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Investigation of Relationships Among Pulmonary Capacity, Physical Activity Levels, and Headache Impact in Young Adults

RESEARCH

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ABSTRACT

Background: There is currently no study that concurrently investigates physical activity, sedentary lifestyle, pulmonary function, HIT-6 Score, and the impact of smoking in young adults.

Purpose: This study aimed to examine the relationships between pulmonary function, physical activity level, and headache occurrence among university students, with a focus on differences between smokers and non-smokers.

Methods: A cross-sectional study was conducted involving 207 university students (103 smokers and 104 non-smokers). Pulmonary function was assessed using Forced Expiratory Volume in 1 second (FEV_1) and Forced Vital Capacity (FVC). Physical activity and sedentary behavior were evaluated using the International Physical Activity Questionnaire (IPAQ). The impact of headaches on daily life was measured using the Headache Impact Test (HIT-6), and exhaled carbon monoxide (CO) levels were recorded to assess smoking exposure.

Results: Regression analysis indicated that FEV_1 significantly predicted HIT-6 Score in both smoker and non-smoker groups ($R^2 = 0.092$, $p = 0.003$; $R^2 = 0.062$, $p = 0.012$, respectively). Additionally, Body Mass Index (BMI) was a significant predictor of HIT-6 Score in the non-smoker group ($R^2 = 0.097$, $p = 0.006$).

Conclusion: FEV_1 and BMI are significant predictors of headache occurrence among university students. Furthermore, sedentary behavior and CO levels differentiate smokers from non-smokers, emphasizing the need for targeted interventions in young adult populations.

Clinical trial registration: ClinicalTrials.gov, NCT06680570, registered on july, 2024.

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Smoking; headache; university students; sedentary behavior; young adults

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INTRODUCTION

University life marks a significant transition in young adulthood, typically defined as individuals aged 18 to 24 years (Hu et al., 2025). This transition involves increased independence, academic demands, and changes in daily routines, which may contribute to the adoption of health-compromising behaviors such as smoking, physical inactivity, and irregular sleep patterns (Malagodi et al., 2024; Langford et al., 2014). These behavioral shifts can have lasting effects on physical and mental health and often persist into later adulthood (Ge et al., 2023).

Smoking remains one of the most critical risk behaviors among university students. Despite growing public health campaigns, smoking continues to occur during early adulthood and is associated with impaired pulmonary function and elevated carbon monoxide (CO) levels (Ge et al., 2023; Aljuhani et al., 2024). These physiological changes may also correlate with reduced physical activity and increased prevalence of health complaints such as headaches.

Headaches are one of the most frequently reported neurological complaints in young adults, significantly impairing academic performance, daily functioning, and quality of life (Haywood et al., 2021). Although commonly self-managed with over-the-counter medications, the lack of clinical diagnosis or structured treatment can lead to worsening symptom severity or chronic conditions (Haywood et al., 2021). Tools such as the Headache Impact Test (HIT-6) allow for quantifying the degree to which headaches interfere with an individual's day-to-day life and are validated in young adult populations (Haywood et al., 2021).

Simultaneously, physical activity plays a crucial role in promoting respiratory and psychological well-being among university students. Hu et al. (2025) demonstrated that self-efficacy in exercise behavior is directly associated with long-term physical activity maintenance. However, studies show that university students often fail to meet recommended activity levels, especially those who smoke (Ge et al., 2023; Aljuhani et al., 2024). Sedentary behavior, along with poor lifestyle habits, further contributes to health deterioration and may increase headache prevalence, though this interaction remains underexplored.

Despite a growing body of literature on smoking, physical activity, and headaches individually, few studies have examined these factors collectively in the same population. In particular, the combined impact of pulmonary function, CO exposure, body mass index (BMI), and lifestyle behaviors on headache severity among smokers and non-smokers warrants further investigation.

