeorge, Ph.D. (School of Kinesiology, The University of Western Ontario)
Stefanie De Jesus, Ph.D. Candidate (School of Kinesiology, The University of Western Ontario)

You are being invited to participate in a research study looking at the long-term effects of exercise on helping women quit smoking. This is a clinical trial (a type of research study) which includes eligible volunteers who choose to take part. Please take your time to make a decision, and discuss this proposal with your personal doctor, family members and friends as you feel inclined. The purpose of this letter is to provide you with the information you require to make an informed decision on participating in this research and to help us talk to you about smoking cessation (quit-smoking). This letter contains information to help you decide whether or not to participate in this research study. It is important for you to understand why the study is being conducted and what it will involve. Please take the time to read this carefully and feel free to ask questions if anything is unclear or there are words or phrases you do not understand. We are asking you to take part because you are a woman who smokes and wish to quit. We hope to recruit a total of 420 women and help them quit smoking and remain smoke-free over a total of 13 months, as well as examine the effect of exercise on maintaining a healthy body weight.

Invitation to Participate in Research and Eligibility Criteria
You are being invited to take part in this research study because you:
(a) are between the ages of 18 and 65
(b) smoke 10 or more cigarettes per day for the past 2 years or more and want to quit
(c) engage in 2 or less 30-minute bouts of moderate (e.g., jogging, playing tennis) or vigorous (e.g., running, spin classes, high impact aerobics) intensity exercise over the past 6 months
(d) do not have a medical condition that prevents you from exercising
(e) are not pregnant or intending on being pregnant over the next 13 months
(f) are able to read and write in English
(g) have a telephone or an email account that we can reach at over the next 13 months

Please note that if you are pregnant, or wish to become pregnant during the course of the study, you are NOT eligible to participate. If you become pregnant during the course of the study, you must notify the study researchers immediately. This is
because low doses of radiation will be administered during one of the tests of the study, and this could cause harm to a foetus or breast-fed baby.

What is the purpose of this study?

This study is intended to evaluate how useful an exercise program, nicotine replacement therapy (e.g., Nicoderm®), and support and advice from an exercise counselor, is at helping women who smoke become smoke-free and remain physically active for 13 months. We will also examine the effects of this program on body composition (e.g., your weight, the ratio between your body fat and your body muscle mass), your physical fitness, and your confidence to perform certain activities.

It has been shown in past research that exercising can help women quit smoking by alleviating smoking withdrawal symptoms. Unfortunately, if the exercise program is stopped, women often resume smoking. Our goal in this study is to help women learn how to stick with an exercise program in their own homes, maintain their health and weight through exercise, and subsequently stay motivated to remain smoke-free. The information we gather will help guide the development of future programs to help women like you who wish to quit.

Specific questions we hope to answer by conducting this study are:
1) Does the type of information and support given by the exercise counsellor make a difference in terms of how long women who have recently quit smoking can remain smoke-free?
2) Does the type of information and support given by the exercise counsellor make a difference in terms of how long women who have recently quit smoking can continue with their exercise program?

WHAT ARE YOU ASKED TO DO IN THIS STUDY?

1) Participate in a lab-based exercise program
   Time involvement = 3 x 45 minutes each week for 14 weeks
   If you choose to participate in this study, you will be asked to take part in an exercise program three times per week for a total of 14 weeks. These exercise sessions will be supervised by a trained exercise counselor, and will all take place in the Exercise and Health Psychology Laboratory (EHPL) at the University of Western Ontario in the Arthur and Sonia Labatt Health Sciences building. Each exercise session will last 45 minutes, and will consist of a warm-up, cardiovascular work-out, and cool-down on pieces of equipment such as the treadmill, stationary bike, stepper, and rower. You will be asked to wear a heart rate monitor so that your efforts can be monitored to ensure that you are working at an effective and safe exercise intensity, based on your fitness level. A trained councilor will be there at all times to assist you. If you miss an exercise session, you will be asked to make up for the missed session on the weekend at a scheduled time.

2) Quit smoking
   Time involvement = 0 minutes
After 4 weeks of this exercise program, we will ask you to stop smoking cigarettes completely. To assist you in doing this, we will be providing you with commercially-available nicotine replacement therapy (NICODERM®) in the form of daily patches that adhere to your skin like a small band-aid. This will be dispersed to you in weekly allotments each week from week 4 through 14 at the EHPL after your exercise sessions. The dose that you will receive from this patch depends on your current level of smoking, but will most likely result in you following the recommended guidelines of:
A) Wearing a 21 mg patch each day for 6 weeks (weeks 4 through 10 of the study)
B) Wearing a 14 mg patch each day for 2 weeks (weeks 11 and 12 of the study)
C) Wearing a 7 mg patch each day for 2 weeks (weeks 13 and 14 of the study)
In total, you will wear these daily patches for 10 weeks while you continue to exercise at our exercise facility.

