SLEEP DISTURBANCE AND DAYTIME SYMPTOMS IN CIGARETTE SMOKERS ATTEMPTING TO QUIT WITHOUT TREATMENT

By

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A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

WASHINGTON STATE UNIVERSITY
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MAY 2015
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Acknowledgment

This investigation was supported in part by funds provided for medical and biological research by the State of Washington Initiative Measure No. 171. I would also like to acknowledge the Alcohol and Drug Abuse Research Program, the National Institutes of Health (grant R21CA167691 to John M. Hinson), and all of the study participants; thank you for making this research possible.

Thank you to my committee: John Roll and Dennis Dyck for their expertise and support, Hans Van Dongen for his guidance over the past 9 years on what it takes to produce quality science, and Matt Layton for providing encouragement, insight, and support throughout the ups and downs of the entire project.

Thanks to all of the research assistants and staff at the Sleep and Performance Research Center at Washington State University, especially: Samantha Riedy (telephone screening, study preparation, study clean-up, lab shifts), Mike Winser (PSG training, lab shifts, and Excel/"Wording" support), Brieann Satterfield (lab shifts and Excel/SAS/"Wording" support), Devon Grant (RA scheduling), Rylie Gabehart (telephone screening and lab shifts), Gemma Paech (help during the writing phase), and Glynis Hull (processing payment and encouragement).

I would also like to thank the following individuals: Kathy Casterline (my aunt) for getting me interested in the sleep field and helping me to take the first step toward pursuing this career, Keith Knittle for allowing me to first shadow at Holy Family Hospital and training me in clinical sleep studies at Aspen Sleep Centers, Greg Belenky for taking a chance to hire me and for your support throughout the years, Lora Wu for your passion of science, Melinda Jackson for quietly leading by example, Annemarie Luik for your continued support and friendship, and
Marcella Oonk for the numerous power hours (I may have fallen asleep on a couple), continued support, and encouragement throughout my graduate studies; thank you my dear friend.

Finally, a BIG THANKS goes to my parents and husband for helping me along the way; I could not have done this without you. Thank you Mom and Dad for watching the kids on Saturdays and for taking time off of work to watch them when they were sick and could not go to daycare. Thank you to my wonderful, amazing husband Billy, who was supportive during my entire 5 year (!) graduate studies stint. Sorry it took a little longer than expected; having two kids during graduate school naturally caused some delays. I can’t thank you enough for allowing me to follow my dream. Your sacrifice during my long hours away was unbelievable; even if it was partly contingent upon going Heliskiing in Canada next year.
SLEEP DISTURBANCE AND DAYTIME SYMPTOMS IN CIGARETTE SMOKERS ATTEMPTING TO QUIT WITHOUT TREATMENT

Abstract

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May 2015

Chairs: Dennis G. Dyck and Hans Van Dongen

Introduction: Relapse rates in cigarette smokers attempting to quit are high, but the factors that drive relapse risk are not well understood. Self-report data have suggested that disturbed sleep may prompt individuals to resume smoking. Here we used polysomnography (PSG) to investigate sleep in smokers before and during a quit attempt without treatment.

Methods: N=14 moderate cigarette smokers (16.2±6.2 cigarettes per day; ages 27.6±5.6 years; 1 woman), healthy and free from drugs besides nicotine, were in the laboratory for three consecutive nights (18:00–09:00) with PSG recordings (10 hours time in bed, 22:00–08:00). On the morning after night 1, subjects initiated a quit attempt without treatment. Differences in daytime symptoms (desire to smoke, withdrawal symptoms, anxiety, irritability, stress, and sleepiness) and sleep architecture between night 1 (smoking), and nights 2 and 3 (abstinence) were investigated. Sleep variables and subjective sleepiness assessments were also compared to an age- and sex-matched control group of non-smokers from another study.

Results: Smokers reported higher levels of withdrawal symptoms and irritability during abstinence. Sleepiness did not change with abstinence, but was significantly higher across all nights when compared to the controls. A significant change across nights was observed for sleep latency (SL), which dropped from 44.9±9.0 minutes (mean±SEM) after smoking to 27.7±8.0 minutes during abstinence. When compared to controls, smokers had more disrupted sleep on all
3 nights, with more stage N1 sleep, less stage N3 sleep, more electroencephalographic (EEG) arousals, and longer latency to stage N3 sleep, despite no differences in total sleep time. All participants relapsed within two weeks of the quit date; N3 sleep was positively correlated with time to relapse.

**Conclusion:** Smokers experienced increased levels of withdrawal symptoms and irritability during abstinence, and greater sleepiness both before and during abstinence, than controls. Sleep improved during abstinence, as evidenced by a shorter sleep latency; however, smokers had more sleep disturbance across all nights when compared to the control group. It remains to be determined whether the sleep disturbance that persisted during abstinence contributes to the high relapse rate in smokers quitting without treatment. More N3 sleep may aid in prolonging relapse.
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Dedication

To my children Drew Robert (2 years old) and Kylee Karen Marie (7 months old) -

Anything is possible if you believe in yourself and work hard; never give up.
1 DISSEPTION SUMMARY

1.1 Introduction

Given the adverse health consequences of cigarette smoking and the difficulty of quitting, predictors of smoking relapse are needed to target treatments and improve cessation rates. Nicotine is a psychostimulant, which has been shown to reduce sleepiness but also cause sleep disruption as evidenced by longer times to fall asleep, more awakenings, and lighter stages of sleep. In turn, disturbed sleep can lead to daytime sleepiness and impairments in daytime functioning and mood, which may prompt individuals to resume smoking to combat sleepiness.

Consistent with this idea, studies have found a link between self-reported sleep disturbances and increased risk of smoking relapse. However, self-reports of sleep tend to be unreliable and do not reveal what aspects of sleep physiology may underlie the risk of relapse.

To fill this gap, this laboratory-based study examined sleep disturbance in cigarette smokers trying to quit without treatment, using polysomnography (PSG), the gold standard of sleep measurement. Moderate cigarette smokers came into the lab for three consecutive nights of PSG recordings—one night before the quit attempt (normal smoking consumption) and two nights during the quit attempt (abstinence). After these three recording days, participants came to the laboratory on a weekly basis for four weeks to test for relapse. Smoking behavior was assessed throughout the study with biochemical measures, self-report, and subjective dependency measures. Daytime symptoms were measured using self-report instruments.

Analyses focused on how the change in smoking status from smoking consumption to abstinence affected sleep and daytime symptoms. Furthermore, PSG-recorded sleep variables, subjective sleep measures, and subjective sleepiness were compared to an age- and gender-matched, non-smoker control group.
1.2 Methods

1.2.1 Participants

Fourteen cigarette smokers (16.2 ± 6.2 cigarettes per day) with no co-occurring medical conditions, free of drugs besides nicotine, participated in the study. Participants were 13 men and one woman, aged 27.6 ± 5.6, which had been recruited to quit “cold turkey” with no treatment intervention. There was one additional subject who resumed smoking within nine hours after the final cigarette whose data was not included.

1.2.2 Study Design Phases

Pre-Laboratory Phase. Participants were recruited with flyers and advertisements and pre-screened over the telephone. Those who were pre-eligible were invited to come to the laboratory for an in-person screening session to determine eligibility. During the screening session, which took place 4.4 ± 2.5 days before the laboratory phase of the study, biochemical tests were performed to objectively measure smoking status, and participants filled out questionnaires of smoking behavior, self-reported sleep, and daytime symptoms. For those eligible to participate, these biochemical tests and questionnaires served as the baseline assessment. During the three days prior to the laboratory phase of the study, participants completed a sleep diary, and called in their bedtimes, wake times, and number of cigarettes smoked daily.

Laboratory Phase. Participants spent three consecutive nights (18:00–09:00) in a sleep laboratory, with scheduled time in bed from 22:00 until 08:00. Participants wore a wrist actigraph while inside the laboratory to document their rest/activity patterns.

On the first night of the study, participants came to the laboratory at 18:00, were prepared for PSG recordings, and went to bed at 22:00. They were allowed to smoke at 19:30, 20:30,
21:30, and any time during the sleep period. Participants got out of bed at 08:00 on the morning of day two and smoked their final cigarette at 08:30, at which time their quit attempt began. Immediately following the final cigarette, carbon monoxide (CO) and urine cotinine (UCot; a metabolite of nicotine) samples were taken.

For days two and three, during abstinence, participants were away from the laboratory from 09:00 until 18:00 in order to make the quit attempt more realistic by exposing them to naturalistic smoking cues. On both nights, participants returned to the laboratory at 18:00, at which point a CO sample was taken to verify abstinence. Participants were again prepared for PSG recordings, and went to bed at 22:00. They got out of bed at 08:00 the following morning, and UCot samples were taken for assessment of cotinine levels.

**Post-Laboratory Phase.** After the three laboratory nights, participants were invited to continue to be in the study for post-laboratory assessments, regardless of smoking status. They were asked to keep track of their first puff of cigarette if they resumed smoking. Post-laboratory assessments took place at 18:00 on the fourth day (i.e., the evening after the laboratory phase), and then on a weekly basis for four straight weeks after the quit attempt. During these assessments, participants returned to the laboratory for CO and UCot tests and to fill out questionnaires on smoking behavior, self-reported sleep, and daytime symptoms.

If participants missed an assessment, they were no longer invited to attend further post-laboratory assessments. However, those who missed an assessment came to the laboratory for final biochemical samples and to fill out a questionnaire about the time to smoking relapse.

Out of the 14 participants, N=10 participants completed all post-laboratory assessments. These participants were included in comparisons between the baseline assessment and the four-week post-laboratory assessment (37.4 ± 4.3 days after the baseline assessment). Of the
remaining four participants, two missed the post-laboratory assessment on the evening after the laboratory phase; one missed the two-week assessment; and one missed the three-week assessment.

Upon completion of the post-laboratory assessments and the final biochemical samples for missed assessments, all 14 participants came in and filled out a final study questionnaire about the quit attempt.

1.2.3 Smoking Behavior

**Smoking Status.** Measures of CO and UCot, and self-reported number of cigarettes were used to verify smoking status during all phases of the study.

*Carbon Monoxide (CO).* The CO breath samples were used as an inclusion criterion (≥10 ppm) during the screening session; the primary verification measure of abstinence (≤ 6 ppm) during the laboratory phase; and a measure of smoking use during the post-laboratory assessments. Analyses focused on comparisons between smoking consumption (night one) and abstinence (nights two and three) to confirm participants (N=14) did not smoke during the laboratory phase. Comparisons between the baseline assessment and the four-week post-laboratory assessment in the smokers who completed all assessments (N=10) evaluated quit attempt success.

*Urine Cotinine (UCot).* The UCot samples were used as an inclusion criterion of smoking status (yes/no) during the screening session; a secondary verification measure of abstinence during the laboratory phase; and a measure of smoking use during the post-laboratory assessments. Analyses focused on comparisons between smoking consumption (night one) and abstinence (nights two and three) to confirm participants (N=14) did not use smokeless tobacco
during the laboratory phase. Comparisons between the baseline assessment and the four-week post-laboratory assessment (N=10) evaluated quit attempt success.

**Self-Reported Smoking.** Participants were asked questions about cigarette use during all phases of the study. The average number of daily cigarettes reported during the screening session was used as an inclusion criterion (≥10 cigarettes). During abstinence (nights two and three) of the laboratory phase, participants were asked if they smoked even a puff since the final cigarette, and if they used any smokeless tobacco products while away from the laboratory. During the post-laboratory phase, participants were asked to keep track of their first puff of cigarette if smoking resumed, in order to quantify time to relapse. Analyses focused on comparisons between the baseline and the four-week post-laboratory assessments (N=10) in order to evaluate quit attempt success.

**Subjective Dependence Patterns**

*Fagerström Test for Nicotine Dependence (FTND).* This instrument evaluated subjective nicotine dependence level (low, low to moderate, moderate, and high) at the baseline assessment and the four-week post-laboratory assessment. Analyses focused on comparisons between these two assessments (N=10) to examine changes in subjective nicotine dependence after the quit attempt.

*Brief Wisconsin Inventory of Smoking Dependence Motives (BWISDM).* This instrument evaluated smoking dependence motives at the baseline assessment and the four-week post-laboratory assessment. Overall score, and the 11 subscales of affiliative attachment, automaticity, loss of control, cognitive enhancement, craving, cue exposure/associative processes, social/environmental goads (increasing smoking motivation), taste, tolerance, weight control, and affective enhancement were evaluated. Analyses focused on comparisons between the
baseline and the four-week post-laboratory assessments (N=10) to examine changes in smoking dependence motives after the quit attempt.

1.2.4 Sleep Measures

**Objective Sleep**

*Polysomnography (PSG)-Recorded Sleep.* The PSG recordings were scored visually according to the criteria of the American Academy of Sleep Medicine (Iber et al., 2007). Differences in sleep architecture between smoking consumption (night one) and abstinence (nights two and three) were investigated for the following sleep variables: total sleep time (TST), sleep efficiency (SE), durations of sleep stages N1, N2, N3, and REM, and latencies to sleep onset (SL), stage N3 (SLN3), and REM (REML). Wake after sleep onset (WASO), wake during the sleep period time (WSPT; wake after sleep onset but before the final awakening), time after final awakening (TAFA; final awakening to lights on), arousal index (AI; brief disruptions during sleep), stage shifts index (SSI; stage changes), peripheral blood oxygen saturation (SpO₂) nadir levels, apnea hypopnea index (AHI), leg movement index (LMI), and leg movement index with arousal (LMIA) were also examined in all N=14 smokers. The PSG-recorded sleep variables were also correlated with self-reported time to relapse, to determine if sleep disturbance was associated with time to relapse.

*Wrist Actigraphy.* Participants (N=14) wore actigraphs all three nights in the laboratory. Differences in the smokers rest/activity patterns between smoking consumption (night one) and abstinence (nights two and three) were investigated for the variables of sleep duration, sleep efficiency, intermittent wakefulness, and time to fall asleep.
Objective Sleep – Comparisons with the Control Group

PSG-Recorded Sleep. The PSG sleep variables were compared between the smokers (N=14) and an age- and sex-matched control group of non-smokers from another study with three consecutive PSG recordings (10 hours time in bed, 22:00–08:00). AHI, LMI, LMIA, and the last two nights of SpO$_2$ nadir levels were not compared because they were not recorded in the controls.

Self-Reported Sleep

Pittsburgh Sleep Quality Index (PSQI). This instrument evaluated subjective sleep quality at the baseline assessment and again at the four-week post-laboratory assessment. The main variable of interest was the PSQI global score which is an indicator of overall sleep quality. Analyses focused on comparisons between the baseline assessment and the four-week post-laboratory assessment (N=10) to examine sleep quality changes after the quit attempt.

Sleep Diary. N=14 participants kept a sleep diary and recorded subjective assessments of sleep and daily activities in the three days and nights prior to entering the laboratory and during the three nights in the laboratory. Analyses focused on differences between smoking days (three days pre-laboratory and first laboratory night) and abstinence (nights two and three in laboratory) with regard to the variables of self-reported sleep duration, number and duration of nighttime awakenings, duration of daytime naps, number of cigarettes, number of caffeinated drinks, amount of exercise, and visual analog scales of how well participants slept and how well they were feeling.
**Self-Reported Sleep – Comparisons with the Control Group**

*PSQI*. PSQI global scores were compared between the smokers (N=14) and the age- and sex-matched control group to determine if there were baseline sleep quality differences between groups.

*Sleep Diary*. Comparisons between smokers (N=14) and controls (N=14) were limited, because controls did not fill out a sleep diary during the laboratory phase; the sleep diaries used in the studies varied slightly; and the controls were not allowed to nap or consume caffeinated beverages in the week prior to entering the laboratory. Therefore, only comparisons with self-reported sleep duration, number and duration of nighttime awakenings, and visual analog scales of how well participants slept and how well they were feeling were compared between the two groups on the three days prior to entering the laboratory.

### 1.2.5 Daytime Symptoms

**Subjective Smoking Characteristics and Mood Symptoms**

*Visual Analog Scales (VAS)*. These instruments evaluated desire to smoke, withdrawal symptoms, irritability, stress, and anxiety in the smokers during all phases of the study. Analyses focused on comparisons between smoking consumption (night one) and abstinence (nights two and three) to determine if subjective smoking characteristics changed during abstinence (N=14). Comparisons between the baseline assessment and the four-week post-laboratory assessment (N=10) evaluated whether smoking characteristics had changed after the quit attempt.

*Patient Health Questionnaire-9 (PHQ9)*. The PHQ9 was used as an inclusion criterion (≤14) during the screening session to rule out participants with major depression. This questionnaire was also completed during the laboratory and post-laboratory phases to evaluate depressive symptoms. Analyses focused on comparisons between smoking consumption (night
one) and abstinence (nights two and three) to determine if depressive symptoms changed with abstinence (N=14). Comparisons between the baseline assessment and the four-week post-laboratory assessment (N=10) evaluated whether depressive symptoms changed after the quit attempt.

**Subjective Sleepiness Measures**

*Karolinska Sleepiness Scale (KSS).* This questionnaire was used during all phases of the study for self-assessments of momentary sleepiness. Comparisons were made between smoking consumption (night one) and abstinence (nights two and three) to determine whether changes in subjective sleepiness occurred with abstinence in all N=14 participants.

*Epworth Sleepiness Scale (ESS).* This questionnaire was used as an inclusion criterion (≤10) during the screening session to exclude participants with abnormal levels of daytime sleepiness. It was completed at the baseline assessment and at the four-week assessment. Comparisons were made between these assessments (N=10) to see if daytime sleepiness changed after the quit attempt.

**Subjective Sleepiness – Comparisons with the Control Group**

*KSS.* The smokers (N=14) and the control group completed the questionnaires at similar times during the three nights in the laboratory. Results were compared between the two groups to evaluate differences in momentary sleepiness in the laboratory.

*ESS.* Baseline scores were compared between smokers (N=14) and controls (N=14) in order to determine baseline differences in daytime sleepiness between the groups.
1.3 Results

1.3.1 Smoking Behavior

*Smoking Status.* The 14 participants completed the two nights of abstinence in the laboratory without smoking. However, all participants relapsed prior to the two week follow-up session. The self-reported time to smoking relapse ranged from 52.5 hours to 326 hours, with 50% of participants relapsing by 62 hours after the final cigarette.

*CO.* There was a significant decrease in breath CO samples during abstinence in the laboratory phase of the study, demonstrating that participants refrained from smoking during the abstinence period. There was no change in CO from the baseline pre-laboratory assessment to the four-week post-laboratory assessment.

*UCot.* There was a significant decrease in UCot levels during abstinence in the laboratory phase of the study. Consistent with the CO results, there was no change in UCot from the baseline pre-laboratory assessment to the four-week post-laboratory assessment.

*Self-Reported Smoking.* There was no change from the baseline pre-laboratory assessment to the first night of the study in daily reported cigarettes, suggesting participants did not taper or increase consumption of cigarettes in anticipation of the quit attempt. There was a significant decrease in self-reported cigarettes from the baseline assessment to the four-week post-laboratory assessment, indicating that self-report cigarette consumption decreased after the quit attempt.

*Subjective Dependence Patterns*

*FTND.* The FTND scores decreased from the baseline pre-laboratory assessment to the four-week post-laboratory assessment, demonstrating subjective nicotine dependence decreased after the quit attempt.
The affective enhancement component of the BWISDM was the only variable examined that significantly changed from the baseline assessment to the four week post-laboratory assessment. Affective enhancement decreased after the quit attempt, indicating a reduction in the belief that smoking improves mood.

