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Original Article

Sedentary Behavior Worsens the Adverse Impact of E-cigarettes Smoking on Sleep Quality

Hareketsiz Yaşam Tarzı E-sigara İçmenin Uyku Kalitesine Olumsuz Etkisini Artırıyor

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ABSTRACT

Objective: Sleep is vital for homeostasis. Smoking negatively affects sleep quality, whereas regular physical activity and reduced sedentary behavior improve sleep quality. However, the combined effect of e-cigarettes, physical activity, and sedentary behavior remains unknown. Therefore, the current study compared sleep quality according to e-cigarette dependence status among adults with high versus low levels of physical activity and sedentary behavior.

Methods: In 644 adults, sleep, e-cigarette dependence, physical activity, and sedentary behavior were assessed using the Pittsburgh Sleep Quality Index (PSQI), the Penn State E-Cigarette Dependence Index, and the International Physical Activity Questionnaire, respectively.

Results: The two-way ANCOVA, after controlling for gender, income, and disease status, revealed main effects of e-cigarette dependence ($p<0.001$) and sedentary behavior ($p<0.03$), and an interaction effect ($p<0.05$) on the PSQI. Post hoc comparisons showed significantly greater PSQI scores among adults with heavy e-cigarette dependence and in the high sedentary behavior group ($p<0.05$). However, the analysis showed no main effect of physical activity on PSQI scores ($p>0.05$).

Conclusions: The results suggest that heavy dependence on e-cigarettes negatively alters sleep quality. These adverse sleep alterations are exacerbated by sedentary behavior. Programs are needed to reduce e-cigarette use and sedentary behavior to enhance sleep quality.

Keywords: Sleep health and quality, physical activity, sedentary behavior, e-cigarettes, tobacco

ÖZ

Amaç: Uyku, homeostaz için hayati öneme sahiptir. Sigara içmek uyku kalitesini olumsuz etkilerken, düzenli fiziksel aktivite ve hareketsiz yaşam tarzının azaltılması uyku kalitesini iyileştirir. Ancak, e-sigara, fiziksel aktivite ve hareketsiz yaşam tarzının birleşik etkisi hala bilinmemektedir. Bu nedenle, mevcut çalışma, yüksek ve düşük düzeyde fiziksel aktivite ve hareketsiz davranış sergileyen yetişkinler arasında e-sigara bağımlılığı durumuna göre uyku kalitesini karşılaştırmıştır.

Yöntem: 644 yetişkinde uyku, e-sigara bağımlılığı, fiziksel aktivite ve hareketsiz davranış sırasıyla Pittsburgh Uyku Kalitesi İndeksi (PSQI), Penn State E-Sigara Bağımlılığı İndeksi ve Uluslararası Fiziksel Aktivite Anketi kullanılarak değerlendirilmiştir.

Bulgular: Cinsiyet, gelir ve hastalık durumu kontrol edildikten sonra yapılan iki yönlü ANCOVA, e-sigara bağımlılığının ($p<0,001$) ve hareketsiz davranışın ($p<0,03$) ana etkilerini ve PSQI üzerinde bir etkileşim etkisini ($p<0,05$) ortaya koymuştur. Post-hoc karşılaştırmalar, ağır e-sigara bağımlılığı olan yetişkinler ve yüksek hareketsiz davranış grubunda ($p<0,05$) önemli ölçüde daha yüksek PSQI puanları olduğunu gösterdi. Ancak, analiz fiziksel aktivitenin PSQI puanları üzerinde ana bir etkisi olmadığını gösterdi ($p>0,05$).

Sonuçlar: Sonuçlar, e-sigaraya yoğun bağımlılığın uyku kalitesini olumsuz yönde değiştirdiğini göstermektedir. Bu olumsuz uyku değişiklikleri, hareketsiz davranışla daha da kötüleşmektedir. Uyku kalitesini artırmak için e-sigara kullanımını ve hareketsiz davranışı azaltmaya yönelik programlara ihtiyaç vardır.