3) Participate in support group that you are randomly assigned to
Time involvement = 3 x 15 minutes for a total of 3 weeks
You will also be provided with group counseling and support information during weeks 12 through to week 14 of the program. The type of support information you will receive during these weeks depends on which group you are randomized to. In other words, the participants in the study will be assigned at random (like a flip of a coin), that is, by a method of chance, to one of 4 groups. You will have a 1 in 4 chance of being in any one of the support groups. The four support groups are as follows:
1. Lifestyle Exercise Maintenance Group
2. Relapse Prevention Group
3. Health and Nutrition Maintenance Group
4. Lifestyle Exercise Maintenance and Relapse Prevention Group
ALL support groups will receive information related to health for women from the trained exercise counselor you have been working with in a group format (e.g., with the other women you have been exercising with). This information will be delivered for 15 minutes at the end of each exercise session in the EHPL during weeks 12 through 14 of the study.

The trained exercise counselor you have been working with will also follow-up with you via either phone or email (it is your choice which mode of communication you would like to be contacted through) to provide support and encourage you to remain physically active and remain smoke free after the program has ended for 10 additional months.

4) Perform tests
There are a number of tests that you will be asked to do if you choose to participate in this study. ALL tests will be performed within the EHPL under trained research staff. These tests provide the study researchers with evidence that will help us answer the research questions. At baseline testing (before the exercise program begins), we will ask you to perform a number of these tests so that we may measure how you are doing before you quit smoking and before you begin to exercise.

i) Baseline Testing
Time involvement = 3 hours
For baseline testing, you will be asked to visit our exercise facility (the Exercise and Health Psychology Laboratory; EHPL) at the University of Western Ontario. Baseline testing will begin after you have provided the study researchers with written consent from your family physician indicating that he or she supports your involvement in this study. Baseline testing will take approximately 4 hours and will include completing a number of questionnaires, or surveys, as well as some physical tests.

The surveys will ask you about:

• Your motivation to quit smoking (“How motivated are you to quit smoking in the next 7 days?”)
• Physical activity (“In the past week, how often did you do light activities, such as yoga or slow walking?”, “Has your doctor ever advised you NOT to engage in physical activity?”)
• Your response to coping with temptations to smoke (“When I am very angry about something or someone. How likely are you to smoke or exercise?”)
• The types of coping strategies you use when quitting smoking (“I’ve been getting help and advice from other people”)
• Smoking history (“In the past week, how many cigarettes did you consume?”)
• A demographic questionnaire (which asks you about information such as your age, education, marital status, income)
• Your satisfaction with your weight (“How satisfied, or content, are you with your current body weight?”)
• Your confidence in your abilities to do activities related to exercise and quitting smoking (“How confident are you in your ability to exercise for 30min continuously, once per week?”)
• Your smoking cravings (“How irritable do you feel right now?”)
• Your dependence on nicotine (“How soon after you first wake up do you have a cigarette?”)
• Your sleeping patterns (“In the past week, how often did you have trouble falling asleep?”)
• Your mood (“How often during the past week did you feel full of pep?”)
• Your smoking motives (“Do you smoke to help you cope with stress?”)

It is important to note that there are no correct or incorrect answers to these questions, and you may choose to skip any questions you do not feel comfortable in answering.

The physical tests will consist of:

• An aerobic fitness test on a treadmill (often called a maximal oxygen uptake treadmill test). A trained research technician will be performing the test on you, making sure you are safe and comfortable at all times. This test is performed regularly in our laboratory. Length of the treadmill test varies from 9 to 18 minutes, depending on your level of physical fitness. The test begins by having you walk at an easy pace on a treadmill (e.g., the pace you walk when you walk down the street). The speed and incline of the treadmill will then be gradually increased every 3 minutes until you indicate to us that you do not wish to continue, or you reach your age-predicted maximum heart rate, as determined by a trained research technician. During this test you will breath through a mouthpiece connected to a computer that will measure your oxygen consumption. By doing this test,
we will be able to assess your aerobic fitness and also determine the level of training intensity that is safe for you to exercise at during the exercise program. The test will end with a cool-down, where you will walk at an easy, self-selected pace for 5 minutes.