1.3.2 Sleep Measures

Objective Sleep

PSG-Recorded Sleep. Significant changes from the smoking night to the abstinence nights were only observed for sleep latency, with smokers taking longer to fall asleep after smoking than during abstinence. Stage N3 duration was positively correlated with time to relapse.

Wrist Actigraphy. There were no significant changes in rest/activity patterns between smoking consumption (night one) and abstinence (nights two and three) for the variables of sleep duration, sleep efficiency, intermittent wakefulness, and time to fall asleep.

Objective Sleep – Comparisons with the Control Group

PSG-Recorded Sleep. When PSG-recorded sleep was compared between the smokers and controls, the smokers had more disrupted sleep than the controls on all three nights, with more N1, less N3, more arousals, and a longer time to reach stage N3 from sleep onset.

Self-reported Sleep

PSQI. Subjective sleep quality did not change significantly in the smokers from the baseline assessment to the four-week assessment.

Sleep Diary. There were no differences in self-reported sleep duration, duration of nighttime awakenings, duration of daytime naps, number of caffeinated drinks, and amount of exercise during the three pre-laboratory days and the first laboratory day, when participants were
smoking, versus the two laboratory days, during abstinence. Subjects reported to sleep worse during the first laboratory night as evidenced by more self-reported awakenings and VAS reports of sleeping more poorly on the first night.

**Self-reported Sleep – Comparisons with the Control Group**

*PSQI.* There was a difference between groups in baseline sleep quality with the smokers having significantly higher global scores, but still within the normal range.

*Sleep Diary.* Paradoxically, in the three consecutive days prior to entering the laboratory, the smokers reported greater sleep duration, fewer awakenings, and felt more alert, as compared to the controls.

**1.3.3 Daytime Symptoms**

*Subjective Smoking Characteristics and Mood Symptoms*

*VAS.* In the smokers, subjective data from the VAS showed an increase in withdrawal symptoms and irritability during abstinence. There were no changes across nights for desire to smoke, stress, or anxiety.

*PHQ9.* In the smokers, there were no changes in depressive/mood symptoms with abstinence during the laboratory phase of the study. There were also no differences between the baseline assessment and the four-week assessment.

*Subjective Sleepiness Measures*

*KSS.* There was a significant change across time in levels of subjective sleepiness during the laboratory. Smokers reported higher levels of sleepiness before bed when compared to both the early evening and the morning tests. There were no changes in sleepiness during abstinence.
ESS. There were no significant changes in smokers’ daytime sleepiness scores from baseline to the four-week follow-up.

**Subjective Sleepiness – Comparisons with the Control Group**

*KSS*. Smokers reported higher levels of sleepiness on the KSS on all three nights as compared to controls. There was a significant interaction with smokers reporting an increase in sleepiness right before bed when compared to the controls.

ESS. There was no significant baseline difference in daytime sleepiness between the smokers and the controls.

### 1.4 Conclusions

The main goal of this study was to examine polysomnographic sleep disturbance as a potential predictor of smoking relapse in cigarette smokers trying to quit “cold turkey”. Consistent with the low success rate of quit attempts without treatment, all 14 participants relapsed before the end of the study. It was therefore not possible to compare the sleep of smokers who had relapsed to those who had successfully quit long-term.

Primary analyses focused on changes in sleep and daytime symptoms from smoking to abstinence. The study demonstrated an objective change in sleep during the quit attempt, namely, a decrease in sleep latency during abstinence. This represented an improvement in sleep relative to the smoking night, and could have been helpful in the quitting process. However, as expected, self-reported daytime symptoms revealed increases in irritability and withdrawal symptoms after smoking cessation. The increase in these daytime symptoms may have counteracted the positive effect of the improvement in sleep during abstinence. As such, after the quit attempt there may not have been any net improvement in subjective state.
Compared to age- and gender-matched, non-smoker controls, smokers exhibited more objective sleep disturbances both before and after the quit attempt, as indicated by more N1, less N3, more arousals, and greater N3 latency. Furthermore, the smokers experienced greater subjective sleepiness than controls throughout the three laboratory nights, regardless of smoking status. Yet, during the three days prior to entering the laboratory, smokers reported better sleep than the controls. This could be due to the timing of self-reporting; if participants smoked prior to completing the sleep diary, subjective symptoms attributed to the prior night’s sleep could have been masked by the stimulant effect of nicotine.

Overall, the study findings indicate that both smoking consumption and withdrawal disturb sleep and are associated with impairments in subjective daytime functioning. Nicotine is a stimulant known to disrupt sleep, so our finding that sleep was disturbed during smoking consumption is as expected. The observation that smokers reported daytime sleepiness before the quit attempt is notable; it is likely that the smokers used nicotine, in part, to mitigate sleepiness. This suggests that smoking behavior is a vicious cycle: smoking disrupts sleep, which leads to daytime sleepiness, which drives smokers to use nicotine to mitigate the sleepiness, and the nicotine in turn disrupts the sleep the next night, etc.

Importantly, our results found that during abstinence, the disrupted sleep and impairments in subjective daytime functioning did not disappear. This study did not reveal why the sleep and wake disturbances persisted. It may be a result of neurobiological changes (e.g., neurotransmitter receptor changes) induced by long-term nicotine use that take time to return to baseline. Regardless, the quit attempt without pharmacological intervention did not break the vicious cycle – the former smokers still continued to experience the symptoms that presumably
drove them to continue smoking. From this point of view, it is not surprising that all the smokers in the study eventually relapsed.

That said, even though all participants resumed smoking, there was variability in the time to relapse. This was positively correlated with the deepest stage of sleep (N3). Those with more deep sleep (N3) were more likely to hold off longer before resuming smoking. This finding provides preliminary evidence that N3, which is believed to be the most restorative part of sleep, may contribute to the ability to resist the desire to smoke. If this is replicated in a larger follow-up study, it would suggest that an intervention aimed at increasing N3 sleep could be explored to improve smoking cessation success.

In closing, this pilot study showed evidence for changes in objective sleep during abstinence as indicated by a decrease in the time to fall asleep. This positive effect may have been negated by the increases in self-reported daytime irritability and withdrawal symptoms, possibly perpetuating the resumption of smoking. In addition, there was greater sleep disturbance and daytime sleepiness in smokers compared to controls regardless of whether they were smoking or abstained. Further studies, investigating to what extent the persistent sleep disturbance and subjective daytime symptoms during abstinence contribute to the high relapse rate in smokers quitting without treatment, may reveal new treatment targets to aid smokers attempting to quit smoking.
2 INTRODUCTION

Tobacco use is prevalent worldwide and continues to be the number one cause of preventable death in the U.S. (USDHHS, 2010), with approximately 20% of all deaths tobacco related (CDCP, 2004). Despite well-known health risks and increased mortality rates caused by smoking (Warren, Alberg, Kraft, & Cummings, 2014), 45 million U.S. adults smoke cigarettes (CDCP, 2004). Of the 70% of smokers who would like to quit each year, 50% of smokers actually attempt to quit, with half of those relapsing within the first week. Only approximately 6% that try to quit are successful at abstaining from smoking for longer than six months (CDCP, 2011). Furthermore, it typically takes 6–10 quit attempts before a smoker is finally successful at quitting (USDHHS, 2004). Given the adverse health consequences of cigarette smoking and the difficulty of quitting, predictors of smoking relapse are needed to target treatments and improve cessation rates.

Relapse is multidimensional and typically involves an interaction between many different risk factors and emergent processes that can vary during the quit attempt (Warren, et al., 2014). Several studies have examined predictors that increase risk for cigarette smoking relapse. For example, those with higher levels of nicotine dependence (Breslau & Johnson, 2000; Ferguson et al., 2003; Hymowitz et al., 1997; Nørregaard, Tønnesen, & Petersen, 1993; Piper et al., 2006; Shiffman et al., 2004; Zhou et al., 2009); greater severity and duration of withdrawal symptoms (Aubin et al., 2010; Hughes, Gust, & Keenan, 1990; Piasecki et al., 2002); presence of other smokers in the household, workplace, or social network (Derby et al., 1994; Garvey et al., 2000; Hymowitz et al., 1997; Lee & Kahende, 2007, Zhou et al., 2009); psychiatric illness (Ferguson et al., 2003; Perez et al., 2008), alcohol use (Hughes, Rose, & Callas, 2000); stress (Aubin, et al., 2010); and past quit attempt history (Ferguson et al., 2003; Hymowitz et al., 1997; Lee & Kahende, 2007; Murray et al., 2000), have all been shown to be risk factors for smoking relapse.
Studies have also shown a link between self-reported sleep disturbance and relapse to cigarette smoking. This is relevant and important because sleep can affect so many different processes, including mood and reaction to stressors (Fortunato & Harsh, 2006; Pilcher & Huffcutt, 1996) which have been shown to increase relapse risk. In addition, research has suggested that poor sleep quality are both a symptom of and a cause for addiction (Brower & Perron, 2010).

Sleep disturbance has been extensively replicated to predict relapse in alcoholics. Multiple studies have demonstrated alcoholics with baseline impairments of falling asleep and/or more rapid eye movement (REM) sleep are more likely to relapse (for review see Brower, 2003). Sleep disturbance as a predictor of relapse in other substance abuse disorders including: cocaine, amphetamines, opioids, sedative-hypnotics, and nicotine found in cigarettes, are not well-understood and needs to be investigated further (Brower & Perron, 2010). More well-designed studies using polysomnography (PSG; i.e., EEG-based sleep recordings) are needed to better understand the roles of cigarette smoking and nicotine withdrawal in sleep in order to predict relapse (Colrain, Trinder, & Swan, 2004).

The addictive substance in cigarettes is nicotine, which is a psychostimulant shown to reduce sleepiness but also cause sleep disruption. Limited research using PSG to examine differences in sleep between smokers and controls showed that smokers had longer times to fall asleep (Jaehne 2012; Soldatos 1980; Zhang 2006) and reduced total sleep time (Soldatos 1980; Zhang 2006). Results are mixed across studies (for review see Jaehne 2009) with regard to other sleep parameters, such as smokers having more light stages of non-REM (NREM) sleep (stages N1 and N2) and less deep sleep (stage N3) (Zhang 2006); more REM density, apneic events, and leg movements (Jaehne 2012); and more alpha power (during REM and NREM sleep) and less
delta power (during NREM sleep) in the EEG (Zhang 2008). The methodologies of these studies were different, with variations in age range, caffeine consumption, and allowance of comorbid conditions and psychotropic medications which might account for the differences between studies.

Sleep disturbance is also common in smokers during nicotine withdrawal. Studies using self-reported sleep measures showed increased awakenings during smoking cessation (Hatsukami et al., 1984; Hatsukami et al., 1988; Shiffman et al., 1995). Only a handful of studies employing PSG during withdrawal (not to predict relapse) have been conducted to date, yielding inconsistent results. One study showed improvements in sleep during withdrawal, with a decreased sleep latency and increased total sleep time (Soldatos et al., 1980). Two other studies did not show any sleep stage changes or sleep latency differences from smoking to withdrawal, but showed an increase in the number of arousals after withdrawal (Prosise et al., 1994; Jaehne et al., 2014).

Several studies examining predictors of smoking relapse have found self-reported sleep disturbance to be a predictor of smoking relapse. Baseline reports of awakening to smoke (Bover et al., 2008; Foulds et al., 2006; Riemerth et al., 2009); non-specific “awakenings during the night” (Boutou et al., 2008); and self-reported “symptoms or troubles with insomnia” (Augustson et al., 2008) were predictive of future relapse. For estimates of sleep duration, results were mixed as to how this predicted relapse. One study found that more sleep duration predicted success at quitting (Rapp, Buechele, & Weiland., 2007), while a different study paradoxically found that those with greater self-estimated sleep duration at baseline was a predictor of relapse (Persico, 1992).
The self-reported symptoms of sleep disturbance associated with smoking cessation have thus far not been well defined and quantified, and results have been mixed as to the types of sleep disturbance involved. Furthermore, to our knowledge, only one study published to date (Jaehne et al., 2014; to be discussed later) has examined sleep disturbance objectively using polysomnography (PSG), the gold standard of sleep measurement (Ancoli-Israel et al., 2003). This is problematic because subjective sleep reports are imprecise and unreliable, yielding inaccurate estimates of sleep duration, awakenings, and times to fall asleep (Carskadon et al., 1976; Frankel et al., 1976; Means et al., 2003). It has thus remained unclear what aspects of sleep physiology (e.g., increased sleep onset latency, intermittent wakefulness, altered sleep stage distribution, micro-arousals) are related to and may underlie the risk of relapse. More precise, objective data using PSG are needed to evaluate sleep quality and sleep architecture in order to eventually target the development of treatments (Colrain et al., 2004).

Given the estimates of 6–10 quit attempts needed on average in order to eventually be successful at sustained abstinence (USDHHS, 2004), studies examining failed quit attempts and the reasons for relapse may also be informative. There may be predictors within the failed attempt that may aid in making the next quit attempt more successful. Such predictors could be the target of development for intervention strategies.

To help fill these gaps in the current literature, this laboratory-based study examined sleep disturbance in cigarette smokers trying to quit without treatment, using PSG.

Moderate cigarette smokers came into the lab for three consecutive nights of PSG recording—one night before the quit attempt (normal smoking consumption) and two nights during the quit attempt (abstinence). After these three recording days, participants came to the laboratory on a weekly basis for four consecutive weeks to test for relapse. Smoking behavior was assessed
throughout the study with biochemical measures, self-report, and subjective dependency measures. Daytime symptoms of sleepiness, withdrawal symptoms, and mood were measured using self-report instruments.

Analyses focused on how the change in smoking status from smoking consumption to abstinence affected sleep and daytime symptoms in order to identify candidate predictors of smoking relapse. PSG-recorded sleep variables, subjective sleep measures, and subjective sleepiness were also compared to an age- and gender-matched, non-smoker control group who spent three consecutive nights in a sleep laboratory.
3 METHODS

3.1 Experimental Group – Cigarette Smokers

3.1.1 Inclusion/Exclusion Criteria

The targeted sample included moderate to heavy smokers, who smoked ≥10 cigarettes per day, but not smokeless tobacco. They were recruited for their willingness to quit “cold turkey”. They were young adults (aged 22–39), physically and psychologically healthy (besides smoking), not taking any medications, and carefully screened for sleep disorders. In addition, participants had self-reported sleep durations between six and 10 hours per day, bedtimes between 20:00 and midnight, and wake-up times between 06:00 and 10:00. For the full set of inclusion criteria for the experimental group, see Table 1, column 2.

The inclusion criteria were chosen to avoid confounds associated with the dependent or independent variables being studied. For smoking criteria, moderate to heavy smokers were selected with the expectation that they would yield robust effect sizes. Those who used smokeless tobacco, including electronic cigarettes, were not included in order to avoid confounds related to route of administration and chemical properties. The age range of 22–40 was chosen because of age-related changes in sleep architecture (Ohayon & Carskadon, 2004) and increased objective and subjective sleep disturbance associated with old age (Vitiello, Larsen, & Moe, 2004), and to be able to compare sleep data to a control group (Section 3.2). Habitual bedtimes and wake times were selected within two hours on each side of the 22:00 bedtime and 08:00 wake-up time regime in the laboratory portion of the study, to avoid sleep disturbance potentially associated with significant shifts in sleep timing.

Smoking criteria were assessed with questionnaires for smoking status; and carbon monoxide (CO) level and self-reported number of cigarettes for smoking level (moderate to heavy). Participants were generally healthy, with no clinical disorders or illnesses, as verified
with questionnaires, physical exam, and history. Participants were screened for sleep apnea with the Multivariate Apnea Prediction (MAP) index (Maislin et al., 1995). Participants with abnormal daytime sleepiness were excluded based on the Epworth Sleepiness Scale (ESS) (Johns, 1991). The Holland Sleep Disorders Questionnaire (Kerkhof et al., 2013), the Insomnia Symptom Questionnaire (ISQ; Okun et al., 2009), and the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) were used to flag potential sleep disorders.
<table>
<thead>
<tr>
<th>Criteria</th>
<th>Smokers</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking Status</td>
<td>Current smoker wanting to quit;</td>
<td>Not a current smoker</td>
</tr>
<tr>
<td></td>
<td>Has not begun quitting process;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No smokeless tobacco use (including</td>
<td></td>
</tr>
<tr>
<td></td>
<td>electronic cigarettes)</td>
<td></td>
</tr>
<tr>
<td>Smoking Level</td>
<td>Smoke $\geq 10$ cigarettes per day;</td>
<td>N/A</td>
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<tr>
<td></td>
<td>Smoke within 60 min of waking;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CO$^a$ $\geq 10$ ppm$^b$ on initial visit</td>
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</tr>
<tr>
<td>Sleep Health</td>
<td>ESS$^c$ $&lt;11$;</td>
<td>ESS$^c$ $&lt;10$;</td>
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<tr>
<td></td>
<td>MAP$^d$ index $&lt;0.5$;</td>
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<tr>
<td></td>
<td>No sleep or circadian disorder by history</td>
<td>No sleep or circadian disorder by history;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSQI$^e$ $&lt;6$</td>
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<tr>
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</tr>
<tr>
<td></td>
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<td>Wake time 06:00–09:00;</td>
</tr>
<tr>
<td></td>
<td>Bedtime 20:00–midnight</td>
<td>Maintain habitual sleep pattern in week</td>
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<td>Time-Zone Travel</td>
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<td>Not within one month of study</td>
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<td>Shift Work</td>
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<td>Not within three months of study</td>
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<td>Physical Health</td>
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<tr>
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<td>PHQ9$^g$ $&lt;15$</td>
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<tr>
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<td>No history of methamphetamine abuse;</td>
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</tr>
<tr>
<td></td>
<td>Free from traces of drugs (besides</td>
<td>Free from traces of drugs;</td>
</tr>
<tr>
<td></td>
<td>nicotine);</td>
<td></td>
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<tr>
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<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>English Speaker</td>
<td>Proficient at English</td>
<td>Proficient at English</td>
</tr>
</tbody>
</table>

Note. $^a$CO = carbon monoxide. $^b$ppm = parts per million. $^c$ESS = Epworth Sleepiness Scale.
$^d$MAP = Multivariate Apnea Prediction. $^e$PSQI = Pittsburgh Sleep Quality Index. $^f$Oral contraceptives allowed.
$^g$PHQ9 = Patient Health Questionnaire 9.
### 3.1.2 Study design

The study was divided into three phases: pre-laboratory phase, laboratory phase, and post-laboratory phase. The pre-laboratory phase involved screening of participants, a baseline assessment for questionnaires and sample measurements, and at-home assessments where participants reported sleep and activities. In the laboratory phase, participants’ sleep was recorded for three consecutive nights; one night before the quit attempt (normal smoking consumption) and two nights immediately after (abstinence). The post-laboratory phase involved participants returning to the laboratory on a weekly basis for four weeks to fill out questionnaires and biochemical testing for smoking relapse.

The study was approved by the Institutional Review Board (IRB) of Washington State University (IRB# 13177; See Appendix A for Consent Form). All participants were compensated for their participation. Participants were compensated in two installments, once after the laboratory phase and once after the post-laboratory phase.