In studies conducted on healthy living among young adults, factors such as physical activity, nutrition, psychological state, and habits take the lead (Aljuhani et al., 2024; Haywood et al., 2021; Langford et al., 2014). Health behaviors among young adults tend to vary widely due to lifestyle, academic, and psychosocial factors. Some studies suggest that excessive physical activity or dehydration may be linked to headaches, while moderate caffeine intake could reduce their frequency (Aljuhani et al., 2024; Haywood et al., 2021). In the literature, physical activity, lung capacity, body mass index, and HIT-6 Score are frequently highlighted as significant factors in evaluating the health status of young adults (Aljuhani et al., 2024; Ge et al., 2023; Haywood et al., 2021; Hu et al., 2025; Malagodi et al., 2024; Langford et al., 2014).

The objective of this study is to explore the correlation between factors related to healthy living among young adults. It was hypothesized that lower pulmonary function and physical activity, as well as higher sedentary behavior, would be associated with greater headache impact, particularly among smokers.

Therefore, we aimed to investigate the relationship between headache impact test and physical activity and respiratory parameters in university students.

METHODS

This study included two groups of university students: smokers (n = 103) and non-smokers (n = 104). Participants were carefully matched across several variables to ensure comparability between the groups (n = 207). The study design was cross-sectional. The study was conducted at Yalova University between January 2022 and January 2023. Male and female students aged 18–30 years were included. Participants who were free of diagnosed respiratory disorders at baseline, as confirmed by their medical records, were deemed eligible for inclusion. Participants with self-reported smoking habits and CO levels ≥6 ppm were classified as smokers, in line with established cut-off values in the literature. This dual criterion was used to reduce misclassification bias and ensure accurate identification of active smokers (Ge et al., 2023; Aljuhani et al., 2024). Individuals who did not exhibit symptoms of acute illness, such as those associated with upper or lower respiratory infections, were included. Both smokers and non-smokers were represented. Participants showing signs or diagnosed with respiratory conditions such as tuberculosis, post-tuberculosis lung disease, bronchial asthma, Chronic Obstructive Pulmonary Disease, or valvular heart disease were excluded. Students who had recently been ill or undergone stomach surgery were also excluded. The sample size was determined based on guidelines from previous study (Dugral & Balkanci, 2019), aiming for a 95% confidence level with a 1.96 confidence interval and a Type II error margin of 10%, yielding a study power of 90%. A priori power analysis was conducted using G*Power 3.1, targeting a medium effect size ($f^2 = 0.15$), $\alpha = 0.05$, and power $(1-\beta) = 0.90$. This yielded a required sample size of 98 participants per group for regression analysis with up to 4 predictors. As a result, 98 participants were required per group, with an additional allowance of 5–7 individuals per group to account for potential dropouts. The study was conducted with voluntary participation, following the acquisition of informed consent from all participants. Ethical approval (no. 2019-1-22) was secured from the Bursa Uludağ University Ethics Committee, and written permission was obtained from the institution where the research took place.

Only students without any known health issues were selected for the study. Standardized procedures were followed to measure anthropometric parameters, including weight, height, BMI, and WHR. Spirometry was performed using a desktop spirometer (Pony FX®, COSMED, Italy) in accordance with the American Thoracic Society (ATS) guidelines, with participants standing in a quiet, private room. The spirometry tests captured flow-volume curves, with key parameters such as Forced Expiratory Volume in 1 second (FEV_1) and Forced Vital Capacity (FVC) being recorded for analysis. The apparatus recorded and quantified all mandatory flow and volume variables. Pulmonary Function Test results were derived from a combination of Forced Vital Capacity measurements. Students were shown a demonstration of the test before initiation. Three measurements were noted for each student to ensure consistency and sustainability of recorded tests, with the best of the three measurements selected (Dugral & Balkanci, 2019; Moore, 2022).

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ) – SHORT FORM

The IPAQ short form was developed to assess the physical activity levels of individuals aged 15–65 years. The validity and reliability study of the IPAQ short form in Turkey was conducted by Savcı et al. (2006). In evaluating all activities, each activity had to be performed for at least 10 minutes at a time. A score was obtained by multiplying the minutes, days, and MET value, expressed as "MET-minutes/week." Physical activity was classified as low (<600 MET-minutes/week), moderate (600–3000 MET-minutes/week), and high (>3000 MET-minutes/week). Sedentary behavior was operationalized as self-reported sitting time per day (minutes/day) obtained from the IPAQ-SF questionnaire (Savcı et al., 2006; Yeşil et al., 2021).