• A non-invasive body composition test. The body composition test uses a machine called Dual-Energy X-Ray Absorptiometry (DXA; GE Lunar). This machine measures the amount of fat and muscle you have in your body without touching you. We will want to measure your body composition throughout the study, so that we may look for any changes that may occur due to exercise. Although this machine does use an X-ray, the amount of radiation is very minimal. The amount of radiation used in one test is extremely small (0.01 mSv). Each day, you receive approximately 0.01 mSv of natural background radiation from the earth. In comparison, flying on a commercial airplane exposes humans to approximately 0.03 mSv per trip. All that is required of you is that you lie down on the bed surface of the DXA for approximately 5 minutes, while the monitoring arm scans the length of your body. You will be asked to take off any metals you may be wearing, such as earrings, as they could alter the results of the test. You will feel absolutely no pain or discomfort.

• Measures of your smoking status. We will measure your smoking status using physical tests in two separate ways. First, we will ask you to breath into a machine called the Bedfont Smokerlyzer. This machine measures the amount of carbon monoxide (CO) as you breathe out. It does not cause any harm or discomfort to you. This smokerlyzer measures how much you have smoked in the past several hours. Second, we will ask you to provide us with a saliva sample by spitting approximately 10mL into a special test tube. If you have difficulties producing that much saliva, you will be given parafilm (an odourless, tasteless product) to chew on. From this saliva sample, we will measure cotinine, which tells us about your smoking behaviour in the past several days, and 3-hyrdroxcotinine: cotinine ratio, which tells us about the rate at which your body metabolizes (breaks down) nicotine.

• A measure of your lung health, using a device called spirometry. To complete this test, you will take your deepest possible breath and then let all of the air out (exhale) into the sensor on the device. You will breathe out as hard as you possibly can, and for as long as you possibly can.

• A reaction time test to measure your executive function. We will measure your reaction time on a button press computer task. Reaction time is the time it takes you to respond (press a key on keyboard) to a prompt (flash) on the computer screen. Executive functions are a set of abilities that allow you to select a response or make a decision. We are looking at an executive function called inhibition, which is your ability to stop unwanted actions and unwanted responding. One example of inhibition in your everyday life is, when you think something but then stop yourself from saying your thoughts. You are inhibiting (or stopping) your thoughts from being verbalized.

• Smoking topography. Smoking topography is a measure of your smoking behaviour; it can be measured by you putting a small device (CReSS Pocket) on your cigarette which
measures puff volume (how much smoke you take in), maximum puff speed (how quickly you smoke), inter-puff interval (time between puffs), puff time, number of puffs per cigarette, and the time to smoke a single cigarette. We will measure your smoking topography using the CReSS Pocket. This hand-held, computer-based machine measures how you smoke a cigarette by placing your cigarette in the device and breathing through the clean mouth-piece of the device. The CReSS Pocket does not cause any harm or discomfort to you. You will be asked to smoke a cigarette (of your regular brand) with the CReSS Pocket, at a minimum of 10 meters away from any building entrance of the Labatt Health Sciences Building. It is within your rights to refuse to smoke during this research study and we will honour your rights.

- Wearing an accelerometer. At the end of baseline testing, we will give you an accelerometer (motion detector) to wear around your waist at all times except for when sleeping and bathing, for 7 days. This device is small and unobtrusive. After one week, you will be asked to return the device to the study researchers. We will then download the data from the device you wore onto our computer programs.

ii) Post-Testing
   Time involvement = 3 hours
   The same number of tests will be performed again after the study ends, 13 months after baseline, so that we may measure the effects of the program.

iii) Testing throughout the study
   Time involvement = approximately 15 minutes each week

There will also be periodic testing that you will be asked to do throughout the study (in between baseline and post-testing). These tests will consist of tests that you already did at baseline, so you will be familiar with the procedures. The table that follows shows which tests you will be asked to do, and at what times. Please do not hesitate to ask for clarification – we realize there is a lot of information in this table.

What are the risks associated with my involvement in this study?
While in the study, you may experience side effects. Known side effects are listed below, but other effects may occur that we cannot predict.

Exercise: There are some inherent risks of injury associated with exercise participation, particularly among people who are not used to exercising. You may, for example, feel mild muscle “tightness” or soreness that lasts for a couple of days after their first few bouts of exercise. The possible benefits associated with exercise may outweigh the potential minor discomfort of beginning a supervised, laboratory-based exercise program. To minimize the physical risks of exercise, proper warm-up/cool-down and stretching protocols will be performed, with each exercise session being supervised by a trained exercise counsellor. Additionally, the exercise program delivered will be tailored to your individual fitness level, and modified according to your comfort level. You will
gradually, under the supervision of a trained exercise facilitator, work up to a moderate intensity for your aerobic exercise training bouts. Furthermore, you will only be allowed to participate in this exercise program if you provide medical clearance from your physician, and complete the PAR-Q (Physical Activity Readiness Questionnaire) forms to ensure that it is safe for you to begin an exercise program. The exercise facilitator will be both CPR and First Aid trained, and experienced in working with previously inactive populations. Throughout, if any physical or mental risks arise, you will be referred to the Middlesex London Health Unit if issues arise that fall outside of the scope of the study.