**Pre-Laboratory phase.** Cigarette smokers who were interested in quitting without treatment (“cold turkey”) were recruited with flyers and advertisements (Appendix B). Participants were pre-screened over the telephone (Appendix C) to determine pre-eligibility. Pre-eligible participants were given a description of the study, and interested participants were invited to come to the laboratory for a screening session. Those who were found to be ineligible or not interested during the telephone interview were given the phone number of the national smoking quit-line (1-800-QUIT-NOW).

During the laboratory screening session, which took approximately three hours, written informed consent was obtained. Participants also filled out questionnaires of smoking behavior, self-reported sleep, and daytime symptoms. Biochemical tests were performed to objectively
measure smoking status, and height and weight were measured to calculate body mass index (BMI). All participants were given an information sheet about tips to quit smoking, modified from a National Institutes of Health (NIH) web page (Appendix D).

Once pre-eligibility was determined, the physician of record took a history and performed a physical examination to ensure participants were physically and psychologically healthy. Female participants gave a urine sample to check for pregnancy. After this session, eligible participants were enrolled in the study. Information from the questionnaires (e.g., self-reported number of cigarettes, PSQI global score, ESS total score, etc.) and physical examination (e.g., blood pressure, heart rate, BMI, etc.) were obtained during the screening session and constituted as the pre-laboratory baseline assessment.

At-home assessments were done on the three days prior to the start of the laboratory phase of the study. Participants were asked to maintain their regular smoking patterns, activities, and sleeping patterns (including napping) during this time. They were instructed to fill out the sleep and activities diary each morning upon awakening, and in the evening immediately before going to bed. In addition, each day participants called in their bedtimes, wake times, and the number of cigarettes smoked.

**Laboratory phase.** Participants spent three consecutive nights (18:00–09:00) in a sleep laboratory, both during smoking consumption (night one) and during the initial part of a quit attempt during abstinence (nights two and three). See Figure 1 for a diagram of the laboratory phase study design. Sleep periods were 10 hours time in bed (22:00–08:00) and were recorded with polysomnography. While inside the laboratory, participants wore a wrist actigraph to document their rest/activity patterns. Participants filled out questionnaires on smoking behavior and daily activities, self-reported sleep (sleep diary), and daytime symptoms (sleepiness, mood...
and withdrawal symptoms), at the same times each day (18:30, 21:15, and 08:20). Meals took place at 19:45 and 08:40 on each of the days. Participants left the laboratory from 09:00 until 18:00 during the daytime to make the quit attempt more realistic by exposing them to naturalistic smoking cues.

**Figure 1.** Participants spent three consecutive nights in a sleep laboratory both before and during the initial part of a quit attempt. Biochemical tests were performed to verify smoking status throughout the study (C=Carbon monoxide; U=Urine cotinine). On the first night, participants were allowed to smoke (cigarette symbol) at 19:30, 20:30, 21:30 and anytime during the sleep period. Following a 10 hour PSG-recorded sleep opportunity (22:00-08:00), at 08:30 the final cigarette was smoked (cigarette symbol) before the start of the quit attempt. Participants then left the laboratory during the day (white box) starting at 09:00. At 18:00 participants returned to test for smoking relapse. All procedures were the same for nights 2 and 3 except participants were to remain abstinent from smoking without treatment (blue color; no smoking symbol) if they wanted to continue to be in the study. Participants filled out questionnaires (*) on sleepiness, smoking characteristics, mood, and self-reported sleep at the same times throughout the study (18:30, 21:15, and 08:20). After night 3 at 09:00, marked the end of the laboratory phase and participants could resume smoking and still be allowed to continue in the study for the post-laboratory assessments.

Normal smoking consumption (night one). On the first night of the study, participants came to the laboratory at 18:00, and biochemical tests for smoking status, drug screen, and alcohol breathalyzer were administered. Upon passing the drug and alcohol screen, participants put on a wrist actigraph. They locked away all electronic devices and valuables, in order to limit distractions. At 18:30 and 21:15, participants filled out the questionnaires on smoking behavior, self-reported sleep, and daytime symptoms (Table 2). Preparation for PSG recordings started at 18:35 and continued until finished, in between other activities.
At 19:30, 20:30, and 21:30, participants were allowed a five minute smoking break. Participants could only smoke at these times during the waking period on night one. They were allowed to smoke at any time during the scheduled sleep period of the first laboratory night. During smoking breaks, participants were required to wear scrubs over their clothes in order to contain smells. Smoking occurred in a designated area outside, which was approximately 30 feet away from the entrance to the building. Research assistants monitored the participants from inside the building through a window, and would alert participants when two minutes remained in the break. After smoking, participants took off the scrubs and kept them in a cabinet outside the laboratory.

At 22:00, the lights were turned off in the bedrooms and participants went to bed. During the sleep period, participants were not allowed to watch television, listen to music, read, or use their cell phone. If they could not sleep they were instructed to lie quietly with the lights turned off. Participants were able to get up to use the bathroom, get a drink of water, or smoke at any time during the sleep period. Smoking breaks that occurred during the sleep period used the same smoking break procedures as described above.

Participants got out of bed at 08:00 on the morning of day two and filled out questionnaires at 08:20. At 08:30, all participants were required to smoke a final cigarette, after which point their quit attempt began. Immediately following the final cigarette, samples were taken of CO and urine cotinine (UCot; a metabolite of nicotine). Participants left the laboratory from 09:00 until 18:00, making the quit attempt more realistic by exposing them to naturalistic smoking cues. They were instructed to avoid cigarettes, other forms of tobacco, and nicotine medications, as well as drugs and alcoholic drinks.
Abstinence (nights two and three). For nights two and three, the participants returned to the laboratory at 18:00, and a CO breath sample was taken. CO levels were checked against a cut-off of <7 parts per million (ppm); any participant exceeding this level was deemed to have resumed smoking and happened on one occasion (see section 4.1 for explanation). Participants who were below the cut-off were allowed to continue in the study after a negative drug and alcohol test. All of the remaining procedures during the laboratory phase were the same as night one, except participants were not allowed to smoke and only UCot samples (not CO samples) were administered on the mornings after nights two and three.

The time from the final cigarette (08:30 in the morning of day two) to the time when the laboratory phase ended (09:00 in the morning of day four) was 48.5 hours.

Post-Laboratory phase. If participants made it through the entire laboratory phase without smoking, they were invited to continue in the study for post-laboratory assessments. Abstinence was not required during this phase. Participants were asked to keep track of their first puff of cigarette if they resumed smoking. This first puff of cigarette was used to define the timing of relapse in the study.

Post-laboratory assessments took place at 18:00 on night four (i.e., the first evening after the laboratory phase), and then on a weekly basis for four consecutive weeks after the quit attempt (referred to as the one-week, two-week, three-week, and four-week assessments). The weekly assessments were scheduled based on a convenient time for the participant to come in to the laboratory (between 08:00 and 18:00), and took about 10 minutes to complete. During these assessments, participants returned to the laboratory for CO and UCot tests and to fill out questionnaires on smoking behavior, self-reported sleep, and daytime symptoms.
If a participant missed an assessment, they were no longer invited to attend further post-laboratory assessments. However, they were invited to come to the laboratory for final biochemical samples and to fill out a questionnaire about the time to smoking relapse.

Upon completion of the post-laboratory assessments, all participants came to the laboratory one last time to pick up their check and to fill out a final study questionnaire about their quit attempt.

3.1.3 Measurement of Smoking Behavior

Smoking status

Measures of CO, UCot, and self-reported number of cigarettes were used to verify smoking status during all phases of the study (Table 2).

Carbon Monoxide (CO). The CO breath samples are reliable and valid at detecting recent smoking activity and are frequently used in smoking cessation studies (Hung et al., 2006; Jatlow et al., 2008). For this study, all CO samples were taken with the Micro+ smokerlyzer® CO meter (Bedfont Scientific Ltd., Harrietsham, England). For each sample, participants were instructed to breathe in deeply and hold their breath while the CO meter counted down from 10 seconds and then beeped. After the beep, participants blew out all of the air slowly, upon which the CO concentration was measured.

The CO sample that was taken during the screening session determined eligibility (≥10 ppm) and also served as the measurement for the baseline assessment. During the laboratory phase, CO samples were taken upon being admitted to the study on night one (18:00), immediately following the final cigarette on the morning of day two (08:35), and upon returning to the laboratory during abstinence on nights two and three (18:00). CO samples were the primary verification measure of abstinence during the laboratory phase, with a predetermined
cut-off value of <7 ppm based on previous research (Shafiq, et al, 2008). During the post-laboratory phase, CO samples were taken at each assessment (night four at 18:00, and one-week, two-week, three-week, and four-week assessments) to measure recent smoking activity.

Analyses focused on comparisons between smoking consumption (night one and sample after final cigarette) and abstinence (nights two and three) as verification that participants did not smoke during the laboratory phase. The degree of success of the quit attempt was evaluated by comparing the four-week post-laboratory assessment to the baseline assessment in those who completed all assessments.

**Urine Cotinine (UCot).** Cotinine is a metabolite of nicotine and is more typically used to measure tobacco use because of its longer half-life of 20 hours (Jarvis et al., 1988) compared to the two hour half-life of nicotine (Benowitz et al., 1982). Unlike CO, cotinine also detects smokeless tobacco use. During the baseline assessment, the NicQuick® (Instant Technologies Inc., Norfolk, VA) one step cotinine urine test device was used which is a qualitative test with a lateral flow chromatographic immunoassay for the detection of cotinine in urine at a cut-off concentration of 200 ng/ml. The TobacAlert® semi-quantitative urine test (Nymox Corporation, Hasbrouck Heights, NJ) was used as a measure of smoking status. During the UCot samples, participants gave a urine sample, the test strip was held in the sample container for 20 seconds, and then after at least 20 minutes to allow for binding, the test was read according to the lowest red band on the test strip. There were 7 total levels, with each level increasing in increments of 11. Level 00 indicated no tobacco exposure, levels 11, 22, and 33 indicated non-smoker but exposed to second-hand smoke, and levels 44, 55, and 66 indicated a user of tobacco products. The semi quantitative test indicates a range of cotinine per ng/ml for each level: level 00=0-6
ng/ml, level 11=6-30 ng/ml, level 22=30-100 ng/ml, level 33=100-200 ng/ml, level 44=200-500 ng/ml, level 55=500-1,000 ng/ml, and level 66=1,000+ ng/ml.

During the laboratory phase, semi-quantitative UCot samples were taken upon being admitted to the study on night one (18:00), immediately following the final cigarette on the morning of day two (08:35), and the mornings of days three and four (08:35). UCot was not used as a determinant of abstinence, but only as a secondary measure. During the post-laboratory phase, UCot samples were taken at each assessment (fourth day at 18:00, and one-week, two-week, three-week, and four-week assessments) to measure recent smoking activity.

Analyses focused on comparisons between smoking consumption (night one) and abstinence (nights two and three) to confirm participants did not use smokeless tobacco during the laboratory phase.

*Self-Reported Number of Cigarettes.* Participants were asked questions about cigarette use during all phases of the study. The number of cigarettes reported during the screening session determined eligibility (≥10 cigarettes) and also served as the baseline assessment. During the at-home assessment part of the pre-laboratory phase, participants called in the number of cigarettes smoked each day before going to bed. During the laboratory phase, participants reported the number of cigarettes on night one, and on nights two and three (during abstinence) they were asked if they smoked even a puff since the final cigarette.

During the post-laboratory phase, participants were asked to keep track of their first puff of cigarette if smoking resumed. This first puff of cigarette was used to define relapse and served to quantify the time to relapse. During the first week of smoking resumption, the total number of weekly cigarettes were added and divided by seven, in order to get an average daily number for
that week. For all other post-laboratory assessments following smoking resumption, participants reported the daily number of cigarettes smoked each day.

Analyses compared the baseline assessment to the first day of the laboratory phase to determine if participants changed their smoking behavior in preparation for the quit attempt. In addition, the degree of success of the quit attempt was evaluated by the comparison between the four-week post-laboratory assessment and the baseline pre-laboratory assessment in those who completed all assessments.

**Subjective smoking dependence.**

*Fagerström Test for Nicotine Dependence (FTND).* The FTND is a 6-item questionnaire used to assess nicotine dependence level (Heatherton et al., 1991). Participants’ item answers were totaled (each of the items total 1 except items 1 and 4 total 3) and level of dependence was determined based on the following categories: very low (scores from 0 to 2), low (scores of 3 or 4), medium (score of 5), high (scores of 6 or 7), and very high (scores from 8 to 10).

Participants took the FTND at both the baseline pre-laboratory assessment and the four-week post-laboratory assessment. Analyses focused on comparison between the two assessments to determine if smoking dependence changed after the quit attempt.

*Brief Wisconsin Inventory of Smoking Dependence Motives (BWISDM).* The BWISDM is a 37-item questionnaire used to assess different motives of smoking dependence (Smith et al., 2010). Smokers rated 37 smoking statements on a scale from one to seven, with one being “not true of me at all” and 7 being “extremely true of me”. Item ratings were summed for a total score as well as totals for the 11 subscales. Previous research (Piper et al., 2004) has shown that the four subscales of automaticity (smoking without awareness), loss of control (lost the will to control smoking), craving, and tolerance are the most important features of tobacco dependence.
These subscales were averaged for a primary dependence motives score. The other seven subscales, affiliative attachment (strong emotional attachment to smoking/cigarettes), cognitive enhancement (thought that smoking improves cognition), cue exposure/associative processes (cues and tendency to smoke), social/environmental goads (social/environmental contexts invite smoking), taste/sensory processes, weight control, and affective enhancement (smoking improves mood) were averaged for the secondary dependence motives score.

Participants took the BWISDM at both the baseline pre-laboratory assessment and the four-week post-laboratory assessment. Analyses focused on comparisons between the two assessments to determine if the total score and each of the subscales, changed after the quit attempt.
Table 2
Administration of Smoking Behavior, Sleep, and Daytime Symptom Measures for Each of the Three Study Phases

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pre-Laboratory Phase</th>
<th>Laboratory Phase</th>
<th>Post-Laboratory Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BL  AH 1  AH 2 AH 3</td>
<td>N1  D2  N2  D3  N3  D4</td>
<td>N4  1-Wk  2-Wk  3-Wk  4-Wk</td>
</tr>
<tr>
<td>Smoking Behavior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking Status</td>
<td>CO       S</td>
<td>S   S   S   S</td>
<td>S   S   S   S   S</td>
</tr>
<tr>
<td></td>
<td>UCot     S*</td>
<td>S   S   S   S</td>
<td>S   S   S   S   S</td>
</tr>
<tr>
<td></td>
<td>Self-Reported Cigs</td>
<td>S   S   S   S</td>
<td>S   S   S   S   S</td>
</tr>
<tr>
<td>Subjective Dependence</td>
<td>Fagerstrom</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BWISDM    S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Objective Sleep</td>
<td>PSG       B</td>
<td>B   B   B</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Actigraphy  B</td>
<td>B   B   B</td>
<td></td>
</tr>
<tr>
<td>Self-Reported Sleep</td>
<td>PSQI    B</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ISQ       S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Sleep Diary</td>
<td>B         B         B</td>
<td>S   S   S   S   S   S</td>
<td></td>
</tr>
<tr>
<td>Sleepiness</td>
<td>KSS       S</td>
<td>BB   B   BB  B   BB  B</td>
<td>S   S   S   S   S</td>
</tr>
<tr>
<td></td>
<td>ESS       B</td>
<td></td>
<td>S</td>
</tr>
<tr>
<td>Smoking and Mood</td>
<td>VAS       S</td>
<td>SS   S   SS  S   SS  S</td>
<td>S   S   S   S   S</td>
</tr>
<tr>
<td></td>
<td>PHQ9      S</td>
<td>S   S   S   S</td>
<td>S   S   S   S   S</td>
</tr>
</tbody>
</table>

3.1.4 Sleep Measures

Objective sleep

Polysomnography (PSG). All three laboratory sleep periods (22:00–08:00) were recorded using PSG with digital equipment (Nihon Kohden, Foothill Ranch, CA, USA) at a sampling rate of 200 Hz. The PSG recordings included electroencephalogram (EEG) to measure electrical activity of the brain; electromyogram (EMG) to measure muscle tone and movements of chin and legs; electrooculogram (EOG) to measure eye movements; electrocardiogram (ECG) to measure heart activity; a pulse oximeter to measure the percentage of hemoglobin that is saturated by oxygen (SpO$_2$); an oronasal thermister to measure airflow from the nose and mouth; electro-piezo respiratory belts to measure respiratory effort from the chest and abdomen; and a snore microphone to measure snoring events.

The PSG recording parameters and electrode montage were in accordance with the American Academy of Sleep Medicine recommended guidelines (Iber et al., 2007) except the following (owing to technical limitations of the recording set-up): the EEG low frequency filter (LFF) was set at 0.16 Hz instead of the recommended 0.30 Hz; the leg EMG LFF was at 53 Hz and the high frequency filter (HFF) was at 70 Hz; the EOG used the alternative acceptable derivations with both E1 and E2 placed 1 cm below and 1 cm lateral to the outer canthus, cross-referenced to the opposite mastoid (M1 and M2); the ECG leads were placed sub-clavicle on the left and right side from the center of the chest; electro-piezo crystal respiratory belts were used to measure respiratory effort; and no nasal air pressure transducer channel was used.
Electrode placements for EEG derivations (Figure 2) were measured according to the International 10-20 Electrode Placement System (Jasper, 1958) and placed at F3 (frontal left), F4 (frontal right), C3 (central left), C4 (central right), O1 (occipital left), and O2 (occipital right). All were unipolar derivations, cross-referenced to the opposite mastoid (M1 or M2). At the end of the PSG hook-up, electrode impedances were checked and aimed to be < 5 kΩ.

All records were manually scored by the author on the day of the recording to avoid bias in case of relapse occurring during the subsequent day. Records were scored in 30 second epochs, according to the criteria of the AASM (2007). PSG recording quality was high; none of the records were lost due to equipment failure or unscorable due to artifact.

**Figure 2.** Diagram of the electrode locations according to the International 10-20 Electrode Placement System for electroencephalography. Electrodes were placed at F3, F4, C3, C4, O1, and O2 and cross-referenced to the opposite mastoid. The A1 and A2 as pictured are now referred to as M1 and M2 (mastoid) according to the AASM (2007). Diagram credit (Wikipedia “10-20 system (EEG)”, open source).
Analyses focused on differences in sleep architecture between night one (smoking consumption) and nights two and three (abstinence). The following sleep variables were analyzed: total sleep time (TST), sleep efficiency (SE), durations of sleep stages N1, N2, N3, and REM; latencies to sleep onset (SL), stage N3 (SLN3), and REM (REML); wake after sleep onset (WASO), wake during the sleep period time (WSPT; wake after sleep onset but before the final awakening), time after final awakening (TAFA; final awakening to lights on), arousal index (AI; brief disruptions during sleep), stage shifts index (SSI; number of stage changes), peripheral blood oxygen saturation (SpO2) nadir level, apnea hypopnea index (AHI), leg movement index (LMI), and leg movement index with arousal (LMIA). Sleep latency was defined as the time from lights out until the first epoch of any stage of sleep. Stage N3 and REM latencies were defined as the time from sleep onset to the first epoch of N3 and REM, respectively.

The PSG-recorded sleep variables that changed with abstinence were also correlated with self-reported time to relapse, to determine if any aspects of sleep architecture were associated with time to relapse.

Wrist actigraphy. Actigraphy was used to evaluate rest/activity patterns during all three nights of the laboratory phase. The actigraphs used were the Actiwatch 2 (Philips Respironics, Murrysville, PA, USA), with placement on the non-dominant wrist. Participants wore the actigraphs while in the laboratory and took them off each morning before leaving.