Anahtar kelimeler: Uyku sağlığı ve kalitesi, fiziksel aktivite, hareketsiz davranış, e-sigaralar, tütün

INTRODUCTION

Sleep is crucial for maintaining the homeostasis of multiple vital physiological systems, including cardiovascular, metabolic, immune, neural, and cognitive systems[1]. Conversely, sleep problems are associated with all-cause mortality and an increased risk of cancer, diabetes, obesity, and cardiovascular diseases[2-4]. In recent years, sleep deficiency has become increasingly common.

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Inadequate sleep duration, irregular sleep timing, poor sleep quality, and sleep/circadian rhythm disturbances are some indicators of sleep deficiency[5].

Smoking is a risky behavior associated with some of the most devastating disorders[6,7]. In addition, smoking is associated with sleep problems. It can cause sleep-onset latency, frequent nighttime awakenings, sleep bruxism, and breathing difficulties during sleep[3,8]. The use of electronic cigarettes (e-cigarettes) as an alternative smoking-cessation tactic has recently increased, especially among young people[9,10]. It is a battery-operated electronic device that delivers manufactured nicotine as an inhalable aerosol[11]. According to a recent National Center for Health Statistics report on e-cigarette use, 12.6% of adults have tried e-cigarettes, and 3.7% currently use e-cigarettes[12]. The increased prevalence of e-cigarette use is mainly attributed to advertising that presents e-cigarettes to young people as a harmless alternative to combustible cigarettes. However, exposure to e-cigarettes can result in complications such as asthma, chronic obstructive pulmonary disease, and severe lung inflammation[13]. However, studies on the effects of e-cigarette use on sleep quality are still sparse[3,14-17].

Physical activity is any bodily movement that increases energy expenditure. Despite its well-known benefits, many adults do not meet the recommended amounts of physical activity. Physical activity can prevent the most serious diseases, including coronary heart disease, stroke, cancer, type 2 diabetes, hypertension, and osteoporosis[18]. In addition, regular physical activity promotes relaxation, sleep initiation, and sleep maintenance[19], and prevents sleep problems[20,21]. However, evidence regarding the effect of physical activity and sedentary behavior on smoking-induced sleep problems remains scarce[22], especially among e-cigarette smokers.

Therefore, the current study compared sleep quality according to e-cigarette dependence status among individuals with low versus high levels of physical activity and sedentary behavior. Sleep quality is expected to vary according to the e-cigarette dependence score, especially among individuals with low levels of physical activity and high levels of sedentary behavior.

MATERIALS and METHODS

Study Design and Subjects

The study was cross-sectional and comparative, designed to examine the relationship between e-cigarette smoking, physical activity, and sleep quality. E-cigarette smokers of both genders, aged ≥18 years, were invited to participate in the study. Participants were recruited from local community settings (cafes, malls, and universities) across Jordan.

Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of the Jordan University of Science and Technology (protocol no.: JUST-53/149/2022, date: 07.07.2022).

Sample Characteristics

Socioeconomic and demographic data, including age, weight, height, gender, marital status, education, monthly income, and residence, were collected from participants using a structured form. The participants were categorized by household income as low [≤500 Jordanian Dinar (JD)], medium (501-1,199 JD), and high (≥1,200 JD). With respect to education, the participants were divided into three categories: high school or below, diploma or bachelor's degree, and postgraduate degree. Participants were also divided into healthy individuals (free from chronic disease) and those with chronic disease (e.g., diabetes, hypertension, and cardiovascular disease). Informed consent was obtained from study participants as required by the Institutional Review Board.

Sleep Quality

Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI). The sleep quality assessment tool comprises 19 items that evaluate seven components of sleep status, each with a separate subscore ranging from 0 to 3. These components are (a) sleep duration; (b) sleep disturbance; (c) sleep latency; (d) daytime dysfunction due to sleepiness; (e) sleep efficiency; (f) overall sleep quality; and (g) use of sleep medications. The seven component scores were summed to yield a global score ranging from 0 to 21; higher scores indicate poorer sleep quality[23]. A total PSQI score ≤5 suggests good sleep quality, whereas a score >5 suggests poor sleep quality[23]. PSQI demonstrated acceptable reliability and validity[24].