**Quitting Smoking:** You may experience withdrawal symptoms during the first few days after you quit smoking in this program. Such symptoms may include feeling edgy and nervous, dizzy, sweaty, having trouble concentrating, headaches, difficulty sleeping, increased appetite and weight gain, muscular pain, constipation, fatigue, or having an upset stomach. All of these symptoms are common for those who quit smoking so you should not be alarmed, as these symptoms will go away within a few days. It should be noted, however, that this program provides you with tools that we believe will help counter these withdrawal symptoms. Specifically, moderate intensity exercise has been shown to reduce smoking withdrawal symptoms. The nicotine replacement therapy we provide you with should also eliminate or reduce the smoking withdrawal symptoms. Another common side effect of quitting smoking is that your “smoker’s cough” gets worse for the first few days after you quit. This is your body’s way of attempting to rid the lungs of excess toxins. This may not be alleviated by exercise or nicotine replacement therapy. Your smoker’s cough will improve to a great extent after you have become smoke-free for a number of days.

**Nicotine Replacement Therapy (NICODERM®):** It is important to note that while this product does contain nicotine, it is considered safer and healthier than smoking. We are providing you with this medication as a tool to help you become completely free of your addiction to cigarettes. Some individuals who wear the patch experience redness, swelling, or a rash on their where the patch is placed. This is due to the adhesive material on the patch. Contact your family physician if this occurs. You should also contact your family physician if you develop an irregular heart beat, or if you get symptoms of nicotine overdose such as nausea, vomiting, dizziness, weakness and a rapid heartbeat. These are all potential side effects of taking nicotine replacement therapy; however, the chance of you developing one of these side effects is minimal.

Nicoderm should not be used by people who:
- Are allergic to nicotine
- Are non-smokers or occasional smokers
- Are under 18 years of age
- Are pregnant or breast-feeding
- Have just had a heart attack
- Have life-threatening abnormal heart rhythm
- Have severe or worsening chest pain
- Have recently had a stroke
- Have a generalized skin disorder
Dual-Energy X-Ray Absorptiometry (DXA; GE Lunar): This test uses a small dosage of radiation to conduct a non-invasive x-ray on your body. The amount of radiation is very minimal, and no known side effects are associated with this minimal amount of radiation. The amount of radiation used in one test is extremely small (0.01 mSv). Each day, you receive approximately 0.01 mSv of natural background radiation from the earth. In comparison, flying on a commercial airplane exposes humans to approximately 0.03 mSv per trip. The DXA machine used in the EHPL is tested and calibrated daily to ensure it is working optimally at all times. A trained and certified research technician will always perform this test on you.

Risk to your foetus or baby: If you are pregnant or breastfeeding, there are also side effects that could harm your foetus or baby. Use of nicotine replacement therapy is not recommended while pregnant or breastfeeding. Use of this product could cause harm to your foetus or baby. You are not eligible to participate in this study if you are pregnant or planning on becoming pregnant over the course of this study. If you become pregnant, it is important that you tell one of the study researchers immediately. It should be noted that pregnant women are advised to limit their exposure to radiation due to potential harm to the foetus. As such, women in this study who become pregnant, or who have any reason to believe they may be pregnant at all will not undergo DXA testing.

Do I have to take part?
Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no effect on your future care. If you decide to take part you will be given this Letter of Information to keep and be asked to sign the consent form. If you withdraw from the study, you maintain the right to request that any data collected from you not be used in the study. If you make such a request, all of the data collected from you will be destroyed. Please contact the Principal Investigator if you wish to withdraw from the study.

Participation in other studies
If you are participating in another study at this time, please inform the study researchers right away to determine if it is appropriate for you to participate in this study.