Comparisons were made to determine if rest/activity patterns changed between smoking consumption (night one) and abstinence (nights two and three) for the variables of sleep duration, sleep efficiency, intermittent wakefulness, time to fall asleep.
**Self-reported sleep**

*Pittsburgh Sleep Quality Index (PSQI).* The PSQI is a 19-item, validated questionnaire used to assess sleep quality and sleep disturbance in the past month (Buysse et al., 1989). The questionnaire is comprised of seven component scores: sleep quality, sleep latency, sleep efficiency, sleep duration, sleep disturbances, use of sleeping medication, and daytime dysfunction. The component scores are totaled to create a PSQI global score which determines the severity of sleep problems. Global scores <6 are considered to be within the healthy range.

Participants took the PSQI at both the baseline pre-laboratory assessment and the four-week post-laboratory assessment. Analyses focused on comparisons between the two assessments to determine if the global scores changed one month after the quit attempt.

*Sleep diary.* A sleep and activities diary (see Appendix E) evaluated subjective assessments of sleep and daily activities in the three days and nights prior to entering the laboratory and during the three nights in the laboratory. Participants provided information on self-reported sleep duration, number and duration of nighttime awakenings, duration of daytime naps, number of cigarettes, number of caffeinated drinks, number of alcoholic drinks and minutes and type of exercise. The diary also included visual analog scales of how well participants slept and how well they were feeling.

Analyses focused on differences between smoking days (three days pre-laboratory and first laboratory night) and abstinence (nights two and three in the laboratory) to determine if self-reported sleep and activities changed during abstinence.
3.1.5 Daytime Symptoms

*Subjective smoking characteristics and mood symptoms*

*Visual Analog Scale (VAS).* VASs have been used in smoking studies for desire to smoke and nicotine withdrawal symptoms to measure smokers’ subjective experience during the quitting process (Dallery et al., 2003; Houtsmuller & Stitzer, 1999; Schuh & Stitzer, 1995). For this study, VASs were used to assess “current desire to smoke”, “withdrawal symptoms”, “irritability”, “stress”, and “anxiety”, in a range from 0 to 100 anchored by the terms “None” and “Very Strong”. For each of the scales, participants marked with an intersecting line where on the continuum between the anchors they rated themselves.

Participants took the VASs at the baseline pre-laboratory assessment, during all three nights of the laboratory phase (at 18:30, 21:15, and 08:20), and during each of the post-laboratory assessments. Analyses focused on comparisons between smoking consumption (night one, and the morning of day two) and abstinence (nights two and three, and days three and four) to determine whether changes in subjective smoking characteristics and mood occurred with abstinence during the laboratory phase of the study.

*Patient Health Questionnaire-9 (PHQ-9).* The PHQ-9 is a 9-item self-administered questionnaire used to diagnose depressive disorders and their severity (Kroenke, Spitzer, & Williams, 2001). Individuals are asked “Over the last 2 weeks, how often have you been bothered by any of the following problems?” with choices of 0 = “not at all”, 1 = “several days”, 2 = “more than half the days”, and 3 = “nearly every day”, for a total possible score of 27. Scores >14 are considered to be diagnostic of major depression and served as an exclusion criterion for at the baseline assessment.
Participants took the PHQ-9 at the baseline pre-laboratory assessment, during all three nights of the laboratory phase (at 18:30), and during each of the post-laboratory assessments. Analyses focused on comparisons between smoking consumption (night one, and the morning of day two) and abstinence (nights two and three) to determine whether changes in depressive symptoms occurred with abstinence during the laboratory phase of the study. A comparison between the baseline assessment and the four-week post-laboratory assessment evaluated whether depressive symptoms had changed after the quit attempt.

**Subjective sleepiness measures**

*Karolinska Sleepiness Scale (KSS).* The KSS is a validated tool for self-assessment of momentary sleepiness (Åkerstedt & Gillberg, 1990; for review see Åkerstedt et al., 2014). It consists of a nine-point Likert-type scale, with participants checking a box next to the point that describes how sleepy they feel right now. Word descriptors are for points 1, 3, 5, 7, and 9: 1 - “extremely alert”; 3 - “alert”; 5 - “neither alert nor sleepy”; 7 - “sleepy – but no difficulty remaining awake”; and 9 - “extremely sleepy – fighting sleep”.

Participants took the KSS at the baseline pre-laboratory assessment, during all three nights of the laboratory phase (at 18:30, 21:15, and 08:20), and during each of the post-laboratory assessments. Analyses focused on comparisons between smoking consumption (night one, and the morning of day two) and abstinence (nights two and three, and days three and four) to determine whether changes in subjective sleepiness occurred with abstinence during the laboratory phase of the study.

*Epworth Sleepiness Scale (ESS).* The ESS is an eight-item questionnaire used to assess levels of daytime sleepiness (Johns, 1991). Participants rated the chance of dozing or sleeping in specific daytime situations with 0 = no chance of dozing; 1 = slights chance of dozing;
2 = moderate chance of dozing; 3 = high chance of dozing. The total ESS score ranges from 0 to 24. ESS total scores have been shown to be significantly correlated with sleep latency measured during PSG, and individuals with scores >10 are considered to be excessively sleepy and suspected to have a sleep disorder (Johns, 1991).

In this study the ESS was used as an exclusion criterion (>10) to exclude participants with abnormal levels of daytime sleepiness. Participants also completed the ESS at the four-week post-laboratory assessment; the score was compared to that measured at baseline in order to evaluate excessive daytime sleepiness changes after the quit attempt.

### 3.2 Control Group

The results of the smokers were compared to an age- and sex-matched control group of non-smokers to determine if there were differences between groups in measures of polysomnography, self-reported sleep, and sleepiness measures. The controls were taken from part of a previously completed, NIH-funded laboratory study aimed to examine the effects of sleep deprivation on information processing in risky decision making situations (Grant et al., 2013). The controls were from the non-sleep-deprived control group of that study. Controls were matched to the smoker by gender and the closest age. Ten pairs were within one year of age, two pairs within two years, one pair within three years, and one pair within four years. The control group was in the laboratory for three consecutive nights with PSG-recorded sleep with the same bedtimes and wake times as the smokers of the present study. Unlike the smokers, participants in the control group study could not leave the laboratory during the day, and were not allowed to consume caffeine or nap during the study or in the week prior. More detailed comparisons between the control group and the smokers are discussed in each subsection below.
3.2.1 Inclusion/Exclusion Criteria

The inclusion criteria for the control group were similar to those for the experimental group (Table 1). For the control group, the screening process was divided up into two sessions on separate days, unlike the smokers who had one session. Small samples of blood and urine from the control participants were sent to a diagnostic laboratory to check for clinical abnormalities. For the full set of inclusion criteria for the control group, see Table 1, column 3.

3.2.2 Study Design

Pre-laboratory phase. The at-home assessments for the control group began one week prior to the laboratory phase of the NIH-funded study. The controls had to abstain from caffeine and napping during the one week prior to the laboratory study. The controls filled out a sleep diary, but it was not as detailed as the smokers’ sleep and activities diary (see Section 3.2.3 for differences).

Laboratory phase. The control group spent three consecutive days and nights in the sleep laboratory with the same bedtimes and wake times as the smokers, but controls were not allowed to leave the laboratory during the day. During the day, the controls underwent cognitive performance testing approximately every two hours.

Laboratory light levels for the control group were kept at <100 lux, compared to the light levels for the smokers of <350 lux. There were no outside windows in the sleep laboratory so the control group did not have any exposure to daylight during the study. The smokers were exposed to natural daylight during the time away from the laboratory (09:00 – 18:00), potentially during the early evening smoking breaks on night one (depending on time of sunset), early morning smoking breaks on day two (prior to lights on), and during the final cigarette (08:30) on day two.

Post-laboratory phase. There was no post-laboratory phase for the controls.
3.2.3 Sleep Measures

Objective Sleep

PSG. The PSG recording procedures were the same for the controls as for the smokers except AHI, LMI, LMIA, and the last two nights of SpO\textsubscript{2} nadir levels were not recorded in the controls. PSG variables were compared between the groups to see if there were differences between the first night (when smokers were smoking), and how the smoker’s sleep during abstinence (nights two and three) compared to the controls.

Self-reported sleep

PSQI. The PSQI global scores from the baseline assessments were compared between groups to determine if there were differences in sleep quality. There was no PSQI exclusion criterion for the smokers but the controls had a PSQI global score exclusion criterion of >5.

Sleep diary. Comparisons between smokers and controls were limited, because controls did not fill out a sleep diary during the laboratory phase; the sleep diaries used in the studies varied slightly; and the controls were not allowed to nap or consume caffeinated or alcoholic beverages in the week prior to entering the laboratory. For the three days prior to entering the laboratory, comparisons of self-reported sleep duration, number and duration of nighttime awakenings, and visual analog scales of how well participants slept and how well they were feeling were made between the two groups.

Subjective sleepiness

KSS. Comparisons between the smokers and the controls were made for the laboratory phase of the study to evaluate differences in momentary sleepiness. The control group filled out computer-based KSS at 19:00, 21:00, and 09:00. By comparison, the smokers took paper-and-pencil versions of these questionnaires at 18:30, 21:15, and 08:20.
3.3 Statistical Analyses

Statistical analyses were performed in SAS 9.2 (SAS Institute, Cary, NC). Descriptive statistics examined the basic properties of the data set including: means, standard deviations, extremes, skewness and kurtosis. Prior to data analyses, outliers were visually identified with scatter plots for each of the dependent variables. The research protocol was examined to determine if any significant events were noted by the research assistants to see if there was a specific reason for the outlier. Analyses were performed both with and without any identified outliers, to determine if outliers were influential and were reported both ways. The type I error threshold was predetermined at $\alpha = 0.05$. As this was a pilot study, exploratory and hypothesis-generating, type I error thresholds were not reduced to control for multiple comparisons.

Primary analyses focused on changes in dependent variables across nights during smoking (night one) and during the two nights of abstinence (nights two and three) in the laboratory. Within-subject mixed-effects analyses of variance (ANOVAs), with a random effect on the intercept were used with age as a covariate (Figure 3A). Secondary analyses included exploratory covariates of CO reading on night one, self-reported number of daily cigarettes at the baseline assessment, BMI, BMI/CO ratio, number of daily caffeinated and alcoholic drinks, and ethnicity to determine if these variables were significant at affecting the dependent variables being studied.

To assess overall quit-attempt success, comparisons were made between the baseline assessment and the four-week post-laboratory assessment using paired t-tests in the smokers who completed all assessments (Figure 3B).

Comparisons between groups were analyzed using between-subjects mixed-effects ANOVAs with night and group as fixed effects, and a night by group interaction term (Figure 3C.
and D). In addition, baseline differences between the groups were assessed using independent samples t-tests, to examine differences in demographic variables and common questionnaires measured at the baseline pre-laboratory assessments (Figure 3E).

Finally, the Pearson product-moment correlation coefficient was computed to evaluate relationships between PSG variables that changed with abstinence and were different between groups, with time to relapse in the smokers. We were unsure which night might be best associated with time to relapse, therefore we compared all three nights separately, as well as the average of all three nights with time to relapse. In addition, smoking characteristics (Table 4) were also correlated with time to relapse to determine if these variables were associated with time to relapse.

**Figure 3.** Primary statistical comparisons for the study in the smokers (A and B) and between the smokers and the control group (C, D, and E). BL = Baseline assessment. AH = At home. N = Night.
4 RESULTS

4.1 Participants

Of the 329 prospective participants that were screened over the telephone, 121 passed the telephone screening; 23 were eligible after the pre-laboratory screening; 14 participants completed the laboratory phase; and 10 participants completed all assessments (Table 3). For the laboratory phase, one additional participant resumed smoking within nine hours after the final cigarette (CO >7ppm at the 18:00 sample night two); due to the short length of time before resuming smoking, this person’s data was not included in the laboratory sample of 14.

<table>
<thead>
<tr>
<th>Stage in Study</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telephone Screened</td>
<td>329</td>
</tr>
<tr>
<td>Passed Telephone Screening</td>
<td>121</td>
</tr>
<tr>
<td>Arrived to Screening Sessions</td>
<td>38</td>
</tr>
<tr>
<td>Eligible After Screening</td>
<td>23</td>
</tr>
<tr>
<td>Arrived to Laboratory Phase</td>
<td>15</td>
</tr>
<tr>
<td>Abstained During Nights 2 and 3</td>
<td>14</td>
</tr>
<tr>
<td>Completed Night 4 (18:00) Sample</td>
<td>12</td>
</tr>
<tr>
<td>Completed 1-Week Assessment</td>
<td>12</td>
</tr>
<tr>
<td>Completed 2-Week Assessment</td>
<td>12</td>
</tr>
<tr>
<td>Completed 3-Week Assessment</td>
<td>10</td>
</tr>
<tr>
<td>Completed 4-Week Assessment</td>
<td>10</td>
</tr>
</tbody>
</table>
The 14 smokers that completed the laboratory phase were 13 men and one woman. Eleven reported to be Caucasian, and three reported to be Hispanic. Overall, participants were moderate smokers who started smoking early on and had been smoking for 12 years at the time of the study. Smoking characteristics are shown in Table 4.

Table 4

<table>
<thead>
<tr>
<th>Participant Smoking Characteristics</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Number of Cigarettes</td>
<td>16.2</td>
<td>6.2</td>
</tr>
<tr>
<td>CO\textsuperscript{a} at Baseline Assessment</td>
<td>12.8</td>
<td>2.9</td>
</tr>
<tr>
<td>Years Smoking</td>
<td>11.9</td>
<td>5.9</td>
</tr>
<tr>
<td>Age Started Smoking</td>
<td>15.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Previous Quit Attempts</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>FTND\textsuperscript{b}</td>
<td>4.9</td>
<td>1.9</td>
</tr>
<tr>
<td>BWISDM\textsuperscript{c} Total Score</td>
<td>42.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Motivation to Stop Smoking for Good (1-10)</td>
<td>9.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Carbon Monoxide in parts per million. \textsuperscript{b}Fagerstöm Test for Nicotine Dependence. \textsuperscript{c}Brief Wisconsin Inventory of Smoking Dependence Motives.

When the smokers were compared to the age- and sex-matched control group taken from a different study, there were no significant differences in age, BMI, blood pressure and heart rate (as assessed during the physical at the baseline assessment), and average number of alcoholic and caffeinated drinks per day (Table 5). In addition, comparisons between the smokers and controls on the MAP index, Composite Scale of Morningness, and ESS showed no significant differences in risk for sleep apnea, morning/evening type, and daytime sleepiness between groups. The smokers did have a higher overall PSQI score (3.8 ± 2 SD) when compared to the controls (1.9 ± 2 SD), indicating reduced quality of sleep in the smokers, but both groups were well within the normal sleep quality range of ≤5.
Table 5

*Participant Characteristics for the Smoker Group and the Control Group*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Smokers</th>
<th>Controls</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>t</td>
<td>p</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>14</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Female</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity - Caucasian</td>
<td>11</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity - Hispanic</td>
<td>3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Range (years)</td>
<td>22-39</td>
<td>22-36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>27.6 ± 5.6</td>
<td>27.4 ± 4.5</td>
<td>0.07</td>
<td>0.94</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.2 ± 4.6</td>
<td>25.7 ± 3.4</td>
<td>0.30</td>
<td>0.77</td>
</tr>
<tr>
<td>Systolic Blood Pressure</td>
<td>117 ± 9</td>
<td>117 ± 8</td>
<td>0.07</td>
<td>0.95</td>
</tr>
<tr>
<td>Diastolic Blood Pressure</td>
<td>75 ± 7</td>
<td>76 ± 6</td>
<td>0.36</td>
<td>0.72</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>66 ± 5</td>
<td>65 ± 5</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>Alcoholic Drinks (daily)</td>
<td>1.3 ± 1.5</td>
<td>0.8 ± 0.9</td>
<td>1.07</td>
<td>0.29</td>
</tr>
<tr>
<td>Caffeinated Drinks (daily)</td>
<td>2.2 ± 1.6</td>
<td>1.4 ± 1.3</td>
<td>1.45</td>
<td>0.16</td>
</tr>
<tr>
<td>MAP Index</td>
<td>0.17 ± 0.13</td>
<td>0.16 ± 0.09</td>
<td>0.19</td>
<td>0.85</td>
</tr>
<tr>
<td>Morningness/Eveningness</td>
<td>39.3 ± 6.7</td>
<td>38.8 ± 4.8</td>
<td>0.24</td>
<td>0.81</td>
</tr>
<tr>
<td>ESS</td>
<td>5.1 ± 2.7</td>
<td>4.9 ± 3.0</td>
<td>0.24</td>
<td>0.85</td>
</tr>
<tr>
<td>PSQI</td>
<td>3.8 ± 1.7</td>
<td>1.9 ± 1.5</td>
<td>2.90</td>
<td>0.008**</td>
</tr>
</tbody>
</table>

*Note.* One participant reported to be Hispanic and American Indian and was included in the Hispanic group only for the purpose of using ethnicity as a covariate.


Pittsburgh Sleep Quality Index.

4.2 Smoking Behavior

All participants took smoking breaks when offered, except on four occasions; at the 20:30 smoking break opportunity, two participants did not smoke, and at the 21:30 smoking break opportunity, two other participants did not smoke at that time. During the night, none of the participants smoked during the sleep period time (after falling asleep but before the final awakening). One participant smoked before falling asleep (23:10), and another one smoked after their final awakening but before lights on (07:12).
4.2.1 Time to Smoking Relapse

All 14 participants resumed cigarette smoking prior to the two week post-laboratory assessment. The average self-reported time to smoking relapse was 110.8 hours (± 95 SD). Time to relapse ranged from 52.5 hours to 326 hours, with 50% of participants relapsing by 62 hours after the final cigarette (Figure 4). Participants were to avoid all forms of tobacco and nicotine replacement therapies during the post-laboratory phase. There was one participant who smoked a cigar 149.5 hours after the final cigarette, which was counted as relapse for primary correlation analyses. In secondary analyses, time to relapse for this participant was determined as when he resumed smoking cigarettes, which occurred 291.5 minutes after the final cigarette. The secondary correlation analyses are only reported here if the results between the two different definitions of relapse were substantively different.

Correlations between time to relapse and the smoking characteristic variables presented in Table 4 revealed a moderate positive correlation between number of previous quit attempts and time to relapse, r(26)=0.59, p=0.027 (Figure 5). When the secondary definition of relapse was used, the correlation remained moderate but was no longer significant r(26)=0.42, p=0.13. The person with the longest time to relapse (326h) had the highest number of previous quit attempts (8). When this data point was removed the correlation was non-significant and dropped to r(24)=0.17, p=0.58.
Figure 4. Self-reported time to smoking relapse for all participants who completed the laboratory phase (N=14). Diamonds indicate when a participant relapsed (big diamond = two participants relapsing at the same time). Time zero indicates the time of the final cigarette. The black solid line indicates when participants started the post-laboratory phase (48.5 hours after the final cigarette). The blue solid line indicates the time of the sample taken in night four (57.5 hours after the final cigarette). The blue boxes indicate the 10-hour periods when participants could come in to the laboratory for the 1-week (168–178 hours) and 2-week (336—346 hours) post-laboratory assessments.
4.2.2 Smoking Status and Subjective Dependence Patterns

The primary objective measure of smoking status in this study was CO breath samples. During the laboratory phase of the study, there was a significant reduction in CO breath levels during abstinence, $F(3,39)=58.42, p<0.001$ (Figure 6). UCot levels were also significantly reduced during abstinence, $F(1,23)=13.49, p<0.001$ (Figure 7). These results confirm that participants adhered to the study protocol during the laboratory phase by refraining from smoking after the final cigarette.

