Published in final edited form as:
Addict Behav. 2019 March ; 90: 71–76. doi:10.1016/j.addbeh.2018.10.023.

Sleep quality in cigarette smokers: Associations with smoking-related outcomes and exercise

Himal Purani, BS[1], **Samantha Friedrichsen, MPH**[2], and **Alicia Allen, PhD, MPH**[3,*]

[1]Department of Family Medicine & Community Health, Medical School, University of Minnesota, 717 Delaware Street SE, Suite 454, Minneapolis, MN 55414

[2]Department of Family Medicine & Community Health, Medical School, University of Minnesota, 717 Delaware Street SE, Suite 454, Minneapolis, MN 55414

[3]Department of Family & Community Medicine, College of Medicine, University of Arizona, 3950 South Country Club Drive, Suite 330, Tucson, Arizona 85716

Abstract

Introduction: Compared to the general population, cigarette smokers report poorer sleep quality. Poor sleep quality in cigarette smokers is associated with greater nicotine dependence. While exercise is known to improve sleep quality in the general population, less is known about how exercise effects sleep in those who smoke. The goal of this study was to explore the relationships between exercise, sleep, and smoking in cigarette smokers.

Methods: Data on sleep quality (Insomnia Severity Index (ISI) and Pittsburgh Sleep Quality Index (PSQI)), smoking-related outcomes (e.g., cigarettes/day, Fagerstrom Test for Nicotine Dependence, Minnesota Nicotine and Withdrawal Scale, and Questionnaire of Smoking Urges) and exercise (Fitbit activity measures) were collected for 32 participants (63% female, mean age 30.3 ± 1.0 years) participating in a 12-week clinical research study. Analyses included simple linear regression models.

Results: Overall, participants reported poor sleep quality at baseline (PSQI>5). Poorer sleep quality at baseline was associated with increased withdrawal (β=1.63±0.53, p=0.0043), craving (β=0.51±0.43, p=0.2471), and total smoking urges (β=1.10±0.41, p=0.0118). During follow-up (i.e., from baseline to week 12), a daily increase in exercise was associated with improved sleep quality over the same time period (PSQI: β=- 0.82± 0.35, p=0.0379).

Conclusion: Our data suggest that better sleep quality may be associated with lower levels of withdrawal, craving, and smoking urges. Further, exercise may be associated with better sleep quality in cigarette smokers. Future work should explore how increasing exercise and improving sleep quality could inform future smoking cessation interventions.

*Corresponding author. aliciaallen@email.arizona.edu.

Keywords

Sleep quality; exercise; cigarette smoking; smoking behavior; withdrawal

1. Introduction

Compared to individuals who do not smoke cigarettes, those who do smoke cigarettes are more likely to experience sleep problems such as sleep disordered breathing, sleep apnea, insomnia, and poor sleep quality as marked by sleep disturbances such as shorter sleep durations, increased sleep latency, daytime sleepiness, and increased difficulty maintaining sleep (Cohrs et al., 2014; Deleanu et al., 2016; Janson et al., 1995; Jaehne et al., 2012; Liu et al., 2013; McNamara et al., 2014; Wetter et al., 1994). Poor sleep quality is a risk factor for chronic conditions such as depression, obesity, diabetes, and cardiovascular disease (Gangwisch et al., 2006; Gangwisch et al., 2007; Pilcher & Huffcutt, 1996; Roane & Taylor, 2008; Wilson, 2005; Yaggi et al., 2005). These conditions are likely further exacerbated by cigarette smoking (US DHHS, 2014). Thus, examining the interaction between sleep quality and cigarette smoking has critical implications for many chronic health conditions.

To date, research on the relationship between sleep quality and smoking behavior is limited. Understanding this relationship is crucial in designing innovative clinical interventions and, subsequently, improving smoking cessation outcomes. Certain smoking-related outcomes such as withdrawal, craving, nicotine dependence and number of cigarettes smoked per day have been identified as predictors of smoking abstinence and relapse (McCarthy et al., 2006; Sweitzer, Denlinger, & Donny, 2013; Vangeli et al., 2011). For example, a recent smoking cessation study reported that the following factors each independently predicted time to smoking relapse: scores on the Fagerström Test for Nicotine Dependence (FTND), number of cigarettes smoked per day, and self-reported craving on the first day of abstinence (Sweitzer, Denlinger, & Donny, 2013). The study also noted that a single item on the FTND – time to first cigarette in the morning – significantly predicted time to lapse even when controlling for the other significant predictors listed above (Sweitzer, Denlinger, & Donny, 2013). Another study reported the importance of craving in smoking relapse where more than 32% of participants with high craving scores relapsed within one week of cessation (Killen & Fortmann, 1997). Therefore, identifying factors that negatively affect these smoking related outcomes can help us better predict smoking abstinence and tailor treatments to improve abstinence and prevent relapse. One such factor that is suspected to affect smoking-related outcomes is sleep quality. Individuals who reported more sleep disturbances and greater nicotine dependence (i.e., woke during the night to smoke) were more likely to relapse to smoking within six weeks (Peters et al., 2011). Further, a small study (n=19) examined the efficacy of a sleep intervention (cognitive-behavioral therapy for insomnia) in improving smoking cessation outcomes in smokers with insomnia (Fucito et al., 2014). These preliminary results indicated that sleep and smoking cessation counseling resulted in better sleep quality, longer sleep duration, fewer insomnia symptoms, and a greater number of days to relapse (13 days ± 3.54 vs. 10 days ± 4.55; $p = 0.42$), as compared to smoking cessation counseling alone (Fucito et al., 2014). However, further research is needed to better understand the impact of sleep quality on smoking behavior and smoking-related outcomes in cigarette smokers.