Biological specimens given by you for use in this study
The sample we are asking of you during the course of this study is saliva. This saliva sample will be used for the current study only. Specifically, this saliva will be frozen in our laboratory freezer, then shipped and analyzed at the Salimetrics® Laboratory in the United States of America for markers of smoking abstinence (cotinine). The saliva taken at the baseline measurement time point only will be frozen in our laboratory freezer, then shipped and analyzed at the University of Toronto in Canada for an indication of how quickly you metabolize (break down) nicotine in your body (3-hydroxycotinine: cotinine ratio). Bar codes will be used to label your saliva samples, so the laboratory technicians analyzing your saliva will have no information as to who provided the saliva sample. The samples will be stored for a minimum of 3 years. Usage and potential research value will be reviewed annually thereafter. It is typical to keep the samples collected from a
research study for 6 years after the study has been conducted. Once the research value is deemed lower than sufficient to justify storage costs, the samples will be destroyed by standard disposal of biohazardous waste laboratory policies and procedures.

Any specimen(s) obtained for the purposes of this study will become the property of the study researchers and once you have provided the specimens you will not have access to them. The specimen(s) will be discarded or destroyed once they have been used for the purposes described in the protocol. The specimen(s) will be used for research and such use may result in inventions or discoveries that could become the basis for new products or diagnostic or therapeutic agents. In some instances, these inventions and discoveries may be of potential commercial value and may be patented and licensed by the researcher. It is not the purpose of this study to use specimens for any inventions or patents, so it is very unlikely that this will occur as an outcome of a sample you provide us with. You will not receive any money or other benefits derived from any commercial or other products that may be developed form use of the specimens.

**New findings**
If, during the course of this study, new information becomes available that may relate to your willingness to continue to participate, this information will be provided to you by the investigator.

**What are the benefits of my involvement?**
Involvement in this study could help you to increase your levels of physical activity in a safe and supportive setting, and may assist you in remaining smoke free. It may also help you manage your weight and ease weight concerns, and teach you how to maintain your levels of physical activity. Ultimately, to be physically active and to quit smoking is good for your health, and may prevent you from developing co morbidities associated with long-term smoking and from an inactive lifestyle (e.g., cardiovascular disease). Furthermore, your participation will help to inform the development of other programs in the future.

**Are there any costs associated with participation?**
The study medication (NICODERM ®) will be given to you at no cost. You will not be paid to take part in the study; however, you will be reimbursed for your expenses such as parking for visits required as part of this study.

If you have private medical or life insurance, you should check with your insurance company before you agree to take part in the study to confirm your participation in this study will not affect your insurance coverage and/or access to benefits.

This study is covered by an insurance policy and if during the course of the study any injury should occur to you as a result of the administration of the study medication, not due to your fault or negligence, all medical expenses necessary to treat such injury will be paid provided: a) you comply at all times with the study researcher’s instructions b) you promptly report any such injury to the study researchers conducting the study, and c) the expenses are not otherwise covered by your provincial health care. Financial
compensation for such things as lost wages, disability or discomfort due to this type of injury is not routinely available. You do not waive any legal rights by signing the consent form.

**Will information obtained in the study be confidential?**
All the information you provide to the researcher will be kept in the strictest confidence. You will be assigned an identification number and all data collected from you will be recorded and stored under this number only, so study researchers will have any way of connecting your data to you. All data will be stored in coded form on computers accessible only to research staff in a secure office. You will not be identified in any documents relating to the research. No information obtained during the study will be discussed with anyone outside of the research team. If the results of the study are published, your name will not be used.

Representatives of the University of Western Ontario Health Sciences Research Ethics Board and regulatory bodies (Health Canada) may contact you or require access to your study-related records to monitor the conduct of the research. If we find information we are required by law to disclose, we cannot guarantee confidentiality. We will strive to ensure the confidentiality of your research-related records. Absolute confidentiality cannot be guaranteed as we may have to disclose certain information under certain laws.

**Alternative treatments**
An alternative to participating in this study would be to see your family physician for advice on how to quit smoking. You could also choose to not participate in the study and continue on just as you do now.

**Questions?**
If you have any questions about your rights as a research participant or the conduct of the study you may contact the Office of Research Ethics.
If you have any questions about the study, please contact the principal investigator, Dr. Harry Prapavessis.

This letter is for you to keep. You will be given a copy of this letter of information and consent form once it has been signed. If you have any concerns, please feel free to contact one of the researchers below. You may request the general findings of this research study from the researchers after the study is complete. Again, if you have any questions about the conduct of this study, or your rights as a participant, you may contact the Office of Research Ethics, The University of Western Ontario.

Dr. Lyndsay Fitzgeorge  Dr. Harry Prapavessis  Stefanie De Jesus  
Postdoctoral Fellow  Professor  Ph.D. Candidate  
School of Kinesiology,  School of Kinesiology,  School of Kinesiology,  
UWO  UWO  UWO
Informed Consent

Study Title: Getting Physical on Cigarettes

I have read the Letter of Information, had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction. I will be given a copy of the Letter of Information and consent form once it has been signed.