MEASUREMENT OF EXHALED CO (CO BREATH)

CO breath levels were measured three times at each data collection point using the CO Check Pro Baby device (MD Diagnostics Ltd., Kent, England), following the manufacturer's guidelines. Participants were instructed not to smoke for at least one hour prior to CO measurements. Participants were instructed to hold their breath for 20 seconds to ensure equilibration of COHb with alveolar CO before exhaling fully and steadily into the device's mouthpiece, where CO levels were recorded. A threshold of ≥6 ppm was used to classify participants as smokers, as recommended in prior studies (Karelitz et al., 2021). The results were reported in parts per million (ppm). The device was calibrated according to the manufacturer's specifications before use and was recalibrated biannually during the study (Benli et al., 2017).

HEADACHE IMPACT TEST (HIT-6)

The HIT-6 consists of 6 items and assesses a wide range of problems related to headaches. It is based on patient self-report and provides quantitative information related to migraines. The scale scores can range between 36 and 78. A score of ≤49 indicates no impact (Grade I), 50–55 represents moderate impact (Grade II), 56–59 indicates significant impact (Grade III), and a

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score of ≥60 signifies severe impact (Grade IV). The HIT-6 is considered a subjective tool because it reflects the impact of headache severity on quality of life from the patient's perspective. The HIT-6 covers a broad spectrum of headache types and is user-friendly, consisting of only six questions, making it easy for patients to complete. Additionally, it involves a shorter recall period, which can facilitate more accurate self-reporting (Dikmen et al., 2020).

STATISTICAL ANALYSIS

Descriptive statistics were expressed as mean ± standard deviation (SD), count and percentage, frequency and median, depending on the type of the variable. Pearson's $\chi 2$ test was used for determining the relationship between genders and categorical demographic features. The t test was applied to determine the differences numerical characteristics between groups. Spear-man's rank correlation analysis was used to determine relationships between the evaluation parameters. Regression assumptions (linearity, normality, homoscedasticity, and multicollinearity) were checked using residual plots, VIF scores, and Kolmogorov-Smirnov test. Stepwise multiple linear regression analysis was performed to measure the effect of the independent variables on the dependent variables separately in both groups. Stepwise regression was conducted with entry criteria set at $p < 0.05$ and removal at $p > 0.10$. P values < 0.05 were regarded as statistically significant. Data analysis was performed on SPSS software (version 22.0 for Windows).

RESULTS

Table 1 presented the demographic and baseline characteristics of the participants, including age, waist-to-hip ratio (WHR), physical activity level as measured by the International Physical Activity Questionnaire – Short Form (IPAQ-SF), Headache Impact Test (HIT-6), Forced Vital Capacity (FVC), and Forced Expiratory Volume in 1 second (FEV_1). No statistically significant differences were found between smokers and non-smokers for these parameters ($p > 0.05$). However, statistically significant differences were observed between the groups in terms of

PARAMETERS			n	MINIMUM–MAXIMUM		MEAN ± STANDARD DEVIATION	p
BMI (kg/m²)	Smoke		103	16,02–33,06		21,91 ± 3,43	0,456
	Non Smoke		104	16,30–29,86		22,21 ± 3,19	
Age (Years)	Smoke		103	17–46		21,32 ± 3,94	0,310
	Non Smoke		104	20–38		20,61 ± 344	
Gender				**n**	**%**		
	Smoke	Female	103	72	69,90		0,210
		Male		31	30,1		
	Non smoke	Female	104	83	79,8		0,000
		Male		21	20,2		
				MINIMUM–MAXIMUM		**MEAN± STANDARD DEVIATION**	
WHR (cm)	Smoke		103	0,60-0,91		0,76 ± 0,07	0,513
	Non Smoke		104	0,62–1,10		0,75 ± 0,07	
HIT-6	Smoke		103	36,00–74,00		54,84 ± 9,27	0,689
	Non Smoke		104	36–71		54,28 ± 8,66	
IPAQ-S	Smoke		103	1243-27510		7407,41 ± 4277,17	0,474
	Non Smoke		104	1320-21040		6973,27 ± 3245,01	
Sedentary	Smoke		103	630–7560		3638,34 ± 1416,69	0,000*
	Non Smoke		104	378–11340		4614,82–1912,01	
CO (ppm)	Smoke		103	0–22		6,02 ± 5,01	0,000*
	Non Smoke		104	0–7		0,78 ± 1,16	
FVC	Smoke		103	0,53–5,56		2,97–1,05	0,326
	Non Smoke		104	1,06–11,02		3,16 ± 1,45	
FEV_1	Smoke		103	0,23–4,73		1,51 ± 0,87	0,684
	Non Smoke		104	0,18–4,25		1,57 ± 0,87	