Exercise is another factor that is known to affect smoking-related outcomes; however, literature around exercise and smoking behavior offers mixed results. Several studies have shown that acute bouts of aerobic exercise are associated with a significant reduction in cigarette cravings, withdrawal symptoms, and a desire to smoke (Daniel, Cropley, & Fife-Schaw, 2006; Daniel, Cropley, Ussher, & West, 2004; Ussher et al., 2001; Allen et al., 2018). Indeed, a recent meta-analysis of 15 studies concluded that exercise reduces cigarette cravings; however the effect of exercise intensity and mechanisms of action are unknown(Roberts et al., 2012). Further research is needed to understand the mechanisms involved in the effect exercise has on smoking behavior and smoking-related outcomes. One possible underlying mechanism is stress reduction – the effects of exercise on smoking behavior may be an indirect effect of the effect of exercise on sleep quality in cigarette smokers.

In the general population, exercise is known to improve sleep quality (Driver & Taylor, 2000), specifically through increasing total sleep time and decreasing the number of awakenings post sleep onset (Chennaoui, Arnal, Sauvet, & Léger, 2015; Kline et al., 2013; Wang & Youngstedt, 2014). In a randomized controlled trial, individuals randomized to the exercise and sleep hygiene education group reported improvements in sleep quality, sleep duration, and sleep latency compared to the control group (Reid et al., 2010). However, the effects of exercise on sleep quality in individuals who smoke is not well characterized. This gap in literature diminishes our understanding of the relationship between exercise and sleep as it relates to smoking-related outcomes.

In order to preliminarily examine the relationship between exercise, sleep quality, and smokingrelated outcomes among cigarette smokers, we conducted a secondary-data analysis from a pilot, randomized controlled trial designed to study the effect of a 12-week exercise intervention on selfinitiated quit attempts in young adult smokers (Allen et al, In Press). We aimed to: (1) examine the cross-sectional relationship between sleep quality and smoking-related outcomes (e.g., cigarettes/day, craving) prior to implementing an exercise intervention, and (2) explore how change in exercise corresponds to change in sleep quality after participating in a 12-week exercise intervention. We hypothesized that smoking-related outcomes would be inversely related to sleep quality (i.e., better sleep quality would be associated with more favorable smoking-related outcomes). We also hypothesized a positive association between change in exercise levels and change in sleep quality during the 12-week exercise intervention (i.e., an increase in exercise would be related to better sleep quality).

2. Methods

2.1 Study Sample

Individuals who smoked cigarettes were recruited for a study on the role of exercise in self-initiated quit attempts (Allen et al, In Press). In brief, eligibility criteria included being between the ages of 18–40 years old, self-report of smoking (smoking ≥5 cigarettes/day for

>6 months), minimally active at the time of enrollment (defined as self-reported ≤2 physical activity sessions per week), interest in increasing their exercise (self-reporting a score of ≥7 on a 10-point Likert-type scale with 10 being very interested), and desire to quitting smoking within the next six months. Exclusion criteria included contraindications to increasing physical activity and, in women, pregnancy. Additional details can be found elsewhere (Allen et al, In Press).

2.2 Study Procedures

After an initial eligibility conducted by phone, participants attended a screening visit at the research clinic where they gave informed consent followed by vital sign measurements, medical history, smoking history, and a medical exam which included an electrocardiogram and the VO2 peak exercise test performed on a cycle ergometer (Bittoun, 2008; Noakes, 2008; Allen et al., 2018). The study nurse practitioner and principal investigator then verified the final eligibility. Participants also filled out several questionnaires at the screening visit regarding their demographics, smoking behavior, and medical history.