Figure 5. Correlation between time to relapse (hours) with previous number of quit attempts. Greater number of quit attempts was significantly associated with longer time to relapse.
Figure 6. Mean values (± SEM) for expired breath carbon monoxide (parts per million) during the laboratory phase plotted across time. Filled boxes indicate samples taken at 18:00 on night 1 and 08:35 on day 2 (smoking) with the red line indicating time points continuously in the laboratory and open boxes indicate samples taken at 18:00 on nights 2 and 3 (abstinent). Gray blocks indicate when participants were scheduled to sleep (22:00–08:00). There was a significant main effect of time, confirming that participants maintained abstinence after the final cigarette during the laboratory phase.
Figure 7. Mean values (± SEM) for urine cotinine semi-quantitative range during the laboratory phase. Filled red boxes indicate samples taken at 18:00 on night 1 and 08:35 on day 2 (smoking) with the red line indicating time points continuously in the laboratory. The white boxes indicate samples taken at 08:35 on the mornings of day 3 and day 4 (abstinence). Gray blocks indicate when participants were scheduled to sleep (22:00–08:00). There was a significant main effect of time, confirming that participants reduced nicotine consumption after the final cigarette during the laboratory phase.

To determine if participants changed smoking behavior in preparation of the quit attempt, both self-reported number of cigarettes and CO levels were examined from the baseline assessment to the first night in the laboratory. There was a trend for reducing daily cigarettes in preparation for the quit attempt, t(13)=1.97, p=0.071. However, objective measures of CO found a significant increase after baseline to the first night in the study, t(13)=2.38, p=0.034. Since all smokers eventually relapsed, an attempt was made to quantify how relatively successful each participants’ quit attempt was. Baseline assessments of CO, number of daily cigarettes, and subjective dependence measures were compared to the four-week post-laboratory assessment in those participants who completed both sessions (N=10). There was no difference in CO levels between the two assessments, t(9)<0.01, p>0.99. However, for self-reported daily cigarettes,
there was a significant reduction from 15 (± 2 SEM) cigarettes at the baseline assessment to 9 (± 2 SEM) cigarettes at the four-week post-laboratory assessment (Figure 8).

Reduced levels of smoking were also observed in the subjective dependence measures. When subjective nicotine dependence was evaluated with the FTND, there was a reduction of 1.8 (± 0.6 SEM) points on the scale, which brought the group average down from medium dependence to low dependence, t(9)=2.97, p=.016 (Figure 9). Moreover, when smoking dependence motives were compared between assessments using the BWISDM measure, there was a significant reduction for the Affective Enhancement subscale, which reflects the thought that smoking improves mood, t(9)=2.30, p=0.047 (Figure 10). There were no statistically significant differences for the BWISDM total score, t(9)=1.44, p=0.19, the primary dependence motives score, t(9)=1.65, p=0.13, the secondary dependence motives score, t(9)=0.89, p=0.40, or any of the other 10 smoking motive subscales, t(9)<1.65, p>0.13.
Figure 8. Mean values (± SEM) for self-reported daily cigarettes for the baseline assessment (blue) and the 4-week post-laboratory assessment (red). Although all participants relapsed, as a group they significantly reduced their daily number of cigarettes four weeks after the quit attempt.
Figure 9. Mean values (± SEM) for Fagerström Test for Nicotine Dependence for the baseline assessment (blue) and 4-week post-laboratory assessment (red). Participants significantly reduced subjective nicotine dependence four weeks after the quit attempt.

N=10; $p=0.02$
**Figure 10.** Mean values (± SEM) for the Affective Enhancement subscale of the Brief Wisconsin Inventory of Smoking Dependence Motives. Participants significantly reduced the scores on the Affective Enhancement subscale, which reflects the thought that smoking improves mood.

N=10; p=0.047
4.3 Sleep Measures

4.3.1 Polysomnography

Differences in sleep architecture between smoking consumption (night one) and abstinence (nights two and three) were investigated in the smokers. Objective change in sleep across nights was only observed in sleep latency, $F(2,26)=3.62, p<0.041$ (Figure 11). There was a significant difference between night one (smoking) and night two (abstinence), $t(26)=2.69, p=0.012$. During smoking, participants took 44.9 ($\pm$ 9 SEM) minutes to fall asleep, compared to 22.1 ($\pm$ 9 SEM) minutes for night two and 33.4 ($\pm$ 9 SEM) minutes for night three.

![Figure 11](image_url)

**Figure 11.** Mean values ($\pm$ SEM) for PSG-recorded sleep latency (minutes) during the three laboratory nights in the experimental group (smokers). The filled box is during smoking (night 1); the open boxes are during abstinence (nights 2 and 3). There was a significant effect over time, and a significant difference between smoking night one and abstinence night two.
After visual inspection of the data, there were two data points from a single individual that stood out as outliers, with a sleep latency of 202.5 minutes on night one and 135.5 minutes on night three. On night one this participant took a smoking break after lying awake for over an hour in order to “clear his mind and reset”. It was unclear why the sleep latency for night three was so high. When both of these outliers were removed, there was still a significant effect of night, F(2,24)=3.90, \( p<0.034 \), and the difference between night one and night two remained significant, t(24)=2.77, \( p=0.011 \).

When the analyses were repeated in the smokers with the exploratory covariates, none of the results changed. Ethnicity, night 1 CO, and average daily cigarettes were significant covariates for AI (\( p<0.045 \)); number of daily caffeinated drinks was a significant covariate for WASO (\( p=0.037 \)); and night 1 CO was a significant covariate for SpO2 nadir (\( p=0.046 \)).

The PSG-recorded sleep from the smokers was compared to the non-smoker control group. Overall, there were significant differences between groups for sleep latency, stage N1 minutes, stage N3 minutes, latency to stage N3, and arousal index. This was despite no differences between groups in the amount of sleep, F(1,52)=0.54, \( p=0.47 \).

For sleep latency, there was an interaction effect of group by night, F(2,52)=5.76, \( p=0.006 \). Smokers took 21.9 (± 11 SEM) minutes longer to fall asleep on the first night after smoking compared to the controls, t(9)=2.09, \( p=0.041 \) (Figure 12).
Figure 12. Mean values (± SEM) for PSG-recorded sleep latency (minutes) in the smokers (red) and in the non-smoker control group (black) during the three laboratory nights. The filled box is during smoking (night 1) and open boxes are during abstinence (nights 2 and 3). Smokers had significantly longer sleep latencies on night one after smoking than the controls. Smokers averaged 35.4 minutes of N1 each night, compared to 23.2 (± 3 SEM) minutes for the controls, F(1,52)=8.57, p=0.005 (Figure 13). The greater amount of lighter stages of sleep (N1) was associated with less deeper stages of sleep as evidenced by 30.9 (± 12 SEM) minutes less of N3 per night when compared to the controls, F(1,52)=6.25, p=0.016 (Figure 14). Latency to N3 was increased in the smokers; across the three nights, it took 18.9 (± 7 SEM) minutes longer to reach N3 sleep than in the control group, F(1,52)=7.69, p=0.008 (Figure 15). Upon visual examination of the data, there was one data point that stood out as an outlier with a latency to N3 on the second night of 285 minutes. Further inspection of the sleep
recording showed a normal sleep latency of 16 minutes, but the participant woke up before reaching N3 and then had a prolonged wake period of over four hours before returning back to sleep. When this data point was removed, the result for latency to N3 was still significant, $F(1,51)=11.77, p=0.001$.

There was also a difference between groups in EEG arousals. The smokers averaged 14.6 ($\pm$ 1 SEM) EEG arousals per hour of sleep compared to 10.1 ($\pm$ 1 SEM) arousals for the control group, $F(1,52)=7.59, p=0.008$ (Figure 16).

There were no significant differences between groups for PSG-assessed Wake, $F(1,52)=0.52, p=0.47$; WASO, $F(1,52)=0.42, p=0.52$; or WSPT, $F(1,52)=0.09, p=0.77$, but there was a trend for a difference between groups in time after final awakening, $F(1,52)=2.72, p=0.105$. Removal of one outlier in the control group (79 minutes) and one outlier in the smokers (59.5 minutes) changed the result to significant, $F(1,50)=7.98, p=0.007$, with smokers averaging 6.1 ($\pm$ 2 SEM) minutes more time after the final awakening than the controls.

There was a significant difference across nights for both groups in the amount of REM minutes, $F(2,52)=4.12, p=0.022$, with night one having significantly less REM than night two, $t(9)=2.87, p=0.006$, but no significant effect of group or night by group interaction. All other PSG variables showed no significant differences between nights or groups.
Figure 13. Mean values (± SEM) for PSG-recorded N1 (minutes) in the smokers (red) and in the non-smoker control group (black) during the three laboratory nights. The filled box is during smoking (night 1) and open boxes are during abstinence (nights 2 and 3). Smokers had significantly more N1 across all nights than the controls.
Figure 14. Mean values (± SEM) for PSG-recorded N3 (minutes) in the smokers (red) and in the non-smoker control group (black) during the three laboratory nights. The filled box is during smoking (night 1) and open boxes are during abstinence (nights 2 and 3). Smokers had significantly less N3 than the controls.
Figure 15. Mean values (± SEM) for PSG-recorded N3 latency (minutes) in the smokers (red) and in the non-smoker control group (black) during the three laboratory nights. The filled box is during smoking (night 1) and open boxes are during abstinence (nights 2 and 3). Smokers had significantly longer latencies to N3 across all nights than the controls.
Figure 16. Mean values (± SEM) for PSG-recorded arousal index (minutes) in the smokers (red) and in the non-smoker control group (black) during the three laboratory nights. The filled box is during smoking (night 1) and the open boxes are nights during abstinence (nights 2 and 3). Smokers had significantly more arousals per hour of sleep across all nights than the controls.
The PSG-recorded sleep variables for each night that changed within smokers (SL) and between groups (N1 minutes, N3 minutes, N3 latency, and A1) were correlated with time to relapse to determine if better sleep quality was associated with longer time to relapse. There was a moderate correlation for N3 minutes on baseline night one. Those who had more N3 minutes were more likely to have a longer time to smoking relapse, \( r(14)=0.47, p=0.088 \) (Figure 17).

![Graph showing correlation between time to relapse (hours) and night one duration of N3 sleep (minutes).](image)

**Figure 17.** Correlation between time to relapse (hours) with night one duration of N3 sleep (minutes). Greater night one N3 was associated with longer time to relapse during smoking.
4.3.2 Wrist Actigraphy

Rest-activity patterns were analyzed to determine if there were sleep changes across nights with smoking status. There were no changes across nights for actigraphy variables of sleep duration, sleep efficiency, time to fall asleep, and wake after sleep onset, F(2,22)<0.98, p>0.39.

4.3.3 Self-reported Sleep

**PSQI.** There were no significant changes in subjective sleep quality when PSQI global scores were compared in the smokers (N=10) from the baseline assessment to the 4-week post-laboratory session, t(9) = 1.08, p=0.31.

**Sleep and Activities Diary.** In the smokers, there was a significant effect across days (three days at home and three days in the laboratory) for self-reported nighttime awakenings, F(5,65)=2.83, p=0.02; and for the three VAS of “How did you feel today (mentally exhausted/sharp)?”, F(5,63)=2.42, p=0.045, “How did you sleep last night (extremely poorly/very well)?”, F(5,65)=4.00, p=0.003, and “How do you feel right now (extremely sleepy/very refreshed)?”, F(5,65)=2.46, p=0.042. Overall, participants reported they slept poorly during the first night in the laboratory after smoking (Figure 18). They further reported significantly more awakenings during the laboratory phase than while sleeping at home (Figure 19). They reported being more mentally exhausted during abstinence as seen when comparing night one to night two, t(63)=2.28, p=0.026, and to night three, t(63)=2.90, p=0.005.

Paradoxically, in the three days prior to entering the laboratory, the smokers reported 54.3 (± 18) minutes per night of greater sleep duration, F(1,48)=8.73, p=0.005 (Figure 20), and fewer awakenings, F(1,49)=4.15, p=0.047 (Figure 21), than the controls.
**Figure 18.** Mean values (± SEM) for the VAS “How did you sleep last night?” with anchors of “extremely poorly” and “very well” during the three days prior to entering the study (at home) and during the laboratory phase. The filled boxes indicate smoking days and the open boxes are during abstinence. There was a significant effect of time, with participants reporting to have slept poorly on the first night of the laboratory study after smoking.

**Figure 19.** Mean values (± SEM) for self-reported awakenings during the night in the three days prior to entering the study (at home) and during the laboratory phase. The filled boxes indicate smoking days and the open boxes are during abstinence. There was a significant effect of time, with participants reporting to have more awakenings during the laboratory phase of the study.
Figure 20. Mean values (± SEM) for self-reported sleep duration at home in the three days prior to entering the study in the smokers (red) during smoking consumption and in the non-smoker control group (black). The smokers had significantly greater self-reported sleep duration than the control group during the at-home, pre-laboratory phase of the study.

Figure 21. Mean values (± SEM) for self-reported number of nighttime awakenings at home in the three days prior to entering the study in the smokers (red) during smoking consumption and in the non-smoker control group (black). The smokers reported significantly fewer awakenings than the controls during the at-home, pre-laboratory phase of the study.
4.4 Daytime Symptoms

4.4.1 Subjective Smoking Characteristics and Mood Symptoms

VAS. Subjective data from the VAS (Figure 22, panels A-E) showed a significant effect of time for Stress (Figure 22, panel B), Withdrawal Symptoms (Figure 22, panel C), Irritability (Figure 22, panel D), and Current Desire to Smoke (E), F(8,104)≥2.39, p≤0.021. Both Withdrawal Symptoms and Irritability showed a significant increase in symptoms from smoking to abstinence, F(2,110)=8.79, p<0.001, and F(2,110)=3.17, p=0.046, respectively (Figure 22, panels C and D). There were no changes across time for Anxiety, F(8,104)=1.68, p=0.11 (Figure 22, panel A).

PHQ9. There were no differences between smoking and abstinence days in the laboratory for depressive symptoms as measured by the PHQ9, F(1,27)=2.08, p=0.16. There were also no differences in total scores between the baseline assessment and the four-week assessment, in those who completed all assessments (N=10), t(9)=0.14, p=.90.

4.4.2 Subjective Sleepiness Measures

KSS. The smokers completed the KSS two times per night (18:30 and 21:15) and once in the morning (08:20) during the laboratory phase of the study to report moment-to-moment sleepiness (Figure 22, panel F, red lines). As expected, there was a significant effect of time across all nine sessions, F(8,104)=8.56, p<0.001. There was a significant effect of time of day, F(2,110)=26.10, p<0.001 with smokers reporting higher levels of sleepiness before bedtime on all three nights than the 18:30 test bout, t(110)>6.98, p<0.001, or the morning test bout, t(110)>5.11, p<0.001. Overall, there were no differences in sleepiness across smoking and abstinence days, F(2,110)=2.04, p=0.14.
When levels of sleepiness were compared between groups, the smokers had significantly higher levels of sleepiness across all laboratory nights, including during the smoking night, $F(1,208)=12.94, p<0.001$ (Figure 22, panel F). There was a significant interaction effect of time by group, due to the larger increase in sleepiness before bed in the smokers $F(8,208)=4.00$, $p<0.001$.

**ESS.** In the smokers, there were no significant differences in excessive daytime sleepiness scores between baseline and the 4-week post-laboratory assessment in the 10 participants that completed both sessions, $t(9)=0.16, p=0.87$. 
Figure 22. Mean values (± SEM) of daytime symptoms (VAS: A-E; KSS: F) plotted against clock time across all three nights in the study. Gray bars are during sleep periods; filled boxes during smoking; open boxes during abstinence; and black circles are comparisons to a control group (F). For the VAS, there were similar temporal profiles across all measures with significant changes across time for B-E and a significant increase in Withdrawal symptoms (C) and Irritability (D) during abstinence. For the KSS (F), smokers levels of sleepiness did not change based on smoking status. Smokers were sleepier and showed more fluctuation in responses when compared to the controls.
5 DISCUSSION

5.1 Main Findings

The main goal of this study was to examine polysomnographically assessed sleep disturbance as a potential predictor of smoking relapse in cigarette smokers trying to quit without treatment. In contrast with other smoking cessation studies in self-quitters, which found abstinence rates to be 21% (Brown et al., 2009), 27% (Garvey et al., 1992) and 19% (Hughes et al, 1992) one-month after quitting, none of the 14 participants in the present study remained abstinent past the 2-week post-laboratory assessment. Previous literature has shown that those aged 35 and older (Lee & Kahende, 2007) and 45 and older (Hymowitz et al., 1997) are likely to have better cessation outcomes. The apparently greater difficulty quitting in our sample could be related to their relatively young age range (22 – 40; mean ± SD: 27.6 ± 5.6). Regardless of the reason, in this study it was not possible for us to compare the sleep of smokers who had relapsed to those who had successfully quit.

Even though all participants resumed smoking, there was variability in the time to relapse. Of the 14 participants who made it through the two nights in the laboratory without smoking (48.5 hours), 67% had relapsed by the third day, 79% by the fifth day, and 86% within the first week after the quit date. Two previous studies have shown similar one-week relapse rates in self-quitters, namely 76% (Hughes et al, 1992) and 82% (Brown et al., 2009). Another study demonstrated a slightly lower relapse rate of 49%, but this may be due to longer recall times of one month which may have led to inaccurate estimates (Garvey et al., 1992).

In our study, participants had to remain abstinent for 48.5 hours, at which point they could resume smoking and still continue to be in the study. Prior research has shown that rapid resumption of smoking can occur within the first 48 hours (Brown et al., 2009; Gilpin & Pierce, 1994; Hughes et al., 1992). One participant’s data was discarded because he was not deemed to
have made a serious quit attempt (relapsed within 9 hours). Yet, 14 participants made it through the two nights of abstinence, despite returning to their naturalistic environment (e.g., home, work) during the day (09:00 – 18:00). It may be that abstinence rates were initially high because compensation was contingent upon abstinence in the first 48.5 hours. Studies using contingency management as a formal intervention have shown that this type of behavioral treatment results in increased smoking abstinence (McDonell et al., 2014; Packer et al., 2012). Regardless, the relapse rates observed in this study are consistent with the idea of focusing interventions and follow-ups within the first week after quitting because of high likelihood of relapse early on (Garvey et al., 1992; Gilpin & Pierce, 1994; Hughes et al., 2004).

Given the variability in the relapse rate, we were interested in determining if there were any predictors associated with a longer time to relapse. This is potentially important because longer periods of abstinence on previous quit attempts predict future abstinence success (Garvey, 1992; Ferguson et al., 2003). We found a positive association between the number of previous quit attempts and time to relapse (r=0.59). Participants with more quit attempts may have learned what pitfalls or triggers to avoid and/or which strategies seemed to help them in past quit attempts.