Consenting Signature:

Participant: ________________________________________________________

Please Print Name

Participant: ________________________________________________________

Please Sign Name

Date: ____________________

Please send me the overall conclusions from this trial: Yes □ No □

Researcher Signature:

Person obtaining informed consent: __________________________________________

Please Print Name

Person obtaining informed consent: __________________________________________

Date: ____________________

Please Sign Name
Appendix G: Questionnaires for Study 3
Sociodemographic Questionnaire

CONTACT INFORMATION:

First Name: _________________________  Last Name: _________________________
Address: ________________________________________________________________

STREET ADDRESS, CITY, POSTAL CODE

Home Phone: ________-________-________

Email Address: ____________________________________________________________

Date of Birth: ________/______/______

Section A

1. Age: ________ (in years)

3. What language do you speak most often at home?

   (Please check one)  □ English  □ French  □ Cantonese  □ Mandarin  □ Italian  □ German  □ Punjabi  □ Spanish  □ Polish  □ Portuguese  □ Arabic  □ Other (specify: ___________________________)

4. Were you born in Canada?  (Please check one)  □ Yes  □ No

5. Marital status: (Please check one)  □ single  □ separated  □ married  □ divorced  □ widowed  □ common law
Section B – Children

Please complete the following questions about any children you may have.

6. Do you have any children? (Please check one)  □ Yes  □ No

7. If yes, please list their ages, separated by commas:

Section C – Education & Employment

1. What is the highest grade (or year) of regular school have you completed? (Please check one)

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<th>Elementary</th>
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<th>College/University</th>
<th>Graduate School</th>
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2. What is the highest degree you earned? (Please check one)

□ High school diploma
□ College certificate
□ Bachelor’s degree
□ Masters degree
□ Doctorate
□ Professional (MD, LLB, DDS, etc.)
□ Other (specify: ______________________) □ None of the above

10. Which of the following best describes your main daily activities and/or responsibilities? (Please check one)

□ Working full-time
□ Working part-time
□ Unemployed or laid-off
□ Looking for work
□ Keeping house or raising children full-time
□ Student

11. Are you currently working? (Please check one)  □ Yes  □ No

If YES, approximately how many hours/week are you working? _____________
12. Which of these categories best describes your total combined family income for the past 12 months? This should include income (before taxes) from all sources, wages, rent from properties, social security, disability and/or veteran’s benefits, unemployment benefits, workman’s compensation, help from relatives (including child payments and alimony), and so on.

*Please check one:*

- [ ] Less than $5000
- [ ] $5000 - $11999
- [ ] $12000 - $15999
- [ ] $16000 - $24999
- [ ] $25000 - $34999
- [ ] $35000 - $49999
- [ ] $50000 - $74999
- [ ] $75000 - $99999
- [ ] $100000 +
- [ ] don’t know
- [ ] no response

**Section D – Smoking History & Current Practices**

13. What is the approximate date and time of the last cigarette you have smoked?

Date: ____________  Time: ____________

14. Does anyone in your household currently smoke?

*Please check one*  
- [ ] Yes
- [ ] No

15. In your best estimate, what percentage of your friends and family smoke?

*Please check one*  
- [ ] 0 – 10%
- [ ] 11 – 20%
- [ ] 21– 30%
- [ ] 31 – 40%
- [ ] 41 – 50%
- [ ] 51%

**Section E – Medical Information**

To the best of your knowledge, do you have:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yes</th>
<th>No</th>
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<tr>
<td>High blood pressure</td>
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<td>High blood cholesterol</td>
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<td>High blood sugar</td>
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<tr>
<td>Diabetes (Type II)</td>
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</table>

Please list your current drugs & medications (i.e., blood pressure pills, prescribed medicine):
Do you drink Alcohol?  □ Yes  □ No

If yes, number of drinks per week? _______ _______ _______
------------------------
          (Beer)      (Wine)    (Hard Liquor)

Section F

How did you hear about our program?

□ UWO Staff email
□ UWO Student email
□ Your place of work (please name workplace) ________________
□ The Londoner Newspaper
□ The London Free Press
□ Smokers’ Helpline
□ The Canadian Cancer Society
□ The Health Unit
□ Other (please specify) _________________________________
FAGERSTROM TEST FOR NICOTINE DEPENDENCE

1. How soon after you wake up do you smoke your first cigarette?
   i) After 60 minutes
   j) 31-60 minutes
   k) 6-30 minutes
   l) Within 5 minutes

2. Do you find it difficult to refrain from smoking in places where it is forbidden?
   e) No
   f) Yes

3. Which cigarette would you most hate to give up?
   e) The first in the morning
   f) Any other

4. How many cigarettes per day do you smoke?
   i) 10 or less
   j) 11-20
   k) 21-30
   l) 30 or more

5. Do you smoke more frequently during the first hours after awakening than during the rest of the day?
   e) No
   f) Yes

6. Do you smoke even if you are so ill that you are in bed most of the day?
   e) No
   f) Yes
SMOKING SATISFACTION QUESTIONNAIRE

DIRECTIONS: If you have smoked since you last completed this questionnaire, please indicate the number that best represents how smoking made you feel.