Within two weeks of the screening visit, eligible participants attended a baseline visit where they were stratified (by readiness to quit) and randomized into one of three groups (1:1:1 ratio): Continuous Aerobic (CA), High Intensity Interval Training (HIIT) or control group. Regardless of randomization, all participants were given a Fitbit Flex (a step tracking device) at their baseline visit and were instructed to wear it daily to track their physical activity throughout the study.

After the baseline visit, all participants attended follow-up clinic visits at weeks four, eight, and twelve. At each clinic visit we collected the following data: carbon monoxide (CO) level, timeline followback (TLFB) to report cigarettes/day, and validated questionnaires. Study questionnaires were collected and managed using REDCap electronic data capture tools hosted at the University of Minnesota – Twin Cities (Harris et al., 2009). All study procedures were approved by the Institutional Review Board at the University of Minnesota. Participants were compensated up to $405 in gift cards and gifts for their participation

2.3 Exercise Interventions

In brief, both the CA and HIIT exercise interventions were 12-week programs. The CA intervention included three 30-minute sessions per week, where one session was completed with the personal trainer and the other two sessions were completed by the participant on their own time. The intervention started with walking on a treadmill and slowly building up the participant's stamina so that they were jogging for the full 30-minute duration by the end of the study. The HIIT intervention included one 20-minute weekly session of physical activity using a stationary bike at the gym. This program included a 1:4 work to rest ratio where participants started off with a five-minute warm up at 50% of their heart rate reserve (HRR) followed by two minutes of pedaling at a low intensity (35–45% of their HRR and ~40–50 revolutions per minute), and finally 30 seconds of high intensity pedaling (~80–90 revolutions per minute). Participants repeated this pattern three more times for a total of four bouts with each bout lasting 2.5 minutes. Finally, at the end of each session, a three-minute cool down was performed including light stretching to complete the 20-minute exercise session. This HIIT intervention was modeled after the Wingate Protocol (Shiraev & Barclay, 2012). Participants randomized to the control group were asked not to change their physical activity levels during the 12 week follow-up, and were then offered an exercise intervention of their choice (HIIT or CA) at the end of their Week 12 clinic visit.

2.4 Study Measures

Sleep quality was assessed at each clinic visit using two validated questionnaires: the Pittsburgh Sleep Quality Index (PSQI) and the Insomnia Severity Index (ISI). The PSQI measures sleep quality retrospectively over the previous month using self-report/recall; it consists of nineteen individual items which evaluate the seven components of sleep quality: (1) sleep duration; (2) sleep disturbance; (3) sleep latency; (4) daytime dysfunction due to sleepiness; (5) sleep efficiency; (6) overall sleep quality; and (7) sleep medication usage (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). These seven component scores (scored 0–3) are added together to yield one global score between 0–21, with higher scores indicating worse sleep quality (Buysse et al., 1989). A global PSQI score ≤5 indicates good sleep quality and >5 indicates poor sleep quality (Buysse et al., 1989). The ISI measures the nature and severity of insomnia retrospectively over the previous month using self-report/recall (Bastien, Vallières, & Morin, 2001). It consists of 7 individual items scored on a 5-point Likert-type scale (e.g., each item is rated from 0–4) to yield a total score between 0–28 (Bastien, Vallières, & Morin, 2001). A score of 0–7 indicates no clinical insomnia, 8–14 indicates subthreshold insomnia, 15–21 indicates moderate insomnia, and 22–28 indicates severe insomnia (Bastien, Vallières, & Morin, 2001).

To assess smoking-related outcomes, the average number of cigarettes smoked per day for the seven days prior to each clinic visit was collected using timeline followback (TLFB) (Sobell et al., 1996). Each participant's physiological dependence on nicotine was measured using the validated Fagerstöm Test for Nicotine Dependence (FTND) questionnaire (Heatherton et al., 1991). The FTND questionnaire consists of six items which yield a total score between 0–10. A score of 0–2 indicates low nicotine dependence, 3–4 indicates low–moderate dependence, 5–7 indicates moderate dependence and a score of 8 or higher indicates high nicotine dependence (Heatherton et al., 1991). Smoking-related outcomes were also assessed using two validated questionnaires, which were completed at each clinic visit. The first, Minnesota Nicotine Withdrawal Scale (MNWS), measures nicotine craving and withdrawal symptoms retrospectively over the previous week on a scale from 0 (not present) to 4 (severe) (Hughes and Hatsukami, 1998). The MNWS withdrawal score is also assessed by taking into account symptoms associated with withdrawal such as irritability, anxiety, depressed mood, difficulty concentrating, increased appetite, insomnia and restlessness. These sub-components of the MNWS were analyzed to determine whether sleep-related items (insomnia, awakening at night, etc.) on the MNWS withdrawal scale were driving the association between withdrawal and sleep quality. The second, Questionnaire of Smoking Urges Brief (QSU-B), measures overall smoking urges and two factors: Factor 1—a strong desire and intention to smoke, with smoking perceived as rewarding and Factor 2—an urgent desire to smoke in anticipation of relief from negative affect (Cox, Tiffany, and Christen, 2001). All items for the QSU-B were assessed using a

Likert-type scale ranging from 0 (strongly disagree) to 7 (strongly agree) (Cox, Tiffany, and Christen, 2001).