Within the literature, the relationship between previous quit attempts and abstinence shows mixed results. Some studies have found more past quit attempts are associated with quitting success (Hymowitz et al., 1997; Stapleton et al., 1995) and others have found it to be more associated with relapse (Borland et al., 1991; Lee & Kahende, 2007, Murray et al., 2000). In our study with a small sample size, the person with the most quit attempts (8) also abstained the longest (326 hours). More participants are needed to determine if this data point was truly an outlier.
Even though all of the smokers in this study relapsed, we observed a reduction of smoking and subjective dependency that was corroborated with multiple measures. There was a greater than 40% reduction in self-reported cigarettes from the baseline session (15.0 cigarettes) to the four-week assessment (8.9 cigarettes). The FTND was significantly reduced by 1.8 points on the scale, bringing the group level of dependency down from medium dependence to low dependence. Further, the prevalence of the thought that smoking improves mood was reduced as measured by the BWISDM Affective Enhancement subscale. Lower levels of dependency have been associated with greater likelihood of abstinence (Ferguson et al., 2003; Hymowitz et al., 1997). For our sample, it is not known whether the reduction in cigarettes and subjective dependency was maintained past the four-week session, and how this reduction might affect future quit attempts.

Although there was not a significant reduction in the objective measure of CO, this could be due to variations in the session times. The baseline session typically occurred late morning, and the four-week assessment occurred later in the afternoon. As the times for these specific sessions were primarily based on participants’ convenience of coming to the laboratory, times for both of these sessions varied. Standardizing the times would have improved the validity of this finding, but would have likely hindered the attendance rate.

With regard to sleep measurements, primary analyses focused on changes from smoking to abstinence. The study demonstrated a specific objective change in sleep during the quit attempt, namely, a decrease in sleep latency during abstinence. This finding was found in one other previous study, which additionally demonstrated more total sleep time during smoking cessation (Soldatos et al, 1980), which our study did not find. All other studies examining smoking cessation in smokers without treatment, found more sleep disturbance during abstinence
with increased sleep stage transitions and awakenings (Prosise et al., 1994) and increased WASO and EEG arousals (Jaehne et al., 2014). Unlike the findings of these two studies, our results represented an improvement in sleep during abstinence relative to the smoking night.

However, as expected, self-reported daytime symptoms revealed increases in irritability and withdrawal symptoms during abstinence. Although these increases were not significant in the VAS of current desire to smoke, anxiety, or stress, the temporal pattern was very similar among all of the VAS, with highest impairments occurring at 18:30 and lower levels at 21:15 and 08:20. A study by Teneggi et al. (2002) showed craving levels lowest in the morning and gradually increased throughout the day with a final peak at the last (20:00) assessment. This study did not include an assessment after 20:00, so it is not necessarily in contrast to our results. Nevertheless, the increase in irritability and withdrawal during abstinence may have counteracted the positive effect of the improvement in sleep during abstinence. As such, after the quit attempt there may not have been any net improvement in subjective state.

Compared to age- and gender-matched, non-smoker controls, smokers exhibited more objective sleep disturbances both before and after the quit attempt, as indicated by more N1, less N3, more arousals, and greater N3 latency. Overall, this general pattern of poor sleep in smokers has been previously shown when sleep in smokers (after smoking) was compared to non-smoker controls – as evidenced by shorter time from sleep onset to the final awakening (Jaehne et al., 2012), less total sleep time (Soldatos et al., 1980; Zhang et al., 2006), more N1 (Zhang et al., 2006), less N3 (Zhang et al., 2006), longer sleep latency (Jaehne et al., 2012; Soldatos et al., 1980; Zhang et al., 2006), higher rapid eye movement density (Jaehne et al., 2012), more apneas (Jaehne et al., 2012), and more leg movements (Jaehne et al., 2012). In general, our comparison
between the smokers and controls yielded results consistent with the previous literature, in the sense that smokers had poorer sleep quality.

Yet in our study, when subjective sleep was compared between the groups in the three days before the laboratory phase, the smokers reported better sleep than the controls with more sleep duration and less number of awakenings. In light of the objective laboratory data, it is not likely that their pre-laboratory sleep was actually better, but it could be the timing of the self-reporting that was affecting these subjective results. The smokers were instructed to fill out the sleep diaries upon awakening and just before going to bed, but it is possible that some participants smoked prior to completing the diary. The positive effect of smoking a cigarette may have masked subjective symptoms associated with the prior night’s sleep.

The smokers experienced greater subjective sleepiness than the controls on all three laboratory nights, including when they were frequently using nicotine, a stimulant. It is noteworthy that the controls were not allowed to consume caffeine within a week of starting and during the study from which their data were drawn. To our knowledge, there has only been one other study that examined momentary sleepiness in smokers during abstinence. This study, by Prosise and colleagues (1994), used the multiple sleep latency test to objectively measure sleepiness in smokers during smoking abstinence, and documented decreased sleep latency (i.e., greater objective sleepiness). This was in contrast to our subjective results which showed no change with abstinence. The participants in the Prosise study were much older (41.6 ± 5 years) compared to our study (27.6 ± 5.6 years) and could have been the reason for the difference in results.

When we examined sleep predictors for time to relapse, we found that longer time to relapse was best associated with the deepest stage of sleep (N3) on the first night during smoking
This finding provides preliminary evidence that N3, which is believed to be the most restorative part of sleep (Dijk, et al., 2010), may contribute to the ability to resist the desire to smoke. If this is replicated in a larger follow-up study, it would suggest that an intervention aimed at increasing N3 sleep could be explored to improve smoking cessation success. To our knowledge, only one other study to date (Jaehne et al., 2014) in a slightly older age group (29.4 ± 9.6) examined PSG predictors in subjects that relapsed and found that less REM and longer REM latency predicted relapse three months after a quit attempt. They speculate their results are congruent with the reciprocal interaction model (McCarley & Hobson, 1975) and those who relapsed had reduced cholinergic stimulation from the lack of nicotine.

5.2 Limitations

As mentioned previously, the main limitation of our study was that no one was able to successfully quit. Due to this, we were unable to compare objective sleep variables between those who relapsed to those who successfully quit. We were able to examine predictors for longer time to relapse. Future studies could examine polysomnographic sleep predictors for smoking relapse with treatment interventions.

Another significant limitation of this pilot study was the small sample size. Recruitment for this study was more difficult than anticipated. To compare recruitment effort between the present study of smokers and the previously completed control studies, the total number of people initially establishing telephone contact for each study was divided by the final sample size. For the smoking study, there were 23.5 people contacted for each smoker who completed the laboratory phase (329/14=23.5). For the control study, the equivalent ratio is 11.8 (639/54=11.8). Thus, twice as many smokers were telephone screened per person in the study when compared to the control group.
Eight additional participants (35%) had completed all of the screening procedures and were enrolled in the study, but on the day of the study, failed to show up. After further attempts to contact them, most could not be reached again. It is likely that part of this absenteeism had to do with the difficulty of initiating a quit attempt in general, but also initiating a quit attempt with a specific quit date that was dictated. Future studies need to take into consideration greater recruitment efforts, more time to complete a study, and relatively high absenteeism rates, when addicted populations are being asked to quit “cold turkey” on a specific timeline as a part of the study design.

Another limitation to our study was the semi-quantitative urine cotinine test that was used. This test was sensitive enough to detect second-hand smoke, so for the purposes of our use, any previous levels of smoking were saturated at the highest level of 66 (1,000+ ng/ml) and test levels were slow to drop even during abstinence. During the two abstinence measurements 24 and 48 hours after the final cigarette, levels only dropped to levels 62 and 53, respectively; still far above the level of 22, which was considered not to be a user of tobacco products. We do not believe that participants used smokeless tobacco products during abstinence, given that regular users of these products were screened out during the telephone screening. That said, presence of nicotine from smokeless sources cannot be ruled out completely.

5.3 Conclusions

Overall, the study findings indicate that both smoking consumption and withdrawal are associated with disturbed sleep and impairments in subjective daytime functioning. Nicotine is a stimulant known to disrupt sleep, so our finding that sleep was disturbed during smoking consumption is as expected. The observation that smokers reported daytime sleepiness before the quit attempt is notable; it is likely that the smokers used nicotine, in part, to mitigate sleepiness.
This suggests that smoking behavior is a vicious cycle: smoking disrupts sleep, which leads to daytime sleepiness, which drives smokers to use nicotine to mitigate the sleepiness, and the nicotine in turn disrupts the sleep the next night, etc.

Importantly, our results found that during abstinence, the disrupted sleep and impairments in subjective daytime functioning did not disappear. This study did not reveal why the sleep and wake disturbances persisted. It may be a result of elevated numbers of nicotinic receptors induced by long-term nicotine use that can take between 6-12 weeks to return to non-smoker levels (Cosgrove et al., 2009). Regardless, the quit attempt without pharmacological intervention did not appear to break the vicious cycle – the former smokers still continued to experience the symptoms that presumably drove them to continue smoking. From this point of view, it is not surprising that all the smokers in the study ended up relapsing.

In closing, this pilot study showed evidence for changes in objective sleep during abstinence as indicated by a decrease in the time to fall asleep. This ostensibly positive effect may have been negated by the increases in self-reported daytime irritability and withdrawal symptoms, possibly perpetuating the resumption of smoking. In addition, there was greater sleep disturbance and daytime sleepiness in smokers compared to controls regardless of whether they were smoking or abstained. Further studies, investigating to what extent the persistent sleep disturbance and subjective daytime symptoms during abstinence contribute to the high relapse rate in smokers quitting without treatment, may reveal new treatment targets to aid smokers attempting to quit smoking. Based on our preliminary results, treatments aimed at increasing N3 sleep may aid in prolonging the time to relapse, which could lead to more successful quit attempts in the future.
REFERENCES


CONSENT FORM

Study title: Smoking Cessation and Sleep

Co-principal investigator: Matt Layton, MD, PhD 509-358-7502
Co-principal investigator: Amy Bender, MS, RPSGT 509-358-7756
Co-investigator: Hans Van Dongen, PhD 509-358-7755
24-hour emergency number: Physician of record cell phone 509-389-1108

RESEARCHERS’ STATEMENT: We are asking you to be part of a research study. The purpose of this consent form is to give you the information you need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all of your questions, you can decide if you want to be in the study or not. This process is called “informed consent.” Your informed consent is necessary for you to participate in this study. We will give you a copy of this form for your records. This research study has been reviewed and approved for human participation by the WSU Institutional Review Board.

PURPOSE: The purpose of this study is to learn more about sleep patterns in smokers trying to quit. Sleep will be recorded in the laboratory the night before your quit attempt and up to two nights following your quit attempt. Using this information, we hope to better understand the relationship between sleep and smoking cessation, which could eventually lead to developing new treatments to help smokers trying to quit.

SELECTION OF PARTICIPANTS: You have been invited to participate in this study because of your expressed interest to quit smoking, in addition to being generally healthy and aged 22–40.
PROCEDURE:

First Screening Session: You will first attend a 2-hour screening session at the Sleep and Performance Research Center. Note that during this 2-hour session, you will not be able to smoke on WSU’s smoke-free campus. The screening will include measurement of your height and weight, a urine test (approximately 4 ounces of urine), a carbon monoxide breath test, and an alcohol breathalyzer test. The urine sample will be tested to make sure you are free of traces of drugs, and also measure cotinine (a by-product of the breakdown of nicotine) in your body. The carbon monoxide test will measure your recent smoking activity, and the breathalyzer test will make sure you are alcohol-free. This information will be used to determine your eligibility into the study.

In addition, you will be asked to fill out the following questionnaires in order to determine your eligibility to participate in the study: a list of personal information (such as date of birth), a number of questions regarding your smoking habits and smoking history, a confidential medical questionnaire regarding your health and medical history, a set of sleep questionnaires, and some questionnaires about your mood. Your honesty is counted on in completing these questionnaires. You will also fill out a tax identification number form and an invoice voucher, which are needed to process the payment for your participation in the study. During this session, you will also receive a document with useful tips to quit smoking and information on what withdrawal symptoms to expect.

Second Screening Session: You will then attend a second 1-hour screening session at the Sleep and Performance Research Center. Note that during this second session you will not be able to smoke on WSU’s smoke-free campus. You will fill out some more questionnaires regarding your mood, smoking habits, and sleep. You will also get a physical exam from the study physician. The physical exam will involve visually examining your eyes, ears, nose and throat; listening to your heart and lungs; listening to and palpating (pushing on) your stomach; examining your nerves, muscle strength, sensation, and reflexes; and taking your pulse and blood pressure. If you are female, you will give a urine sample to test for pregnancy.

At the end of the second screening session, you will be scheduled for the three consecutive nights in the laboratory, including your target quit date. You will be given a diary to record your smoking, sleep times, and activities in the three days before the laboratory phase of the study.

Pre-Experimental Phase: In the three days before the laboratory phase of the study, you will be asked to maintain your regular smoking patterns, activities, and sleep patterns (including napping if you normally nap). You will receive a diary to keep track of these activities daily. The diary has questions about your sleep, the number of cigarettes you smoked, the number of caffeinated and alcoholic beverages you consumed, and activities you
completed throughout the day. Furthermore, you will be asked to call in your bedtimes and wake times, and the number of cigarettes that you smoked, for these three days. On the day of the first laboratory night, you will be asked not to drink any alcohol or use any drugs but you will continue to smoke normally.

**Laboratory Phase:**

**Day 1: The Day before Quitting.** On the pre-determined day, you will arrive at the Sleep and Performance Research Center at 6:00pm for the first night of the study. As soon as you arrive, you will be asked to change into a clean set of clothes that you will eventually wear to bed. You will return your sleep and activities diary, and will be given a new one later on in the study. You will be given an actigraph, which you will wear on your non-dominant wrist like a watch. This will measure your general sleep-wake patterns.

You will then be asked to give a urine sample, a carbon monoxide breath sample, and an alcohol breathalyzer sample. The urine sample will be used to test for traces of drugs (to ensure you are drug-free) and to measure cotinine (a by-product of nicotine) in your body. The carbon monoxide test will measure your recent smoking activity, and the breathalyzer will measure your recent alcohol use (to make sure you are free of alcohol). You will then fill out a few questionnaires about your mood and desire to smoke. You will also be given some time to familiarize yourself with the laboratory environment and to meet the other study participants. There may be up to three other participants with you in the laboratory.

From 6:30pm until about 9:00pm, you will be prepared for the recording of your sleep. To measure your sleep, small electrodes will be placed on the skin of your scalp, face, chin, chest, and lower legs. The scalp electrodes will be held in place by a special paste, which can be applied directly to the skin and can be removed with water. The face, chin, chest, lower leg, finger, and breath electrodes will be attached using small adhesive pads. To measure your breathing patterns, stretchy belts will also be placed above your clothes on your chest and stomach, and breath sensors will be placed below your nose. In addition, a sensor will be placed on your right index finger that shines a red light through the finger nail to determine how much oxygen is in your blood.

After this process is complete, you will do a few brief exercises (looking up and down, closing your eyes, grinding your teeth, holding your breath, etc.) so that we can make sure that all the sensors are working properly. At around 7:45pm, we will give you a snack.

Throughout the first night before going to bed, smoke break opportunities will occur at 7:30pm, 8:30pm, and 9:30pm. You will not be required to smoke at these times, but given the opportunity if you so choose. If you take the opportunity to smoke, you will be asked to wear a pair of scrubs and a lab coat to go over your clothes. There will be a designated smoking area outside of the laboratory, a short distance away (at least 25 feet) from the
building entrance. A staff member will monitor you from inside the building. You will have 5 minutes to smoke, and the staff person will alert you to come inside. When you return, we will collect the scrubs and lab coat, and you will be asked to wash your hands before re-entering the laboratory. These procedures will help contain smoking smells and cues for the quitting phase of the study.

While in the laboratory, you will not be able to access the internet, use a cell phone, receive e-mail or text messages, watch live television, or listen to live radio. Except in case of emergency, you will not be allowed to have any visitors or to make or receive any phone calls. Free-time will be limited, but you may have time to watch a movie, and may listen to music or read while you are being hooked-up for the sleep recordings. In addition, the evening snack and morning breakfast will be at scheduled times of 7:45pm and 08:40am. You will be allowed to drink as much water and other non-alcoholic drinks as you want. However, you will have to refrain from alcohol during the laboratory portion of the study.

At approximately 9:15pm, you will fill out your sleep and activities diary and other questionnaires about your smoking desire and mood. At 10:00pm, the lights will be turned off in your bedroom and you will be required to go to bed and try to sleep until 8:00am. During this period, you will not be allowed to leave the laboratory, watch television, listen to music, read, or use your cell phone. If you cannot sleep, you can lie quietly and rest with the lights turned off in your bedroom. You will be allowed to get out of bed to go to the bathroom, to drink water, or to smoke. If you get up to smoke, you will again be wearing a pair of scrubs and a lab coat to go over your clothes, and use the designated smoking area outside of the laboratory. A staff member will monitor you from inside the building and alert you when your 5-minute break is up. When you return to the laboratory, we will collect the scrubs and lab coat, and you will be asked to wash your hands before re-entering the laboratory.

Throughout the night, there will be a member of the research team in the laboratory to provide assistance if needed and to monitor your activities. This person will be able to see you on a television screen via a camera (which can see in the dark). Thus, the research team can see from a distance if you have any problems sleeping and whether you are in or out of bed. Laboratory camera images are recorded and kept available for about one month after the study, after which they will be automatically erased. However, the camera images recorded during your sleep period will be stored on a computer as part of your sleep record, and will not be erased.

The recordings of your sleep and breathing patterns will continue throughout the sleep period. If you get up during the night, a member of the research staff may quickly fix any sensors that have fallen off during the night. The recordings will allow us to see if you have any sleep disorders. If we find evidence that you have a sleep disorder, you will not be allowed to continue the study. In that case, the study physician will meet with you, describe the findings, and recommend that you see your physician.
Day 2: the Quitting Day. At 8:00am the next morning, the lights will be turned on and you will be required to get out of bed. All of the sensors for recording sleep and breathing will be removed. Your scalp electrodes will be removed with warm water and waterless shampoo. You will fill out a few questionnaires on how you slept and on your mood, desire to smoke, and how you are feeling.

At exactly 8:30am, you will be asked to smoke your final cigarette before quitting. You will again be wearing a pair of scrubs and a lab coat to go over your clothes, and use the designated smoking area outside of the laboratory. A staff member will be monitoring you from inside the building and alert you when your 5-minute smoke break is up. When you return to the laboratory, we will collect the scrubs and lab coat, and you will be asked to wash your hands. You will then provide us with a urine sample and a breath sample to check you’re your baseline smoking levels. You will also be served breakfast and will be given the opportunity to take a shower.

At approximately 9:00am you will be able to go home to do your normal activities (e.g., go to work, run errands, etc.). During the day, you should avoid cigarettes, other forms of tobacco, and nicotine medications (nicotine gum, chew, bupropion etc.), as well as drugs and alcoholic drinks. You will be asked to keep track of your daily activities as you did the three days before entering the laboratory.

In the evening, you will return to the laboratory at 6:00pm. You will be asked to change into a clean set of clothes that you will eventually wear to bed. You will then be asked to give a urine sample, a carbon monoxide breath sample, and an alcohol breathalyzer sample. The urine sample will be used to test for traces of drugs (to ensure you are drug-free). The carbon monoxide test will measure your recent smoking activity, and the breathalyzer will measure your recent alcohol use (to make sure you are free of alcohol). The carbon monoxide breath test will be used to determine whether you smoked cigarettes. As long as these tests show that you did not consume any cigarettes, alcohol, or drugs, you will continue on with the study.