Physical Activity

The short Arabic version of the International Physical Activity Questionnaire (IPAQ) was used to measure physical activity and sedentary behavior. The IPAQ is a self-reported questionnaire consisting of seven questions to assess vigorous, moderate, and walking physical activity, as well as sedentary behavior. The IPAQ has been used in people from a variety of socioeconomic statuses and demographic groups and has demonstrated acceptable validity, reliability, and standardization[25,26]. The participants were divided into high and low physical

activity and sedentary behavior levels according to above and below 50th percentile, respectively[27].

E-Cigarette Smoking Status

The Penn State E-Cigarette Dependence Index was used to estimate e-cigarette use among participants. The index includes 10 items, with item scores ranging from 0 to 20. Participants were categorized into dependence groups: none (0-3), light (4-8), intermediate (9-12), and heavy (≥13)[28].

Statistical Analysis

The SPSS software was used for all statistical analyses. Data were reported as mean ± SD and as percentages, and the p-value threshold was set at $p<0.05$. Physical activity and sedentary behavior were classified as low or high according to whether they were below or above the 50th percentile[29]. E-cigarette dependence was categorized into four levels: none, light, intermediate, and heavy[28]. Hierarchical regression was used to examine the associations of physical activity, sedentary behavior, and e-cigarette dependence with the global sleep score. Two-way analysis of covariance (ANCOVA) was used to examine differences in sleep score by physical activity and e-cigarette dependence levels and by sedentary behavior and e-cigarette dependence levels. Confounders for hierarchical regression and ANCOVA were identified using linear regression. Potential confounders entered into the regression model included age, gender, obesity, disease status, marital status, residence, education, and income. Factors found to be significantly related to global sleep scores were considered confounders and adjusted for in the hierarchical regression analysis. In addition to the confounders used in the hierarchical regression, sedentary behavior was included in the physical activity*e-cigarette dependence ANCOVA, whereas physical activity was included in the sedentary behavior*e-cigarette dependence ANCOVA. The data that support the findings of this study are available from the corresponding author upon reasonable request.

RESULTS

As shown in Table 1, 644 individuals agreed to participate in the study, of whom 305 were e-cigarette users. The age, weight, height, and body mass index ranges of the participants were 18-78 years, 33-148 kg, 135-200 cm, and 15.0-45.9 kg/m^2, respectively. The majority of participants were male, had no diseases, lived in rural areas, and held a high school diploma. Table 2 shows that the majority of participants had high physical activity (50.1%), high sedentary behavior (53.1%), and no e-cigarette dependence (55.3%).

According to the linear regression analysis including age, gender, obesity, disease status, marital status, place of residence, education, type of work, and income, only gender ($p<0.03$), income ($p<0.02$), and disease status ($p<0.001$) were related to sleep score. Subsequently, age, disease status, physical activity, and sedentary behavior were considered confounders and adjusted for in hierarchical regression and ANCOVA.

According to hierarchical regression analysis, e-cigarette dependence ($p<0.001$) and sedentary behavior ($p<0.02$), but not physical activity ($p>0.6$), were related to the PSQI score. The two-way ANCOVA shown in Figure 1 revealed a main effect of e-cigarette

Table 1. Participant characteristics (n=644).