Exercise was measured using the Fitbit Flex, which recorded the number of steps and minutes each participant spent engaging in light, fair, and very active exercise daily from baseline to Week 12. When movement is more strenuous than regular walking, Fitbit devices classify them as “active minutes” based on metabolic equivalents (METs). Change in exercise from Baseline to Week 12 was assessed using activity averages from the 7 days before Week 0 and the 30 days before Week 12. Due to missing data and technical issues with the Fitbit, physical activity data was only analyzed for a subsample of the participants who had complete data through week 12 of the study (n=13).

2.5 Statistical Analysis

Descriptive statistics were used to describe the study sample. For our first aim, simple linear regression models with smoking variables as predictors (each in their own model) and sleep quality measures as the outcomes were used to assess the associations at baseline between sleep quality and smoking-related outcomes. These results are reported as regression point estimates (β) and standard errors (SE). Prior to running linear regression models, outcome distributions were examined for normality using histograms and Quantile-Quintile plots. For our second aim, the change in sleep quality from baseline to week 12 was compared between the exercise participants and control participants using Wilcoxon two-sample tests, and within subjects using Wilcoxon signed rank sum tests. Lastly, the association between change in Fitbit-recorded exercise levels (baseline week to week 12) and change in sleep quality (baseline to week 12) was assessed with simple linear regression in a subset of participants (n=13) from the control group and the exercise group who completed the study and had Fitbit Flex data at their week 12 visit. One participant had an invalid response to an item on the PSQI at baseline, thus their response for this item at the screening visit was used instead. Similarly, this occurred for one participant at week 12, and thus their week 4 response was substituted. SAS Software v. 9.4 was used for analysis (SAS Institute Inc., Cary, NC), and p-values <0.05 were considered statistically significant.

3. Results

3.1 Participants

The study sample (n=32) was mostly female (63%), white (72%), and had at least some college education (72%). On average, study participants were (mean ± SE) 30.3 ± 1.0 years old, smoked 13.1 ± 0.9 cigarettes/day, and had a FTND score of 3.6 ± 0.4. At baseline, participants had a poor sleep quality (PSQI: 6.6±0.5) with low risk for insomnia (ISI: 5.8±0.7), and walked, on average, 8,277.0 ± 729.0 steps per day, spent 108.8 ± 32.3 minutes being lightly active, 8.0 ± 4.5 minutes being fairly active and 3.8 ± 2.3 minutes being very active.

3.2 Cross-Sectional Associations between Sleep Quality and Smoking Outcomes

For every one-point increment in the PSQI score (e.g., poorer sleep quality), QSU Total increased by (β ± SE) 1.10 ± 0.41 units (p = 0.0118), QSU Factor 1 increased by 0.64

± 0.29 units (p = 0.0319), and QSU Factor 2 increased by 1.31 ± 0.54 units (p = 0.0206) (Table 1). Similarly, the MNWS withdrawal score increased by 1.63 ± 0.53 units (p = 0.0043) for every one-point increment in the PSQI score. Further, 5 of the 7 items that comprised the MNWS withdrawal score increased with point estimates ranging from 1.05 ± 0.47 (p = 0.0313) for the ‘difficulty concentrating’ item to 1.47 ± 0.46 (p = 0.0031) for the ‘depressed mood, sad’ item.

For every one-point increment in the ISI sleep quality score (e.g., increased severity of insomnia), the MNWS withdrawal score and the QSU Factor 2 score increased statistically significantly by 2.90 ± 0.73 units (p = 0.0004) and 1.71 ± 0.81 units (p = 0.0430), respectively. All seven of the MNWS withdrawal score items significantly increased with each one-point increment in the ISI sleep quality, with point estimates ranging from 0.67 ± 0.59 (p = 0.0083) for ‘angry, irritable, frustrated’ item to 2.51 ± 0.64 (p = 0.0004) for the ‘depressed mood, sad’ item. No other statistically significant associations were found.

3.3 Change in Exercise Level and Sleep Quality from Baseline to Week 12

For every 10-minute increase in minutes spent being lightly active per day from Baseline to Week 12, the sleep quality score on the PSQI decreased by 0.11 ± 0.05 units (p = 0.0322) (Table 2). Also, for every 10-minute increase in minutes spent being fairly active per day from Baseline to Week 12, the PSQI score decreased by 0.82 ± 0.35 units (p=0.0379). Changes in exercise were not statistically significantly associated with changes in the ISI score.