Table 1 Descriptive statistics of categorical variables.

**p < 0,005 Abbreviations: BMI: Body Mass Index; CO: Carbon-monoxide, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 second, HIT-6: Headache impact test, IPAQ-SF: International Physical Activity Questionnaire-short form; WHR: Waist-Hip Ratio.

sedentary behavior (SB) and carbon monoxide (CO) levels ($p < 0.001$ for both). These differences are visually represented in Figure 1, which compares average sedentary time and CO levels across the two groups. A statistically significant gender imbalance was observed in the non-smoker group, with a notably higher proportion of female participants (79.8%) compared to males ($p < 0.001$).

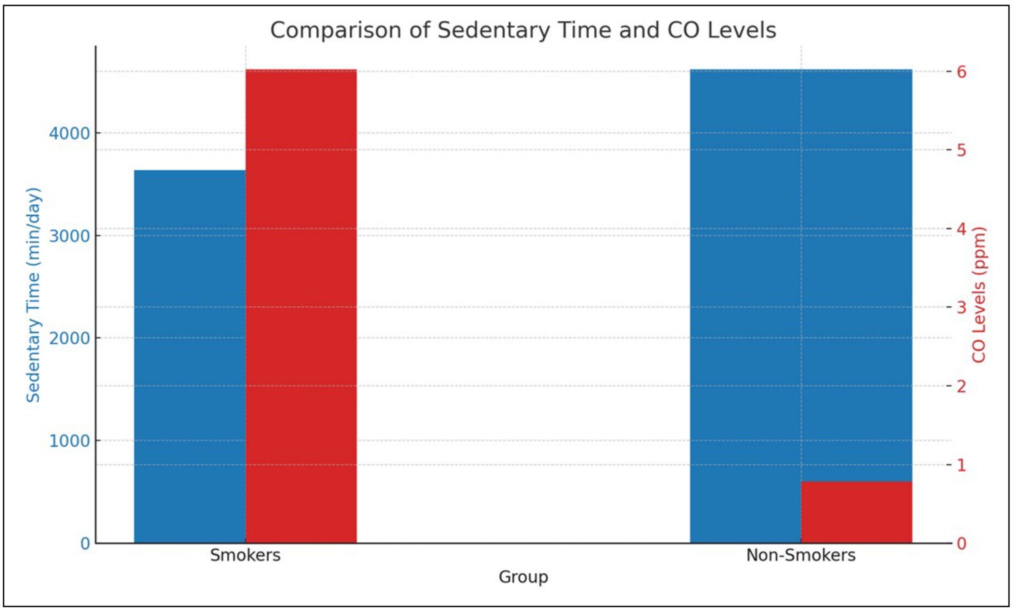

Figure 1 Comparison of daily sedentary time and CO levels between smokers and non-smoker university students. Blue bars represent sedentary time (minutes/day), while red bars indicate exhaled CO levels (ppm).

Correlation analysis in the smoker group revealed the following: a strong positive correlation was found between FVC and FEV_1 ($r = 0.707$, $p < 0.001$); a moderate negative correlation was observed between FVC and HIT-6 scores ($r = -0.281$, $p = 0.010$); a weak positive correlation was found between WHR and FVC ($r = 0.256$, $p = 0.016$); and a weak negative correlation was noted between WHR and HIT-6 scores ($r = -0.242$, $p = 0.028$). CO levels were also strongly positively correlated with the number of cigarettes smoked per day ($r = 0.543$, $p < 0.001$) (Table 2).