Parameter		% or mean (SD)
Age (years), mean (SD)		32.3 (14.2)
Weight (kg), mean (SD)		77.7 (17.4)
Height (cm), mean (SD)		171.2 (0.9)
BMI (kg/m^2), mean (SD)		26.5(5.6)
Income (JD), mean (SD)		690.5 (268.3)
	Low (%)	37.3
	Middle (%)	23.3
	High (%)	39.4
Gender (%)		
	Female	30.9
	Male	69.1
Location (%)		
	Rural	57.0
	Urban	43.0
Smoking status (%)		
	Never smoked	52.6
	Electronic-cigarette smokers	47.4
Disease status (%)		
	Healthy	85.1
	Have chronic disease	14.9
Education (%)		
	High school and less	64.8
	Diploma/bachelor's	26.9
	Postgraduate	8.4
Marital status (%)		
	Single	59.3
	Married	37.6
	Widowed	1.2
	Divorced	0.5
	Engaged	1.4

SD: Standard deviation, BMI: Body mass index, JD: Jordanian Dinar

dependence (p<0.001) but no main effect of physical activity (p=0.14) or interaction effect (p>0.20) on PSQI score after controlling for sedentary behavior. Post-hoc analysis revealed that individuals with heavy e-cigarette dependence had higher PSQI scores than those with no (p<0.001), light (p<0.001), and intermediate (p<0.01) dependence. Another two-way ANCOVA, depicted in Figure 2, revealed main effects of e-cigarette dependence score (p<0.001) and sedentary behavior (p<0.05), and an interaction effect (p<0.05), on PSQI score after controlling for physical activity. Post-hoc analysis revealed that individuals with heavy e-cigarette dependence had higher PSQI scores than those with no (p<0.001), light (p<0.001), and intermediate (p<0.01) dependence. When participants were stratified according to e-cigarette dependence (Table 3), a one-way ANCOVA revealed that PSQI scores were higher among individuals with high sedentary behavior within the light (p<0.02) and heavy (p<0.009) e-cigarette dependence groups. No differences were found between the high and low sedentary levels in the none (p>0.267) and intermediate

Table 2. Participant physical activity and sedentary behavior and e-cigarettes dependency score (n=644).

Parameter		n
Physical activity		
	Low	316
	High	328
Sedentary behavior		
	Low	302
	High	342
E-cigarettes dependence score		
	None	356
	Light	53
	Moderate	77
	Heavy	158

Table 3. PSQI scores in sedentary behavior and according to e-cigarette dependency (n=644).

E-cigarettes dependency	Sedentary activity level	PSQI score	p-value
Non-smokers	Low	6.45±4.0	0.267
	High	6.96±4.0	
Light	Low	4.41±4.2	0.020
	High	6.25±3.0	
Intermediate	Low	6.78±3.6	0.296
	High	5.85±3.3	
Heavy	Low	6.78±4.3	0.009
	High	8.60±4.5	

PSQI: Pittsburgh Sleep Quality Index

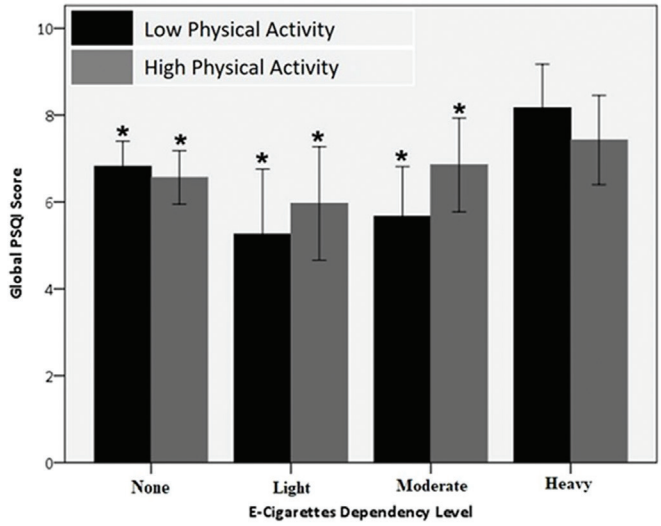

Figure 1. Differences in PSQI score according to e-cigarettes dependency level in the individuals with low versus high physical activity level. Data is presented in mean ± SE. *p<0.05 versus heavy e-cigarettes dependency level.