The rest of the procedures that evening are the same as the day before, except that you will no longer be allowed to smoke if you want to continue your participation in the study. While in the laboratory, you will continue to wear the wrist activity monitor on your non-dominant arm. You will not be able to access the internet, use a cell phone, receive e-mail or text messages, watch live television, or listen to live radio. Except in case of emergency, you will not be allowed to have any visitors or to make or receive any phone calls. Free-time will be limited, but you may have time to watch a movie, and may listen to music and read while you are being hooked-up for the sleep recordings. Just as before, you will eat a snack at 7:45pm, eat breakfast at 8:40am, and you will be able to drink non-alcoholic drinks at any time during the study. You will continue to fill out a few questionnaires about your mood and desire to smoke and you will be prepared for the recording of your sleep. At 10:00pm, the lights will be turned off in your bedroom and you will be required to go to bed and try to sleep until
8:00am. During this period, you will not be allowed to leave the laboratory, watch television, listen to music, read, or use your cell phone. If you cannot sleep, you can lie quietly and rest with the lights turned off in your bedroom. You will be allowed to get out of bed to go to the bathroom or to drink water. Throughout the night, there will be a member of the research team in the laboratory to provide assistance if needed and to monitor your activities.

**Day 3: the Day after the Quitting Day.** At 8:00am the next morning, the lights will be turned on and you will be required to get out of bed. All of the sensors for recording sleep and breathing will be removed. Your scalp electrodes will be removed with warm water and waterless shampoo. You will give a urine sample to measure the amount of cotinine (a by-product of nicotine) in your body. You will then fill out a few questionnaires on how you slept and on your mood, desire to smoke, and how you are feeling. You will also be served breakfast and will be given the opportunity to take a shower. At 9:00am you will be able to go home to do your normal activities (e.g., go to work, run errands, etc.). During the day, you should avoid cigarettes, other forms of tobacco, and nicotine medications (nicotine gum, chew, buproprion etc.), as well as drugs and alcoholic drinks. You will be asked to keep track of your daily activities. In the evening, you will return to the laboratory at 6:00pm. You will be asked to change into a clean set of clothes that you will eventually wear to bed. You will then be asked to give a urine sample, a carbon monoxide breath sample, and an alcohol breathalyzer sample. The urine sample will be used to test for traces of drugs. The carbon monoxide test will measure your recent smoking activity, and the breathalyzer will measure your recent alcohol use. The carbon monoxide breath test will again be used to determine whether you smoked cigarettes. As long as these tests show that you did not consume any cigarettes, alcohol, or drugs, you will continue on with the study.

The rest of the procedures that evening are the same as the day before. At 10:00pm, the lights will be turned off in your bedroom and you will be required to go to bed and try to sleep until 8:00am.

**Day 4: the Second Day after the Quitting Day.** At 8:00am the next morning, the lights will be turned on and you will be required to get out of bed. All of the sensors for recording sleep and breathing will be removed. Your scalp electrodes will be removed with warm water and waterless shampoo. You will give a urine sample to test for the amount of cotinine (a by-product of nicotine) levels in your body. You will then fill out a few questionnaires on how you slept and on your mood, desire to smoke, and your experiences during the study. You will also be served breakfast and will be given the opportunity to take a shower. At 9:00am you will be able to go home to do your normal activities (e.g., go to work, run errands, etc.). During the day, you should continue to
avoid cigarettes, other forms of tobacco, and nicotine medications (nicotine gum, chew, bupropion etc.), as well as drugs and alcoholic drinks. You will be asked to keep track of your daily activities in your activity diary. You will continue to wear the wrist activity monitor on your non-dominant arm.

In the evening, you will return to the laboratory at 6:00pm for a few minutes. You will fill out a few questionnaires about your mood, desire to smoke, and the activities you did during the day. You will give a urine sample and a carbon monoxide breath sample. The urine sample will be used to measure the amount of cotinine in your body. The carbon monoxide test will measure your recent smoking activity. The urine sample test and the carbon monoxide breath test will again be used to determine whether you smoked cigarettes or used other forms of tobacco or nicotine medications. After this session, you will be scheduled for weekly follow-up visits.

**Weekly Follow-Up Sessions:** In the weeks following the laboratory study, you will return to the laboratory four more times, at one-week intervals after the quit date, to see if you resumed smoking. These sessions will take around 20 minutes each. You will fill out a few questionnaires about your mood, desire to smoke, and sleepiness. You will give a urine sample and a carbon monoxide breath sample to determine whether you smoked cigarettes or used other forms of tobacco or nicotine medications. You will continue to be scheduled for weekly follow-up visits up until the final one-month follow-up visit. At this visit, you will fill out additional questionnaires about your sleep quality. You will return to the laboratory approximately 3 weeks later to pick up your study payment and fill out a final study questionnaire. Your participation will then be complete.

**WITHDRAWAL:** You are free to withdraw your consent and to stop participation in this study at any time by indicating your desire to withdraw to the attending staff. Withdrawal of participation will not affect any current or future connections you may have with Washington State University in any way.
RISKS: Participation in this research study involves some risks that you should be aware of. These risks include:

1. There is a risk that you will experience discomforting withdrawal symptoms associated with smoking cessation after your last cigarette, such as irritability, anxiety, and craving of cigarettes. This is part of the normal nicotine withdrawal process. During both the laboratory and at-home portions of the study, the study physician will be on call if you have any concerns. Should you feel that you are completely unable to refrain from smoking, you are free to withdraw from the experiment at any time.

2. The scalp electrodes and adhesive sensors used for measuring brain electrical activity, eye movements, muscle activity, heart beats and breathing may cause some minor skin irritation. You should tell the staff if this occurs. The presence of the electrodes may cause some minor discomfort, and the paste used to hold electrodes to the scalp may leave some residue until you take a hot shower. The monitoring devices attached to the electrodes are electrically approved and conform to hospital standards for electrical safety.

3. During this study, you will be periodically asked to rate how you are feeling. If we find that you are particularly distressed, we will contact the study physician to assess your condition.

4. The investigators reserve the right to terminate the study at any time they feel it is necessary for your welfare or for research purposes (for example, if you are not adhering to the study protocol).

CONFIDENTIALITY: Your confidentiality in this study is protected to the extent allowed by federal and state law. No publication results will identify you and your name will not be associated with the findings. Authorized representatives of the WSU Institutional Review Board (IRB), a committee charged with protecting the rights and welfare of research subjects, may be provided access to research records that identify you by name.

INJURY FROM RESEARCH PROCEDURES: In the event of major injury resulting from the research procedures, you will be transported to a hospital emergency room. WSU and the research project make no commitment to provide financial compensation for your medical and transportation expenses or medical treatment you may need due to an injury resulting from the research.

COSTS: As a participant in this research study, you will not be required to pay for anything related to the study. All meals in the laboratory will be provided at no charge. No reimbursement will be provided for expenses for transportation to and from the laboratory.
PAYMENT: You will be paid for each portion of the study as follows:
(1) for participation in the initial 2-hour screening session, you will receive $20;
(2) for participation in the second 1-hour screening session, you will receive $10;
(3) for completion of the daily sleep and activities diary, and for calling in your bedtimes, wake times, and
number of cigarettes in the 3 days before the start of the laboratory phase of the study, you will be paid a
total of $15;
(4) for the first night in the laboratory phase, you will be paid $30;
(5) for returning to the laboratory in the evening on the second day for collection of samples, you will be paid
$20;
(6) for the second night in the laboratory phase (first day after quitting), you will be paid $30;
(7) for returning to the laboratory in the evening on the third day for collection of samples, you will be paid $20;
(8) for the third night in the laboratory phase (second day after quitting), you will be paid $30;
(9) for returning to the laboratory in the evening on the fourth day for collection of samples, you will be paid
$20;
(10) for coming to the laboratory for collection of samples one week after the quitting day, you will be paid $15;
(11) for coming to the laboratory for collection of samples two weeks after the quitting day, you will be paid $20;
(12) for coming to the laboratory for collection of samples three weeks after the last quitting day, you will be paid
$25;
(13) for coming to the laboratory for the one-month follow-up visit, you will be paid $30.
It is therefore possible for you to receive payments totaling $285 if you complete all phases of the study. If for
medical or other reasons you are unable to complete the study, you choose to withdraw from the study, or use
alcohol or drugs prior to entering any of the laboratory nights then you will receive payment for the time that you
participated. If you resume smoking after the final laboratory cigarette but before the third night in the laboratory,
you will be paid $20 as described above, to return to the laboratory for a sample and will not be scheduled for the
weekly follow-up visits.
Your payment paperwork will be submitted within one week after your final session in the study. This would
be one week from the one-month follow-up session or within one week of your last session, if you did not
complete the study. It may take up to three weeks for your check to be available after that point.
BENEFITS: There are no direct benefits to participating in this study. The knowledge that we expect to gain from this research study will help us to better understand the relationship between sleep and smoking, and may be a first step towards the development of improved interventions for smoking cessation.

NEW INFORMATION: If any new information becomes available that may affect your willingness to continue participation in the study, it will be provided to you immediately.

QUESTIONS: If you have questions about this study or the information in this form, please contact Amy Bender by phone at (509) 358-7756, or by e-mail at abender@wsu.edu, or by regular mail at: PO Box 1495, Spokane, WA, 99210-1495. If you have questions about your rights as a research participant, or would like to report a concern or complaint about this study, please contact the WSU Institutional Review Board by phone at (509) 335-3668, or by e-mail at irb@wsu.edu, or by regular mail at: Albrook 205, PO Box 643005, Pullman, WA 99164-3005.

STATEMENT OF CONSENT: This study has been explained to me and I have been given the opportunity to ask questions. I give my voluntary consent to take part in this research study. I will receive a copy of this consent document for my records.

__________________________________   _____________________
Signature of Participant      Date

__________________________________
Printed Name of Participant

__________________________________   _____________________
Signature of Researcher      Date

__________________________________
Printed Name of Researcher
Appendix B – Advertisements

Inlander Advertisement

INTERESTED TO QUIT SMOKING FOR THE NEW YEAR?

The WSU Spokane Sleep Center needs smokers 22-40yo willing to quit “cold turkey”.

Earn up to $285. 509-358-7756 for more info.

IRB #13177

Craigslist Advertisement

File Under: General Labor, Jobs
Subject: INTERESTED TO QUIT SMOKING FOR THE NEW YEAR?

The Sleep and Performance Research Center at Washington State University Spokane is sponsoring a research study that you may be eligible for. You must be:

- A current smoker who would like to quit “COLD TURKEY”
- Typically smoke within 60 minutes of waking in the morning
- Aged 22-40
- Not pregnant

This study will examine your sleep in the laboratory for up to three consecutive nights. During the day, you will be able to leave the laboratory from 9am until 6pm. If you complete all aspects of the study you could earn $285.

Contact Amy Bender at 509-358-7756 for more information.

WSU Institutional Review Board has reviewed and approved this study for human participation.

Participants must meet additional inclusion/exclusion criteria.
INTERESTED TO QUIT SMOKING FOR THE NEW YEAR?

The Sleep and Performance Research Center at Washington State University Spokane is sponsoring a research study that you may be eligible for. You must be:

- A current smoker who would like to quit “COLD TURKEY”
- Typically smoke within 60 minutes of waking in the morning
- Aged 22-40
- Not pregnant

This study will examine your sleep in the laboratory for up to three consecutive nights. During the day, you will
be able to leave the laboratory from 9am until 6pm. If you complete all aspects of the study you could earn $285.

   Contact Amy Bender at 509-358-7756 for more information.

   WSU Institutional Review Board has reviewed and approved this study for human participation. Participants must meet additional inclusion/exclusion criteria.
0.1.1 Are You a Smoker Wanting to Quit “Cold Turkey”?

The Sleep and Performance Research Center at WSU Spokane is sponsoring a research study that you may be eligible for. You must be:
1) A current smoker who would like to quit
2) Typically smoke within 60 min. of waking up in the morning
3) Aged 22-40
4) Not Pregnant

This study will examine your sleep in the laboratory for up to 3 consecutive nights. You will be able to leave the lab from 9am until 6pm. If you complete all aspects of the study, **you could earn $285.**

Contact **Amy Bender** at 509-358-7756 for more information. Subjects must meet additional inclusion criteria.

*This study has been approved by the WSU IRB.*
Appendix C – Telephone Screening Form
Telephone Screening Form

Today’s date: ___ / ___ / ______  Staff member calling: _______________________

Do you mind being interviewed regarding your eligibility for this study? _____________

Name (first, last): _____________________________________________________________

Telephone: home: (___) ____-_______ cell: (___) ____-_______ work: (___) ____-_______  

E-mail: ____________________________________________________________________  

Address: __________________________________________________________________ 

How did you hear about us? ___________________________________________________  

Sex (male, female): _____ (if female) Are you currently pregnant? ___ (must be no)  

Age: ___ (must be 22–40)  Date of birth: ___ / ___ / _______

Are you currently smoking? ___ (must say yes)  

At this moment, are you taking any steps to stop smoking? ________________________  

If yes, describe: ____________________________________________________________ (can’t be extreme measures)  

Do you wish to make a serious quit attempt during our study in order to stop smoking for good?  

_________ (must be yes)  

How many cigarettes on average do you smoke per day? ____ (must be 10 or more)  

Do you typically smoke within 60 minutes of waking? _____ (must say yes)  

Do you currently use smokeless tobacco products including nicotine gum, e-cigarettes, chew, etc.?  

___________ (must say no)  

Do you consume alcoholic beverages? _____  

(If yes) How many drinks per week on average? __________  

(if no) Did you previously consume alcoholic beverages within the last year? ________
If yes, ask the next four questions and give 1 point for each yes answer.

Over the past year, have you felt you should cut down on your drinking? _____ (1 point for yes) _____ point
Over the past year, have people annoyed you by criticizing your drinking? _____ (1 point for yes) _____ point
Over the past year, have you felt bad or guilty about your drinking? _____ (1 point for yes) _____ point
Over the past year, have you had a drink first thing in the morning to steady your nerves or get rid of a hangover? _____ (1 point for yes) _____ point

Sum of all 4 questions: _____ must not to exceed 1 point (≥2)

What is your habitual sleep duration? ________________________ (must be 6–10 hours)
What is your habitual bedtime? ____________________________ (must be before midnight)
What is your habitual wake-up time? _________________________ (must be 06:00–10:00)
Do you currently use any illicit drugs or marijuana? ________________________ (must be no)

Did you use any drugs or marijuana in the past? ______________________________
   If yes: What kind of drugs? ______________________________
   How recently? ______________________ (must be at least 1 month ago)
   How often did you use them and for what time frame? _______________

Are you physically healthy? _____________________________________________
Are you currently undergoing any medical treatment? _______________________
Do you currently have any medical conditions? ____________________________
Please describe any diseases or operations you had in the last year: _________________
Are you currently taking any prescription medications daily? _______________
   If yes, what medication and for what? ________________________________ (birth control OK)

Do you have any acute, chronic or recurrent medical conditions related to
breathing: ___; pneumonia: ___; upper respiratory infection: ___; influenza: ___;
mononucleosis: ___; infectious illnesses: ___; diabetes: ___; endocrine system: ___;
heart: ___; blood pressure: ___; rheumatic condition: ___; cancer: ___;
gastrointestinal system: ___; ulcer: ___; inflammatory bowel: ___; diverticulitis: ___;
immune disorders: ___; lupus: ___; skin problems: ___; psoriasis: ___;
eczema: ___; parasites (e.g., pinworm): ___; neurological problems: ___;
hepatitis: ___; jaundice: ___; sickle cell anemia: ___; HIV or AIDS: ___?
During the past 3 months, how often have you used any of the following medications?
Aspirin or Tylenol: __ times/month; Advil or other pain medication: __ times/month;
Blood pressure medication: ___ times/month; Antibiotics: ___ times/month;
Breathing sprays: ___ times/month (which ones?); Thyroid pills: ___ times/month;
Steroids: ___ times/month; Allergy medication: ___ times/month (which ones?);
Cold remedies: ___ times/month; Anti-inflammatory medication: ___ times/month;
Medication during menstruation for pain or muscle tension (females only): ___ (yes/no).

Do you currently have any psychological illnesses? __________________ (must be no)

Did you previously have any psychological illnesses? ____________________________

Are you, or have you been, in psychotherapy? _______________________________

If so, from when to when (dates)? _________________________________________

Do you have any sleep problems or have you ever been diagnosed with a sleeping disorder?
________________________________________

During the past 3 months, how often have you had disturbed sleep because of
breathing problems: ___ times/week; bad dreams: ___ times/week; pain: ___ times/week;
frequent urination: ___ times/week; heartburn: ___ times/week;
indigestion: ___ times/week; headaches: ___ times/week? (must not be daily)

During the past 3 months, did you use any medicine (prescribed or over-the-counter) to help you sleep?
_________________________ If so, how often? ______________ (must not be daily)

Do you have any problems staying awake during the day? __________________________

Do you wear glasses or contacts? ____________________________________________

Have you ever lost consciousness? ___________________________________________

If yes: how long and what were the circumstances? _____________________________

Did you notice any problems thinking or concentrating afterwards? ______________

If yes: describe and give examples: ___________________________________________

Did these problems go away, and when? _______________________________________

Are you presently employed? ________________________________________________

Did you, or do you work rotating night shift work? ________ (must not be within 3mo of study)

Did you, or do you work steady night shift work? ________________ (must not be within 3mo of study)
Did you, or do you plan to, travel by plane to a different time zone, recently or in the near future?  
_________________________________________________ (must not be within 1 month of entering study)  

To be sure that we will be able to pay you at the end of the study, we need to make sure you are eligible to work in the United States. Are you a citizen or national of the U.S., or do you have permission to work in the U.S.?  
__________  

(If not a citizen: Do you have a green card or work authorization? __________ )  

If the person is NOT eligible for the study: Based on your responses you are not eligible to participate in this study. Would you like the nationwide number that can help you quit smoking by providing free support and advice from an experienced cessation counselor? They will provide a personalized plan, self-help materials and coping strategies to help you quit.  
If yes: The number is 1-800-QUITNOW (784-8669). Do you have that written down?  
Thanks for your interest in our study.  

If the person IS eligible for the study:  
Here is a brief overview of the study:  
First you will come into the lab for two screening sessions. During these sessions, you will fill out a number of questionnaires, get a physical exam and provide a urine sample, and breath samples that will test for smoking, drugs, and alcohol use. You will also have the study explained to you in more detail during the first screening session.  
If you qualify, three days prior to the study, you will fill out questionnaires each morning and evening about your sleep and activities. You will also be required to call in your bedtimes, wake times and number of cigarettes smoked each day. After this three-day period, your sleep will be studied in the laboratory for up to three consecutive nights – one night during regular smoking consumption and up to two nights after you have quit smoking. For these nights in the laboratory, you will come to the lab in the evening at 6pm, stay the night, and leave in the morning at 9am. During your time in the lab, you will be inside the lab with up to three other participants and one or more staff members. You will not be able to leave the lab and, except in case of an emergency, you will not be able to have visitors or make or receive phone calls or text messages or use the internet. Do you think this will be a problem for you? ________  

During the first day of the study, you will come to the lab at 6pm. You will give a urine sample and breath samples to verify your smoking status, and to make sure you are drug- and alcohol-free. Then electrodes will be applied to the skin of your face, scalp, chest and legs. During this night only, you will have the opportunity to smoke outside the laboratory at 7:30pm, 8:30pm, and 9:30pm, and anytime during the sleep period. All smoking breaks will be limited to 5 minutes. At 10pm you will go to bed and will be in bed for 10 hours until 8am, for the recording of your sleep. During the sleep period you must rest quietly with the lights turned off except you may get up to use the bathroom, smoke, or to get a glass of water. At 8:30am (30 min after you wake up) you will smoke your final cigarette. At 9am you will be allowed to leave the laboratory. Will any of these procedures be a problem for you? ________
On the second and third days of the study, these procedures will be repeated, except you will no longer be allowed to smoke if you want to continue to be in the study. If you make it through the two-cessation nights in the laboratory without smoking, you will come back to the laboratory briefly once a week for four weeks. You will be giving urine and breath samples to see whether you are still smoke-free.