Table 2 The relations between Age, BMI, WHR, IPAQ-SF, Sedentary, CO, FVC, FEV_1, HIT-6 in groups.

**p < 0,005 Abbreviations: BMI: Body Mass Index; CO: Carbon-monoxide, FVC: Forced vital capacity, FEV_1: Forced expiratory volume in 1 second, HIT-6: Headache impact test, IPAQ-SF: International Physical Activity Questionnaire-short form; WHR: Waist-Hip Ratio.

SMOKER / NON-SMOKER		BMI	WHR	IPAQ-SF	SEDENTARY	CO	FVC	FEV_1	HIT-6	COUNT	AGE
BMI	r	1	0,289**	0,115	0,025	0,001	0,091	−0,004	–,0164	−0,143	0,095
	p		0,008	0,302	0,825	0,996	0,413	0,973	0,137	0,197	0,393
WHR	r	0,294**	1	−0,001	−0,214	0,096	0,265*	0,165	−0,242*	0,086	0,087
	p	0,007		0,992	0,052	0,387	0,016	0,138	0,028	0,438	0,434
IPAQ-SF	r	0,096	−0,226*	1	0,402**	0,113	0,053	0,063	0,057	0,033	−0,081
	p	0,387	0,039		0,000	0,309	0,634	0,571	0,606	0,764	0,466
Sedentary	r	−0,171	−0,336**	0,567**	1	−0,019	−0,078	0,034	0,178	−0,166	−0,058
	p	0,119	0,002	0,000		0,864	0,481	0,760	0,108	0,134	0,605
CO	r	−0,035	0,151	0,040	0,037	1	0,015	−0,119	−0,032	0,543**	−0,013
	p	0,751	0,170	0,718	0,736		0,890	0,284	0,776	0,000	0,908
FVC	r	0,387**	0,457**	−0,093	−0,254*	−0,003	1	0,707**	−0,281*	−0,056	−0,003
	p	0,000	0,000	0,402	0,020	0,981		0,000	0,010	0,614	0,978
FEV1	r	0,297	0,343**	−0,126	−0,186	−0,057	0,617**	1	−0,166	−0,008	−0,005
	p	0,006	0,001	0,253	0,089	0,605	0,000		0,134	0,378	0,967
HIT-6	r	0,080	−0,013	−0,045	0,004	−0,111	−0,225*	−0,105	1	0,121	0,037
	p	0,471	0,907	0,682	0,970	0,315	0,039	0,340		0,277	0,738
Age	r	0,027	−0,133	0,037	0,034	−0,012	−0,111	−0,084	0,143	NA	1
	p	0,804	0,226	0,738	0,757	0,913	0,313	0,449	0,194	NA	

In the non-smoking group, FVC was strongly positively correlated with FEV_1 (r = 0.617, p < 0.001), body mass index (BMI) (r = 0.387, p < 0.001), and WHR (r = 0.457, p < 0.001). FVC was also negatively correlated with HIT-6 scores (r = –0.225, p = 0.039) and sedentary behavior (r = –0.254, p = 0.020). Additionally, WHR showed significant negative correlations with both IPAQ-SF and sedentary behavior values, indicating that higher central adiposity was associated with lower physical activity and increased sedentary time (Taşlı & Sağır, 2021). Although WHR and BMI showed a weak correlation (r = 0.311), WHR-related findings were considered numerically limited and were therefore excluded from further discussion.

Regression analysis revealed that FEV_1 was a significant predictor of headache impact, as measured by HIT-6, in both smokers (R^2 = 0.092, p = 0.003) and non-smokers (R^2 = 0.062, p = 0.012). In the non-smoker group, BMI also emerged as a significant predictor (R^2 = 0.097, p = 0.006) (Table 3).

Table 3 The relationships between the HIT-6 and the FEV_1 as well as the BMI in the smoking and non-smoking group.

Stepwise multiple linear regression model.

B regression coefficient constant term.