PSQI: Pittsburgh Sleep Quality Index, SE: Standard error

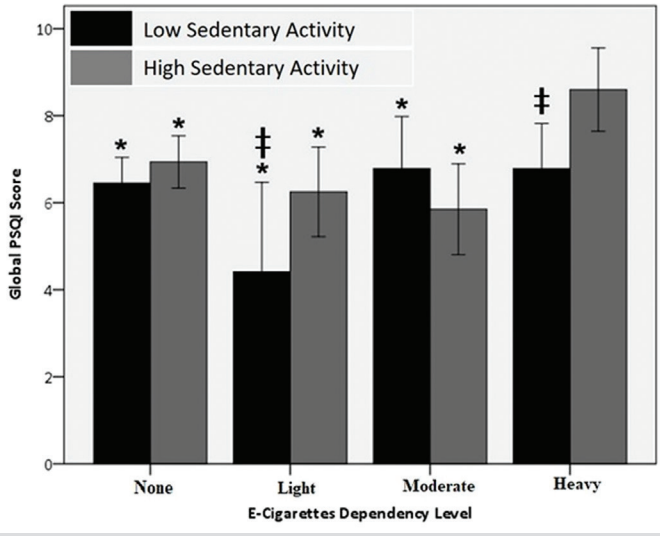

Figure 2. Differences in PSQI score according to e-cigarettes dependency level in the individuals with low versus high sedentary behavior level. Data is presented in mean ± SE. *=p<0.05 versus counterpart with heavy e-cigarettes dependency level. ‡= p<0.05 versus high sedentary behavior level.

PSQI: Pittsburgh Sleep Quality Index, SE: Standard error

(p>0.296) e-cigarette dependence groups. Thus, PSQI scores were higher among individuals with high levels of sedentary behavior.

DISCUSSION

In this study, sleep quality was examined in relation to e-cigarette dependence among individuals with varying levels of physical activity and sedentary behavior. According to the results, e-cigarette dependence and sedentary behavior, but not physical activity, were associated with sleep quality. Additional analyses showed diminished sleep quality among individuals with heavy e-cigarette dependence and increased sedentary behavior after controlling for physical activity. These results are noteworthy, demonstrating that sedentary behavior further worsens the negative impact of e-cigarette use on sleep quality. Therefore, programs to curb the spread of e-cigarettes and to promote alternative strategies for reducing sedentary behavior among adults are needed to improve sleep quality.

The adverse effects of conventional tobacco consumption on sleep quality are well documented. Cigarette smoking alters several sleep parameters, such as sleep depth, sleep duration, sleep latency, sleep stages, nocturnal sleepiness, and daytime awakenings and alertness[30]. However, Fewer, with conflicting results, have examined the combined effect of dual tobacco use (e.g., conventional cigarettes and e-cigarettes) on sleep parameters. For example, Advani et al.[15] found that dual use of tobacco altered sleep latency but not sleep quality, while Kang and Bae[16] reported reduced sleep quality among dual users compared with none or single users of tobacco. Additionally, dual tobacco use was associated with shorter sleep duration, daytime dysfunction due to sleepiness, and increased use of sleeping medications[17]. The current study found changes in sleep quality among exclusive e-cigarette smokers. Only one previous study examined changes in sleep health among exclusive e-cigarette smokers compared with non-smokers and reported more sleep difficulties, greater use of sleep medication, and worse overall sleep health[14].

Current findings indicate that sleep quality is poorer in individuals with greater e-cigarette tobacco dependence. The effects of tobacco dependence on sleep among e-cigarette smokers have not been adequately studied. However, greater tobacco dependence associated with smoking traditional cigarettes has been linked to adverse sleep outcomes. Individuals reporting greater dependence experience diminished sleep quality, sleep insufficiency, sleep disturbances, and frequent nocturnal awakenings[31]. These adverse effects are temporary, but they worsen particularly when smoking occurs near bedtime or during the night[32].