4. Discussion

In this study – which is among the first to examine the relationship between exercise, sleep and smoking within a sample of individuals who smoke – we observed that individuals with poorer sleep quality reported more adverse levels of smoking-related symptoms. The degree of association varied depending on the smoking outcome, with the strongest association between sleep quality and withdrawal. The association with smoking urges varied by sleep-related measure such that the PSQI was significantly and positively associated with all measures of smoking urges (Total Urges, Factor 1, and Factor 2) whereas the ISI was significantly associated with only Factor 2 (i.e., anticipated relief from negative affect). Further, craving was not significantly related to either PSQI or ISI. This suggests that smoking urges, rather than craving, may be related to sleep quality, rather than insomnia. There was also a statistically significant association between change in exercise levels and change in sleep quality, such that individuals who increased the amount of time they spent being fairly active (by the end of the 12-week study) reported improved sleep quality over this same time period as assessed by the PSQI. Given these associations, clinical interventions designed to improve sleep quality, more so than insomnia, (e.g. cognitive behavioral therapy or HIIT/MI exercise interventions) could be used alone or in conjunction with traditional smoking cessation treatments to address withdrawal, cravings and smoking urges and, perhaps subsequently, promote cessation and prevent relapse. Additional research is needed to examine this.

A recent study investigated similar associations between cigarette smoking, nicotine dependence indicators (e.g., withdrawal, craving), and sleep quality in young adult smokers (Dugas et al., 2017). Some of our observations concur with their findings while others differ. Both our study and the Dugas study reported that individuals with poor sleep quality tend to experience greater withdrawal, but our results differ for the relationship between craving and sleep quality were not statistically significant. In contrast to our study, Dugas and colleagues found poor sleep quality to be more frequent among heavier smokers with greater nicotine dependence. However, while we observed no statistically significant relationship between smoking behavior (e.g., cigarettes/day) and sleep quality, the direction of the relationships in our study were consistent with those in the Dugas study. The differences in results between our study and the Dugas study could be attributed to sample differences since we had a small homogenous sample of smokers who were older, motivated to quit smoking and did not present with clinical insomnia or significant sleep disturbances.

As noted previously, there are a few plausible mechanisms that may be responsible for the association between sleep quality and smoking related outcomes, including the effect of nicotine on regulation of sleep-wake cycles, nocturnal craving and withdrawal symptoms, and second-hand smoke exposure (Dugas et al., 2017). One additional possible explanation for the relationship between sleep quality and withdrawal is that the MNWS contains several items that are sleep-related items such as insomnia and sleep problems. It is possible that these items were driving the association between withdrawal and sleep quality. Therefore, we did an item-level analysis of the MNWS items in relation to our sleep quality measures - results indicated that sleep quality was statistically significantly associated with five out of the seven withdrawal subscales, including those that are not related to sleep. This indicates that the sleep-related items on the MNWS were not driving the overall association between sleep quality and withdrawal.

Despite the novel nature of this study and the randomized control design of the parent study, there were several limitations. First, selection bias may be present as participants were healthy, motivated to increase their exercise and quit smoking, and reported no clinical insomnia or significant sleep disturbances at baseline. Therefore, this may limit the generalizability. Next, we relied on selfreported data to measure sleeping behavior and smoking-related outcomes. It is possible that these measurements contain error and, therefore, bias our results. Additionally, the use of cross-sectional data also limits our ability to draw causal inferences regarding the determinants of poor sleep quality and increased smoking behavior/outcomes. Consequently, the directionality and, thus, the causality of the relationship between sleep quality and smoking-related outcomes in this study is unclear. Lastly, only a small subsample of the participants had Fitbit measures at baseline and week 12 (n=13) due to missing data from the Fitbit or malfunctioning Fitbit equipment. Future fully-powered studies are needed to confirm the effect of exercise on smoking-related outcomes and sleep quality in a larger sample of smokers with objective measurements.

This study is among a few to explore the relationship between exercise, sleep quality and smoking-related outcomes. By better understanding the role of sleep quality in smokers in relation to exercise and smoking-related outcomes, we can design more effective, personalized smoking cessation interventions in the future. Future research is warranted on the efficacy of clinical interventions designed to improve sleep quality in smokers to address withdrawal, cravings and smoking urges and, perhaps subsequently, promote cessation.

Abbreviations:

PSQI	Pittsburgh Sleep Quality Index
ISI	Insomnia Severity Index.
FTND	Fagerstrom Test for Nicotine Dependence.
TLFB	timeline follow back.
MNWS	Minnesota Nicotine Withdrawal Scale.
QSU-B	Questionnaire of Smoking Urges-Brief.