<table>
<thead>
<tr>
<th>Not at all</th>
<th>Very little</th>
<th>A little</th>
<th>Moderately</th>
<th>A lot</th>
<th>Quite a lot</th>
<th>Extremely</th>
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1. Was smoking satisfying? ________

2. Did cigarettes taste good? ________

3. Did you enjoy the sensations in your throat and chest? ________

4. Did smoking calm you down? ________

5. Did smoking make you feel more awake? ________

6. Did smoking make you feel less irritable? ________

7. Did smoking help you concentrate? ________

8. Did smoking reduce your hunger for food? ________

9. Did smoking make you dizzy? ________

10. Did smoking make you nauseous? ________

11. Did smoking immediately relieve your craving for a cigarette? ________

12. Did you enjoy smoking? ________
**ACCEPTABILITY QUESTIONNAIRE**

Please put a mark on the line that best describes the question being asked in regards to your experience with the Portable Smoking Topography Measurement Device (CReSS Pocket) that used during your laboratory visits compared to smoking a cigarette without the CReSS Pocket.

**The CReSS Pocket altered how much I puffed (i.e. puff volume)**

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**The CReSS Pocket altered how fast I puffed (i.e. puff velocity)**

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**The CReSS Pocket altered the time between my puffs**

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**The CReSS Pocket altered how long I puffed (i.e. puff duration)**

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The CReSS Pocket altered the number of puffs I took per cigarette

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The CReSS Pocket altered the time to smoke my single cigarette

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The CReSS Pocket made smoking less likely

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The CReSS Pocket reduced smoking enjoyment

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The CReSS Pocket affected the taste of the cigarettes

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The CReSS Pocket made smoking more difficult

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The CReSS Pocket increased my awareness of how much was smoked

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</table>
Appendix H: Ethics Approval Notice for Study 3
Office of Research Ethics
The University of Western Ontario
Room 4180 Support Services Building, London, ON, Canada N6A 5C1
Telephone: (519) 661-3036 Fax: (519) 850-2485 Email: ethics@uwo.ca
Website: www.uwo.ca/research/ethics

Use of Human Subjects - Ethics Approval Notice

Principal Investigator: Dr. H. Prapavessis
Review Number: 16306
Review Date: July 07, 2009
Protocol Title: Getting physical on cigarettes
Department and Institution: Kinesiology, University of Western Ontario
Sponsor: NCIC-NATIONAL CANCER INSTITUTE OF CANADA
Ethics Approval Date: October 01, 2009
Expiry Date: March 31, 2013
Document Reviewed and Approved: UWO Protocol, Letter of information & consent form, advertisement, & recruitment script
Documents Received for Information:

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/ICH Good Clinical Practice Practices: Consolidated Guidelines; and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced study on the approval date noted above. The member of this REB also complies with the membership requirements for REB's as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB's periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the HSREB except when necessary to eliminate immediate hazards to the subject or when the change(s) involve only logistical or administrative aspects of the study (e.g. change of monitor, telephone number). Expedited review of minor change(s) in ongoing studies will be considered. Subjects must receive a copy of the signed information/consent documentation.

Investigators must promptly also report to the HSREB:

a) changes increasing the risk to the participant(s) and/or affecting the conduct of the study;
b) all adverse and unexpected experiences or events that are both serious and unexpected;
c) new information that may adversely affect the safety of the subjects or the conduct of the study.

If these changes/adverse events require a change to the information/consent documentation, and/or recruitment advertisement, the newly revised information/consent documentation, and/or advertisement, must be submitted to this office for approval.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussions related to, nor vote on, such studies when they are presented to the HSREB.