Alterations in sleep architecture associated with e-cigarette smoking have been linked to depression[16] and to narcotic use, and have been attributed to nicotine in e-cigarettes[15]. Nicotine is involved in the regulation of neurotransmitters that are vital for controlling the sleep-wake cycle. These neurotransmitters include acetylcholine, dopamine, serotonin, norepinephrine, and gamma-aminobutyric acid[33]. Additionally, the drop in plasma nicotine, which smokers may experience during nocturnal sleep, can cause withdrawal symptoms, including disturbances in both sleep quality and sleep quantity. Smokers also frequently report sleep problems, including sleep apnea and restless legs syndrome, which may be attributable to smoking-induced respiratory disorders[34].

No previous studies have examined the adverse effect of sedentary behavior on sleep among e-cigarette users or even other tobacco users. Uniquely, the current results suggest that sedentary behavior negatively affects sleep quality and quantity among e-cigarette smokers. The adverse effects of sedentary behavior on sleep are well documented[35-37]. Sedentary behavior has been associated with insomnia, sleep disturbance[36], difficulty falling asleep, frequent nocturnal awakenings, early morning awakenings[38], reduced sleep duration[35], and reduced sleep efficiency[37]. the relationships between sleep quality, subjective sleep quality, sleep latency, sleep disturbance, use of sleeping medication, and daytime dysfunction with sedentary behavior were dose-dependent[39]. Despite the abundant physical and mental benefits of regular physical activity, its effects on sleep remain equivocal. The majority of studies show no relationship between physical activity and sleep architecture[21,40]. Similarly, physical activity in the current study was not associated with sleep, consistent with previous studies. However, some studies have reported that replacing sedentary behavior with physical activity can improve sleep health in older adults[41] and middle-aged adults[42,43]. However, more studies are needed to verify the current findings.

According to the current results, smoking e-cigarettes is associated with poorer sleep quality, particularly among individuals with high levels of sedentary behavior. These results indicate that engaging in sedentary behavior exacerbates the adverse effect of e-cigarette smoking on sleep quality. Given the importance of sleep for homeostasis, programs are needed to educate the public about the health hazards associated with e-cigarette use and sedentary behavior. Subsequently, plans should be initiated to contain e-cigarette use and replace sedentary behaviors with healthier activities.

Study Limitations

The relatively small sample size, recruited from a small Middle Eastern country, and the cross-sectional design limit the generalizability of the findings and the ability to infer causality from the data. Measures of sleep, smoking, physical activity, and sedentary behavior used in the current study are self-reported and thus subject to bias and inaccuracy. Additionally, the discrepancies in recalled time frames for the measured lifestyle behaviors may render these surveys incompatible and prevent them from reflecting one another. Therefore, conducting multi-site longitudinal studies with larger sample sizes that use objective measures is warranted.

CONCLUSIONS

In conclusion, the current study reported altered sleep quality among individuals with heavy e-cigarette dependence. Importantly, sleep architecture alterations associated with e-cigarette smoking are further compromised among individuals with high levels of sedentary behavior, but not among those with high levels of physical activity. These results confirm the adverse health effects of e-cigarette use and sedentary behavior, particularly affecting sleep. Therefore, programs are needed to restrain the spread of e-cigarette use and sedentary behavior, thereby enhancing sleep quality. Additional studies, particularly longitudinal studies, are necessary to confirm the current findings and associated speculations.

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Ethics

Ethics Committee Approval: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Jordan University of Science and Technology (protocol no.: JUST-53/149/2022, dated: 07.07.2022).

Informed Consent: Informed consent was obtained from study participants as required by the Institutional Review Board.

Footnotes

Author Contributions

Concept: M.A.A., O.F.K., Design: M.A.A., O.F.K., Data Collection and/or Processing: M.A.A., O.F.K., Analysis or Interpretation: M.A.A., O.F.K., Literature Search: M.A.A., Writing: M.A.A., O.F.K.

Conflict of Interest: The authors have no conflict of interest to declare.

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