References

Allen AM, Abdelwahab NM, Carlson SC, Bosch TA, Eberly LE, Okuyemi K (2018). Effect of brief exercise on urges to smoke in men and women smokers. Addictive Behaviors; 77: 33–34. https://doi.org10.1016/j.addbeh.2017.09.009.

Allen AM, Carlson SC, Bosch TA, Eberly LE, Okuyemi K, Nair U, Gordon JS (In Press). High Intensity Interval Training and Continuous Aerobic Exercise Interventions to Promote Self-Initiated Quit Attempts in Young Adults Who Smoke: Feasibility, Acceptability, and Lessons Learned from a Randomized Pilot Trial. Journal of Addiction Medicine.

Bastien CH, Vallières A, & Morin CM (2001). Validation of the Insomnia Severity Index as an outcome measure for insomnia research. Sleep Medicine, 2(4), 297–307. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11438246 [PubMed: 11438246]

Bittoun R (2008). Carbon Monoxide Meter: The Essential Clinical Tool — the “Stethoscope” — of Smoking Cessation. Journal of Smoking Cessation, 3(2), 69–70. 10.1375/jsc.3.2.69

Buysse DJ, Reynolds CF, Monk TH, Berman SR, & Kupfer DJ (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Research, 28(2), 193–213. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2748771 [PubMed: 2748771]

Chennaoui M, Arnal PJ, Sauvet F, & Léger D (2015). Sleep and exercise: A reciprocal issue? Sleep Medicine Reviews, 20, 59–72. 10.1016/j.smrv.2014.06.008 [PubMed: 25127157]

Cohrs S, Rodenbeck A, Riemann D, Szagun B, Jaehne A, Brinkmeyer J, … Winterer G(2014). Impaired sleep quality and sleep duration in smokers-results from the German Multicenter Study on Nicotine Dependence. Addiction Biology, 19(3), 486–496. 10.1111/j.1369-1600.2012.00487.x [PubMed: 22913370]

Cox LS, Tiffany ST, & Christen AG (2001). Evaluation of the brief questionnaire of smoking urges (QSU-brief) in laboratory and clinical settings. Nicotine & Tobacco Research, 3(1), 7–16. 10.1080/14622200020032051 [PubMed: 11260806]

Daniel JZ, Cropley M, & Fife-Schaw C (2006). The effect of exercise in reducing desire to smoke and cigarette withdrawal symptoms is not caused by distraction. Addiction, 101(8), 1187–1192. 10.1111/j.1360-0443.2006.01457.x [PubMed: 16869848]

Daniel J, Cropley M, Ussher M, & West R (2004). Acute effects of a short bout of moderate versus light intensity exercise versus inactivity on tobacco withdrawal symptoms in sedentary smokers. Psychopharmacology, 174(3), 320–326. 10.1007/s00213-003-1762-x [PubMed: 14997270]

Deleanu OC, Pocora D, Mihălcuţă S, Ulmeanu R, Zaharie A-M, & Mihălţan FD (n.d.). Influence of smoking on sleep and obstructive sleep apnea syndrome. Pneumologia (Bucharest, Romania), 65(1), 28–35. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/27209838

Driver HS, & Taylor SR (2000). Exercise and sleep. Sleep Medicine Reviews, 4(4), 387–402. 10.1053/smrv.2000.0110 [PubMed: 12531177]

Dugas E, Sylvestre M, O'Loughlin E, Brunet J, Kakinami L, Constantin E, & O'Loughlin J (2017). Nicotine dependence and sleep quality in young adults. Addictive Behaviors, 65, 154–160. 10.1016/j.addbeh.2016.10.020 [PubMed: 27816041]

Fucito LM, Redeker NS, Ball SA, Toll BA, Ikomi JT, & Carroll KM (2014). Integrating a Behavioural Sleep Intervention into Smoking Cessation Treatment for Smokers with Insomnia: A Randomised Pilot Study. Journal of Smoking Cessation, 9(1), 31–38. 10.1017/jsc.2013.19 [PubMed: 24995044]

Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, Rundle AG, Zammit GK, Malaspina D (2006). Short Sleep Duration as a Risk Factor for Hypertension: Analyses of the First National Health and Nutrition Examination Survey. Hypertension, 47(5), 833–839. 10.1161/01.HYP.0000217362.34748.e0 [PubMed: 16585410]

Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, Rundle AG, Zammit GK, Malaspina D (2007). Sleep duration as a risk factor for diabetes incidence in a large U.S. sample. Sleep, 30(12), 1667–1673. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18246976 [PubMed: 18246976]

Heatherton TF, Kozlowski LT, Frecker RC, & Fagerström KO (1991). The Fagerström Test for Nicotine Dependence: a revision of the Fagerström Tolerance Questionnaire. British Journal of Addiction, 86(9), 1119–1127. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/1932883 [PubMed: 1932883]