Chair of HSREB: Dr. Joseph Gilbert

Ethics Office to Contact for Further Information

This is an official document. Please retain the original in your files.
Use of Human Participants - Ethics Approval Notice

Principal Investigator: Prof. Harry Prapavessis  
Review Number: 16308  
Review Level: Delegated  
Approved Local Adult Participants: 420  
Approved Local Minor Participants: 0  
Protocol Title: Getting physical on cigarettes  
Department & Institution: Kinesiology, University of Western Ontario  
Sponsor: National Cancer Institute of Canada

Ethics Approval Date: September 20, 2011  
Expiry Date: July 31, 2014

Documents Reviewed & Approved & Documents Received for Information:

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<th>Document Name</th>
<th>Comments</th>
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<td>Revised UWO Protocol</td>
<td>Removal of vascular imaging, addition of executive function measure, smoking topography &amp; 2 questionnaires (habitual exercise &amp; smoking motives)</td>
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<td>Revised Letter of Information &amp; Consent</td>
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</table>

This is to notify you that The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects (HSREB) which is organized and operates according to the Tri-Council Policy Statement: Ethical Conduct of Research Involving Humans and the Health Canada/CIHI Good Clinical Practice Practice: Consolidated Guidelines, and the applicable laws and regulations of Ontario has reviewed and granted approval to the above referenced revision(s) or amendment(s) on the approval date noted above. The membership of this REB also complies with the membership requirements for REBs as defined in Division 5 of the Food and Drug Regulations.

The ethics approval for this study shall remain valid until the expiry date noted above assuming timely and acceptable responses to the HSREB’s periodic requests for surveillance and monitoring information. If you require an updated approval notice prior to that time you must request it using the UWO Updated Approval Request Form.

Members of the HSREB who are named as investigators in research studies, or declare a conflict of interest, do not participate in discussion related to, nor vote on, such studies when they are presented to the HSREB.

The Chair of the HSREB is Dr. Joseph Gilbert. The UWO HSREB is registered with the U.S. Department of Health & Human Services under the IRB Registration number IRB00008142.

Ethics Officer is Contact for Further Information

This is an official document. Please retain the original in your files.

The University of Western Ontario  
Office of Research Ethics  
Support Services Building Room 5150 • London, Ontario • CANADA - N6G 1G9  
PH: 519-661-3036 • F: 519-850-2466 • ethics@uwo.ca • www.uwo.ca/research/ethics
Appendix I: Reprint Permission
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| Billing address | [Blacked out] |
CURRICULUM VITAE

STErfANIE DE JESUS

EDUCATION

Doctor of Philosophy, Kinesiology
The University of Western Ontario 2011-2015

Masters of Arts, Kinesiology
The University of Western Ontario 2009-2011

Bachelor of Science, Honors Specialization in Biology
The University of Western Ontario 2005-2009

SCHOLARSHIPS

CIHR Training Program in Population Intervention for Chronic Disease Prevention: A Pan Canadian Program 2013-2015

Ontario Graduate Scholarship 2013-2015

CIHR Strategic Training Program in Cancer Research and Technology Transfer 2011-2013

REFEREED MANUSCRIPTS


**REVIEWED PRESENTATIONS**


overweight and obese youth with operated heart defects. Oral presentation will be given at the Multiple Health Behavior Change Special Interest Group Breakfast Meeting at the Society of Behavioural Medicine Annual Meeting, Philadelphia, Pennsylvania, United States.


**De Jesus, S., Murray, E., & Prapavessis, H.** (February 5-8, 2014). *No evidence for harm reduction: Acute exercise modifies ad libitum smoking and affect but not smoking behaviour.* Poster was presented at the Society for Research on Nicotine and Tobacco 20th Annual Meeting, Seattle, Washington, United States.

**De Jesus, S., Fitzgeorge, L., Faulkner, G., Maddison, R., & Prapavessis, H.** (February 5-8, 2014). *Predictors of smoking abstinence following an exercise-aided pharmacotherapy smoking cessation trial for women.* Poster was presented at the Society for Research on Nicotine and Tobacco 20th Annual Meeting, Seattle, Washington, United States.


**De Jesus, S., Cramp, A.G., Kossert, A., Lockwood, D., Cornish, S., & Page, C.** (November 4-8, 2013). *Cancer Care Talks: Evaluation of Evidence-based Self-management Supportive Cancer Care Seminars.* Oral presentation was given at the 15th World Congress of the International Psycho-Oncology Society, Rotterdam, Netherlands.


De Jesus, S. & Prapavessis, H. (March 14-16, 2013). *Smoking behaviour patterns over a three week period in an exercise-aided smoking cessation programme*. Poster was presented at the Society for Research on Nicotine and Tobacco International Meeting, Boston, Massachusetts, United States.


TEACHING EXPERIENCE

KIN3388B: Psychology of Sport
Faculty of Health Sciences, The University of Western Ontario
Winter 2014 Term

KIN2962B: Exercise for Specific Populations
Faculty of Health Sciences, The University of Western Ontario
Summer 2013 Term