For participating in the study, you can receive up to $285 if you come to all of the sessions. You will also be free to withdraw from the study at any time. Your payment will be prorated if you end up smoking again or withdraw from the study. You will get the full details of how payments break down when you come in for the screening sessions. Are you interested in participating in this research study? _______

We need to schedule you for our next available screening sessions and study dates. Would the following dates work for you?

– First screening session: __ / __ / _____, ____ am/pm -- ____ am/pm

– Second screening session: __ / __ / _____, ____ am/pm -- ____ am/pm

– First laboratory night: __ / __ / _____, 6pm – __ / __ / _____, 9am

– Quit date of: __ / __ / _____, 8:30 am
    Will this quit date be a problem for you? ______________

– Followed by two more nights in the laboratory during abstinence: __ / __ / _____, 6pm – __ / __ / _____, 9a
    __ / __ / _____, 6pm – __ / __ / _____, 9a

It is very important that we can count on your availability on these dates!
The laboratory nights begin at 6pm and end at 9am. This means that you may have to coordinate with [work to leave early or come in late and] your family that you can be away.
Will this be a problem for you? ______________________

Do you foresee any problems with transportation to and from the Sleep and Performance Research Center on any of the dates discussed? ________________________________

If subject is eligible and available for this study:
– Pass on telephone number for inquiries or to re-schedule your appointment: (509) 358-7756.
– We will see you on ___/___/_____ at ___am/pm for the first screening session. You will be paid $20 for this session.
– Thank them for their interest!
– For confidentiality purposes, do not mention subjects’ names etc. in e-mails

If subject is not eligible or not available for this study, describe why: ______________________________________________________________
______________________________________________________________

Notes: __________________________________________________________________________
Inclusion/Exclusion Criteria:

1. Currently wanting to quit smoking but has not begun the quitting process, as assessed by self-report, questionnaire
2. Smoke ≥10 cigarettes per day, as assessed by questionnaire
3. No use of smokeless tobacco, as assessed by questionnaire
4. Initial carbon monoxide breath sample of ≥10ppm (taken at screening session 1)
5. Smoke within 60 minutes of waking, as assessed by questionnaire
6. Proficient English speaker, as assessed by conversation or self-report
7. Aged 22-40, as assessed by license or ID
8. Physically and psychologically healthy (i.e., no clinical disorders and/or illnesses), as assessed by history, questionnaires, and a physical exam.
9. No current medical or drug treatment (excluding oral contraceptives), as assessed by history, and questionnaires
10. Free from traces of drugs (besides nicotine) during screening session 1 and prior to the three laboratory nights, as assessed by urine drug screen
11. Free of traces of alcohol during screening session 1 and prior to the three laboratory nights, as assessed by breathalyzer
12. Not having a clinically significant alcohol problem (≥2 points on CAGE alcohol screening, 4 questions above), as assessed by questionnaire
13. No current history of psychiatric illness and no presently clinically relevant history of psychiatric illness, as assessed by questionnaire and history
14. No history of drug (other than nicotine) or alcohol abuse in the past year and no history of methamphetamine abuse, as assessed by urine screen, history and questionnaires
15. No history of moderate to severe brain injury, as assessed by questionnaire
16. Not pregnant, as assessed by self-report, urine screen
17. No sleep or circadian disorder (nicotine induced insomnia will be allowed and assessed by questionnaire and follow-up by the physician of record to verify it is not insomnia by other causes) as assessed by questionnaires, actigraphy, and baseline polysomnography.
18. Good habitual sleep, between 6 and 10 hours in duration, going to bed between 20:00 and midnight and getting up between 06:00 and 10:00.
19. No travel across time-zones within one month of entering the study, as assessed by questionnaire
20. No shift-work within three months of entering the study, as assessed by questionnaire
21. No history of learning disability, as assessed by questionnaire
22. Not vision impaired unless corrected back to normal, as assessed by questionnaire
Smoking - Tips on How to Quit

There are many ways to quit smoking. There are also resources to help you. Family members, friends, and co-workers may be supportive. But to be successful, you must really want to quit.

Most people who have quit smoking were unsuccessful at least once in the past. Try not to view past attempts to quit as failures. See them as learning experiences.

It is hard to stop smoking or using smokeless tobacco. But anyone can do it.

Know the symptoms to expect when you stop. Common symptoms include:

- An intense craving for nicotine
- Anxiety, tension, restlessness, frustration, or impatience
- Difficulty concentrating
- Drowsiness or trouble sleeping
- Headaches
- Increased appetite and weight gain
- Irritability or depression

How bad your symptoms are depends on how long you smoked. How many cigarettes you smoked each day also plays a role.

FEEL READY TO QUIT?

First, set a quit date. Quit completely on that day. Before your quit date, you may begin reducing your cigarette use. But remember, there is no safe level of cigarette smoking.

List the reasons why you want to quit. Include both short- and long-term benefits.

Identify the times you are most likely to smoke. For example, do you tend to smoke when feeling stressed or down? When out at night with friends? While drinking coffee or alcohol? When bored? While driving? Right after a meal or sex? During a work break? While watching TV or playing cards? When you are with other smokers?

Let your friends, family, and co-workers know of your plan to stop smoking. Tell them your quit date. It can be helpful if they know what you are going through, especially when you are grumpy.

Get rid of all your cigarettes just before the quit date. Clean out anything that smells like smoke, such as clothes and furniture.
MAKE A PLAN

Make a plan about what you will do instead of smoking at those times when you are most likely to smoke.

Be as specific as possible. For example, drink tea instead of coffee. Tea may not trigger the desire for a cigarette. Or, take a walk when you feel stressed.

Remove ashtrays and cigarettes from the car. Put pretzels or hard candies there instead. Pretend-smoke with a straw.

Find activities that focus your hands and mind. But make sure they are not taxing or fattening. Computer games, solitaire, knitting, sewing, and crossword puzzles may help.

If you normally smoke after eating, find other ways to end a meal. Play a tape or CD. Eat a piece of fruit. Get up and make a phone call. Take a walk (a good distraction that also burns calories).

CHANGE YOUR LIFESTYLE

Make other changes in your lifestyle. Change your daily schedule and habits. Eat at different times, or eat several small meals instead of three large ones. Sit in a different chair or even a different room.

Satisfy your oral habits in other ways. Eat celery or another low-calorie snack. Chew sugarless gum. Suck on a cinnamon stick.

Go to public places and restaurants where smoking is prohibited or restricted.

Eat regular meals, and don't eat too much candy or sweet things.

Get more exercise. Take walks or ride a bike. Exercise helps relieve the urge to smoke.

SET SOME GOALS

Set short-term quitting goals and reward yourself when you meet them. Every day, put the money you normally spend on cigarettes in a jar. Later, buy something you like.

Try not to think about all the days ahead you will need to avoid smoking. Take it one day at a time.

Even one puff or one cigarette will make your desire for more cigarettes even stronger. However, it is normal to make mistakes. So even if you have one cigarette, you don't need to take the next one.

References


Appendix E – Sleep and Activities Diary
CONFIDENTIAL SLEEP and ACTIVITIES DIARY

ID # _______________________

At Home ___ /___ /______ - ___ /___ /______

Laboratory Night 1 (during smoking) ___ /___ /______

Quit Date and Laboratory Night 2 ___ /___ /______

Laboratory Night 3 ___ /___ /______

Call in bedtimes, wake times and number of cigarettes at:
(509) 358-7751, option 3

Please bring this diary with you to the laboratory

For questions, call Amy Bender (509) 358-7756.
Sleep and Performance Research Center
Washington State University Spokane
P.O. Box 1495
Spokane, WA 99210-1495
1. What time is it now? ___ : ___ am/pm

2. At what time are you going to bed today? ___ : ___ am/pm

3. Did you sleep or nap today during the morning, afternoon, or evening? _____
   At ___ : ___ am/pm for ___ hours and ___ min
   At ___ : ___ am/pm for ___ hours and ___ min

4. Did you work today? ______ Did you go to work or work at home? ______
   From ___ : ___ am/pm to ___ : ___ am/pm

5. Overall, how did you feel today? Mark an X at a place along the lines below:
   sleepy     alert
   sick       healthy
   physically exhausted       energetic
   mentally exhausted       sharp

6. Indicate number of caffeinated drinks today: ___ coffee, ___ soda, ___ tea, ___ energy drinks

7. Indicate number of alcoholic drinks today: ______

8. Did you smoke today? ______ How many cigarettes? ______

9. Did you use any other forms of tobacco (if yes, explain)? __________________________________________

10. Did you exercise or do any physical activities today? ______
    What activities/exercise specifically? ___________________________________________________________
    For how long? ______________________

11. List all the medications you took today: _______________________________________________________

12. List any illness, infection, pain, discomfort, worry, or problem you had today: ____________________
    _______________________________________________________________________________________
    _______________________________________________________________________________________
    _______________________________________________________________________________________

Notes: _____________________________________________________________________________________
    _______________________________________________________________________________________
    _______________________________________________________________________________________
    _______________________________________________________________________________________
About today…
Please indicate whether you have experienced any of the following today for more than 5 minutes. If you did, please also indicate the peak intensity of the experience (1 = very low intensity; 2 = low intensity; 3 = moderate intensity; 4 = high intensity; 5 = very high intensity) and the duration of the experience (in minutes).

<table>
<thead>
<tr>
<th>Experience</th>
<th>Yes or No</th>
<th>Intensity (1-5)</th>
<th>Duration (min)</th>
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Please call 509-358-7751, option 3, at the time when you are going to bed. Give your name, ID number, your bedtime, and the number of cigarettes you smoked today. Thank you!
Please call in when you wake up at 509-358-7751, option 3. Give your name, ID, your wake-up time, and if you smoked last night after you went to bed, but before you woke up for the day. Thank you!

Date: ___ / ___ / _______                ID: __________
SATURDAY MORNING

13. What time is it now? ___ : ___ am/pm

14. How did you sleep last night? Mark a vertical line (|) at a place along the line below:

    extremely poorly | | | | | | | | | | very well

15. How do you feel right now? Mark a vertical line (|) at a place along the line below:

    extremely sleepy | | | | | | | | | | very refreshed

   Falling Asleep
16. What time did you go to bed with the intent to sleep? ___________
17. How long did it take you to fall asleep last night? _______ minutes
18. Last night, did you feel that you had trouble falling asleep (if yes, explain)? ___________________
   ___________________________________________________________________________________
   ___________________________________________________________________________________

   Awakenings Last Night (after you fell asleep but before you woke up for the day)
19. Please list the duration, timing, reason, and whether you smoked for each awakening

<table>
<thead>
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<th>Awakening</th>
<th>Approximate duration (min)</th>
<th>Approximate time it occurred</th>
<th>Initial Reason (bathroom, partner, needed to smoke, etc.)</th>
<th>Did you smoke (y/n)</th>
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Final Awakening (right before you got up for the day)

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<th>What time did you wake up today?</th>
<th>Reason (alarm, spontaneous, needed to smoke, etc.)</th>
<th>Was this too early? (y/n)</th>
<th>How soon after you woke up did you smoke?</th>
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20. Approximately how much total sleep did you get last night? _______________________________

21. List all the medications or supplements you took last night: _______________________________
____________________________________________________________________________________
____________________________________________________________________________________

22. List any illness, infection, pain, discomfort, worry, or problem you had last night:
____________________________________________________________________________________
____________________________________________________________________________________

Notes:

____________________________________________________________________________________
____________________________________________________________________________________
____________________________________________________________________________________
5. What time is it now? ___ : ___ am/pm

6. At what time are you going to bed today? ___ : ___ am/pm

7. Did you sleep or nap today during the morning, afternoon, or evening? _____
   At ___ : ___ am/pm for ___ hours and ___ min
   At ___ : ___ am/pm for ___ hours and ___ min

8. Did you work today? _____ Did you go to work or work at home? _______
   From ___ : ___ am/pm to ___ : ___ am/pm

5. Overall, how did you feel today? Mark an X at a place along the lines below:
   sleepy | alert
   sick   | healthy
   physically exhausted | energetic
   mentally exhausted | sharp

23. Indicate number of caffeinated drinks today: ___ coffee, ___ soda, ___ tea, ___ energy drinks

24. Indicate number of alcoholic drinks today: _______

25. Did you smoke today? ______ How many cigarettes? _______

26. Did you use any other forms of tobacco (if yes, explain)? ____________________________
   ________________________________________________________________________________

27. Did you exercise or do any physical activities today? _______
   What activities/exercise specifically? ____________________________
   For how long? ________________

28. List all the medications you took today: ____________________________

29. List any illness, infection, pain, discomfort, worry, or problem you had today: __________
   ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________

Notes: ________________________________________________________________________________
   ________________________________________________________________________________
   ________________________________________________________________________________
About today…
Please indicate whether you have experienced any of the following today for more than 5 minutes. If you did, please also indicate the peak intensity of the experience (1 = very low intensity; 2 = low intensity; 3 = moderate intensity; 4 = high intensity; 5 = very high intensity) and the duration of the experience (in minutes).

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Please call 509-358-7751, option 3, at the time when you are going to bed. Give your name, ID number, your bedtime, and the number of cigarettes you smoked today. Thank you!
Please call in when you wake up at 509-358-7751, option 3. Give your name, ID, your wake-up time, and if you smoked last night after you went to bed, but before you woke up for the day. Thank you!

Date: ____ /____ /_________                ID: __________                               SUNDAY MORNING

30. What time is it now?  ___ : ___  am/pm

31. How did you sleep last night? Mark a vertical line (|) at a place along the line below:

   extremely poorly  |  very well

32. How do you feel right now? Mark a vertical line (|) at a place along the line below:

   extremely sleepy  |  very refreshed

**Falling Asleep**
33. What time did you go to bed with the intent to sleep? _____________

34. How long did it take you to fall asleep last night? _______ minutes

35. Last night, did you feel that you had trouble falling asleep (if yes, explain)? ___________________

   __________________________________________________________________________________
   __________________________________________________________________________________

**Awakenings Last Night (after you fell asleep but before you woke up for the day)**
36. Please list the duration, timing, reason, and whether you smoked for each awakening

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### Final Awakening (right before you got up for the day)

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<th>What time did you wake up today?</th>
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37. Approximately how much total sleep did you get last night? ________________________________

38. List all the medications or supplements you took last night: ________________________________
_______________________________________________________________________________________

39. List any illness, infection, pain, discomfort, worry, or problem you had last night:
_______________________________________________________________________________________

### Notes:
_______________________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________
9. What time is it now? ___ : ___ am/pm

10. At what time are you going to bed today? ___ : ___ am/pm

11. Did you sleep or nap today during the morning, afternoon, or evening? _____
   At ___ : ___ am/pm for ___ hours and ___ min
   At ___ : ___ am/pm for ___ hours and ___ min

12. Did you work today? ______ Did you go to work or work at home?_______
   From ___ : ___ am/pm to ___ : ___ am/pm

5. Overall, how did you feel today? Mark an X at a place along the lines below:

   sleepy ┌────────────────────────┐
        │ HEALTHY                |
        │ alert                 |
        │ sick                  |
   physically exhausted ┌────────────────────────┐
                         │ energetic            |
                         │ sharp               |
   mentally exhausted

40. Indicate number of caffeinated drinks today: ___ coffee, ___ soda, ___ tea, ___ energy drinks

41. Indicate number of alcoholic drinks today: _______

42. Did you smoke today? ______ How many cigarettes? _______

43. Did you use any other forms of tobacco (if yes, explain)? _________________________________
   ___________________________________________________________________________________

44. Did you exercise or do any physical activities today? _______
   What activities/exercise specifically? ___________________________________________________
   For how long? __________________

45. List all the medications you took today: _______________________________________________

46. List any illness, infection, pain, discomfort, worry, or problem you had today: __________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

Notes: _______________________________________________________________________________
   ___________________________________________________________________________________
   ___________________________________________________________________________________
About today…
Please indicate whether you have experienced any of the following today for more than 5 minutes. If you did, please also indicate the peak intensity of the experience (1 = very low intensity; 2 = low intensity; 3 = moderate intensity; 4 = high intensity; 5 = very high intensity) and the duration of the experience (in minutes).

<table>
<thead>
<tr>
<th>Experience</th>
<th>Yes or No</th>
<th>Intensity (1-5)</th>
<th>Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upset stomach or bowel</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Headache</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Difficulty concentrating</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sadness</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Back aches or pains</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Giddiness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Muscular aches or pains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint aches or pains</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Itchy skin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling too hot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling too cold</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frightened</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Worried</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unusual quietness</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Unusual excitement</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Unusual tiredness</td>
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<td></td>
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<tr>
<td>Feeling confused</td>
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<td></td>
<td></td>
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<tr>
<td>Feeling anxious</td>
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</tbody>
</table>

Please call 509-358-7751, option 3, at the time when you are going to bed. Give your name, ID number, your bedtime, and the number of cigarettes you smoked today. Thank you!
Please call in when you wake up at 509-358-7751, option 3. Give your name, ID, your wake-up time, and if you smoked last night after you went to bed, but before you woke up for the day. Thank you!

Date: ___ / ___ / _________                ID: __________                               MONDAY MORNING

47. What time is it now? ___ : ___  am/pm

48. How did you sleep last night? Mark a vertical line (|) at a place along the line below:

   extremely poorly | very well

49. How do you feel right now? Mark a vertical line (|) at a place along the line below:

   extremely sleepy | very refreshed

Falling Asleep
50. What time did you go to bed with the intent to sleep? ____________

51. How long did it take you to fall asleep last night? _______ minutes

52. Last night, did you feel that you had trouble falling asleep (if yes, explain)? ___________________
   __________________________________________________________________________________
   __________________________________________________________________________________

Awakenings Last Night (after you fell asleep but before you woke up for the day)
53. Please list the duration, timing, reason, and whether you smoked for each awakening

<table>
<thead>
<tr>
<th></th>
<th>Approximate duration (min)</th>
<th>Approximate time it occurred</th>
<th>Initial Reason (bathroom, partner, needed to smoke, etc.)</th>
<th>Did you smoke (y/n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awakening 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Awakening 2</td>
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<td>Awakening 3</td>
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<td>Awakening 4</td>
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<tr>
<td>Awakening 5</td>
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<tr>
<td>Awakening 6</td>
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</tbody>
</table>
**Final Awakening (right before you got up for the day)**

<table>
<thead>
<tr>
<th>What time did you wake up today?</th>
<th>Reason (alarm, spontaneous, needed to smoke, etc.)</th>
<th>Was this too early? (y/n)</th>
<th>How soon after you woke up did you smoke?</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

54. Approximately how much total sleep did you get last night? _______________________________

55. List all the medications or supplements you took last night: _______________________________

56. List any illness, infection, pain, discomfort, worry, or problem you had last night:

____________________________________________________________________________________

**Notes:**

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________