Hughes J, & Hatsukami DK (1998). Errors in using tobacco withdrawal scale. Tobacco Control, 7(1), 92–93. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9706762

Jaehne A, Unbehaun T, Feige B, Lutz UC, Batra A, & Riemann D (2012). How smoking affects sleep: A polysomnographical analysis. Sleep Medicine, 13(10), 1286–1292. 10.1016/j.sleep.2012.06.026 [PubMed: 23026505]

Janson C, Gislason T, De Backer W, Plaschke P, Björnsson E, Hetta J, Kristbjarnason P, Vermeire G, Boman G (1995). Prevalence of sleep disturbances among young adults in three European countries. Sleep, 18(7), 589–597. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8552930 [PubMed: 8552930]

Killen JD, and Fortmann SP (1997). Craving is associated with smoking relapse: Findings from three prospective studies. Exp. Clin. Psychopharmacol 5, 137–142. [PubMed: 9234050]

Kline CE, Irish LA, Krafty RT, Sternfeld B, Kravitz HM, Buysse DJ, … Hall MH (2013). Consistently High Sports/Exercise Activity Is Associated with Better Sleep Quality, Continuity and Depth in Midlife Women: The SWAN Sleep Study. SLEEP, 36(9), 1279–1288. 10.5665/sleep.2946 [PubMed: 23997360]

Liu JT, Lee IH, Wang CH, Chen KC, Lee CI, & Yang YK (2013). Cigarette smoking might impair memory and sleep quality. Journal of the Formosan Medical Association, 112(5), 287–290. 10.1016/J.JFMA.2011.12.006 [PubMed: 23660225]

McCarthy DE, Piasecki TM, Fiore MC, & Baker TB (2006). Life before and after quitting smoking: An electronic diary study. Journal of Abnormal Psychology, 115(3), 454–466. 10.1037/0021-843X.115.3.454 [PubMed: 16866586]

McNamara JPH, Wang J, Holiday DB, Warren JY, Paradoa M, Balkhi AM, … McCrae CS (2014). Sleep disturbances associated with cigarette smoking. Psychology, Health & Medicine, 19(4), 410–419. 10.1080/13548506.2013.832782

Noakes TD (2008). Testing for maximum oxygen consumption has produced a brainless model of human exercise performance. British Journal of Sports Medicine, 42(7), 551–555. 10.1136/bjsm.2008.046821 [PubMed: 18424484]

Peters EN, Fucito LM, Novosad C, Toll BA, & O'Malley SS (2011). Effect of night smoking, sleep disturbance, and their co-occurrence on smoking outcomes. Psychology of Addictive Behaviors, 25(2), 312–319. 10.1037/a0023128 [PubMed: 21443301]

Pilcher JJ, & Huffcutt AI (1996). Effects of sleep deprivation on performance: a meta-analysis. Sleep, 19(4), 318–326. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8776790 [PubMed: 8776790]

Prochaska JO et al. (2001). Counselor and stimulus control enhancements of a stage-matched expert system intervention for smokers in a managed care setting. Prev. Med 32, 23–32. 10.1006/pmed.2000.076 [PubMed: 11162323]

Reid KJ, Baron KG, Lu B, Naylor E, Wolfe L, & Zee PC (2010). Aerobic exercise improves selfreported sleep and quality of life in older adults with insomnia. Sleep Medicine, 11(9), 934–940. 10.1016/j.sleep.2010.04.014 [PubMed: 20813580]

Roane BM, & Taylor DJ (2008). Adolescent insomnia as a risk factor for early adult depression and substance abuse. Sleep, 31(10), 1351–1356. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/18853932 [PubMed: 18853932]

Roberts V, Maddison R, Simpson C, Bullen C, & Prapavessis H (2012). The acute effects of exercise on cigarette cravings, withdrawal symptoms, affect, and smoking behaviour: systematic review update and meta-analysis. Psychopharmacology, 222(1), 1–15. 10.1007/s00213-012-2731-z [PubMed: 22585034]

Shiraev T, & Barclay G (2012). Evidence based exercise: Clinical benefits of high intensity interval training. Australian Family Physician, 41(12), 960–962. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/23210120 [PubMed: 23210120]

Sobell LC, Brown J, Leo GI, & Sobell MB (1996). The reliability of the Alcohol Timeline Followback when administered by telephone and by computer. Drug and Alcohol Dependence, 42(1), 49–54. 10.1016/0376-8716(96)01263-X [PubMed: 8889403]

Sweitzer MM, Denlinger RL, & Donny EC (2013). Dependence and Withdrawal-Induced Craving Predict Abstinence in an Incentive-Based Model of Smoking Relapse. Nicotine & Tobacco Research, 15(1), 36–43. 10.1093/ntr/nts080 [PubMed: 22513801]

United States Department of Health and Human Services (US DHHS). (2014). The Health Consequences of Smoking – 50 Years of Progress: A Report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotin, Office of Smoking and Health.

Ussher M, Nunziata P, Cropley M, & West R (2001). Effect of a short bout of exercise on tobacco withdrawal symptoms and desire to smoke. Psychopharmacology, 158(1), 66–72. 10.1007/s002130100846 [PubMed: 11685385]

Vangeli E, Stapleton J, Smit ES, Borland R and West R (2011), Predictors of attempts to stop smoking and their success in adult general population samples: a systematic review. Addiction, 106, 2110–2121. doi:10.1111/j.1360-0443.2011.03565.x [PubMed: 21752135]

Wang X, & Youngstedt SD (2014). Sleep quality improved following a single session of moderateintensity aerobic exercise in older women: Results from a pilot study. Journal of Sport and Health Science, 3(4), 338–342. 10.1016/j.jshs.2013.11.004 [PubMed: 25685605]

Wetter DW, Young TB, Bidwell TR, Badr MS, & Palta M (1994). Smoking as a risk factor for sleep-disordered breathing. Archives of Internal Medicine, 154(19), 2219–2224. DOI: 10.1001/archinte.1994.00420190121014 [PubMed: 7944843]

Wilson JF (2005). Is sleep the new vital sign? Annals of Internal Medicine, 142(10), 877–880. 10.7326/0003-4819-142-10-200505170-00026 [PubMed: 15897548]

Yaggi HK, Concato J, Kernan WN, Lichtman JH, Brass LM, & Mohsenin V (2005). Obstructive Sleep Apnea as a Risk Factor for Stroke and Death. New England Journal of Medicine, 353(19), 2034–2041. 10.1056/NEJMoa043104 [PubMed: 16282178]

Author Manuscript

Author Manuscript

Author Manuscript

Highlights

- Cigarette smokers are at increased risk for poor sleep quality.
- Poorer sleep quality was associated with greater withdrawal and cravings.
- An increase in exercise was associated with improved sleep quality.

Table 1.

Association between Sleep Quality & Smoking Outcomes

	PSQI β ± SE	P-value	ISI β ± SE	P-value
Average # of CPD (7 days preceding visit)	−0.15 ± 0.11	0.1547	−0.21 ± 0.16	0.1955
Nicotine Dependence (FTND Score)	−0.12 ± 0.22	0.5732	−0.43 ± 0.32	0.1867
MNWS Withdrawal Total	1.63 ± 0.53	0.0043*	2.90 ± 0.73	0.0004*
Angry, irritable, frustrated	1.17 ± 0.39	0.0059*	0.67 ± 0.59	0.0083*
Anxious, nervous	0.46 ± 0.42	0.2797	1.26 ± 0.59	0.0398*
Depressed mood, sad	1.47 ± 0.46	0.0031*	2.51 ± 0.64	0.0004*
Difficulty concentrating	1.05 ± 0.47	0.0313*	1.65 ± 0.68	0.0221*
Increased appetite, hungry, weight gain	0.50 ± 0.44	0.2687	1.50 ± 0.61	0.0204*
Insomnia, sleep problems, awakening at night	1.36 ± 0.42	0.0029*	2.21 ± 0.60	0.0009*
Restless	1.32 ± 0.45	0.0064*	1.94 ± 0.67	0.0067*
MNWS Craving	0.51 ± 0.43	0.2471	−0.02 ± 0.66	0.9734
QSU Total Smoking Urges	1.10 ± 0.41	0.0118*	0.74 ± 0.66	0.2724
QSU Factor 1	0.64 ± 0.29	0.0319*	0.20 ± 0.46	0.6596
QSU Factor 2	1.31 ± 0.54	0.0206*	1.71 ± 0.81	0.0430*

Data indicate β *± SE* from simple linear regression;

* p-value<0.05

Only includes participants (n=32) from the baseline visit.

Table 2.

Association between Change in Exercise & Change in Sleep Quality from Baseline to Week 12

	PSQI β ± SE	P-value	ISI β ± SE	P-value
Change in Daily Steps, increment of 1000	−0.21 ± 0.20	0.3172	−0.12 ± 0.24	0.6247
Change in daily minutes lightly active, increment of 10	−0.11 ± 0.05	0.0322 *	−0.09 ± 0.06	0.1540
Change in daily minutes fairly active, increment of 10	−0.82 ± 0.35	0.0379 *	−0.08 ± 0.50	0.8684
Change in daily minutes very active, increment of 10	−1.31 ± 0.62	0.0592	−0.53 ± 0.85	0.5507

Data indicate β ± SE from simple linear regression;

*p-value<0.05

Only includes participants (n=13) with complete data from the exercise group and control group