VARIABLES	B	BETA	p	R^2
HIT-6 (Smoker)				
Constant	63,261		0,000	0,092
FEV_1	–2,831	–0,321	0,003	
HIT-6 (Non-smoker)				
Constant	47,241		0,000	
FEV_1	–2,115	–0,355	0,012	0,062
BMI	0,618	0,228	0,006	0,097

DISCUSSION

The primary objective of this study was to examine the associations between smoking, pulmonary function, physical activity, and headache impact in university students. Specifically, we investigated how Forced Expiratory Volume in 1 second (FEV_1) influenced headache impact in both smokers and non-smokers. The results from regression analysis provided significant insights into these relationships.

This study demonstrates that FEV_1 is a significant predictor of headache impact in both groups. Regression analysis revealed a negative correlation between FEV_1 and HIT-6 scores, suggesting that reduced lung function was associated with increased headache impact in this population. This finding aligns with the understanding that smoking impairs pulmonary function by introducing harmful chemicals, such as carbon monoxide, which reduce oxygen transport in the blood. Reduced pulmonary function may lead to lower oxygenation levels (hypoxia), potentially contributing to headaches through cerebral vasodilation and inflammation. This mechanism is supported by previous research highlighting the systemic impacts of smoking on respiratory and neurological health (Flynn et al., 2022).

In the non-smoking cohort, pulmonary function also appeared to play a significant role in headache outcomes (Flynn et al., 2022). A noteworthy distinction between smokers and non-smokers was observed in terms of sedentary behavior, which likely contributed to group differences. Sedentary behavior is associated with multiple adverse health outcomes, including weight gain and metabolic dysfunction, both of which are potential risk factors for headache (Flynn et al., 2022; Saracco et al., 2022). In our sample, non-smokers particularly females exhibited significantly greater sedentary time, which may help explain the elevated HIT-6 scores in this group. This interpretation aligns with the findings of Saracco et al. (2022), who reported that among 4,926 university students, approximately 50% experienced headaches, primarily linked to insufficient physical activity.

The literature indicates that the definition of sedentary activities remains somewhat ambiguous (Bigal & Hargreaves, 2013). For example, whether sitting while studying or using a smartphone constitutes sedentary behavior is still debated. In our study, sedentary behavior was not assessed directly, but sitting time was evaluated via the IPAQ-SF. The non-smoking group was found to have higher sitting time, leading us to hypothesize that the effects of pulmonary function in non-smokers may be partly explained by sedentary lifestyle factors (Qubty & Gelfand, 2016).

Previous studies have consistently shown that headaches are more prevalent among females (Hu et al., 2025; Langford et al., 2014; Ekelund et al., 2016). The observed association between reduced pulmonary function and headache symptoms in sedentary, non-smoking women may be attributable to a combination of physiological and behavioral mechanisms, including impaired oxygenation, altered circulatory dynamics, increased muscle tension, psychological stress, and systemic inflammation (Saracco et al., 2022). Although subgroup analysis by gender was not formally conducted in this study, existing literature indicates that females are generally more sedentary than males, which may partially account for our findings.

Interestingly, while non-smokers exhibited higher levels of sedentary behavior, the inverse trend was observed among smokers. Although smokers may appear more physically active, their activity is often unstructured or socially driven, rather than representing consistent, health-promoting exercise. This distinction suggests that the behavioral profiles of smokers and non-smokers may diverge not only in smoking status but also in the quality and intent of physical activity engagement (Aljuhani et al., 2024; Ge et al., 2023; Haywood et al., 2021; Langford et al., 2014).

In this study, no significant difference in BMI was found between smokers and non-smokers. However, BMI emerged as a significant predictor of headache impact within the non-smoking group during regression analysis. Interestingly, correlation analysis revealed no direct association between BMI and headache scores, suggesting that BMI alone may not influence headache outcomes in a linear fashion. The predictive role of BMI in regression models indicates that, when adjusted for other factors, BMI may exert an indirect or interacting effect. Previous research has demonstrated that the relationship between BMI and headache varies across populations (e.g., Asia vs. Europe), and that increased BMI may be associated with heightened headache risk in some cohorts (Aljuhani et al., 2024; Ge et al., 2023; Haywood et al., 2021; Langford et al., 2014). Although a consistent, universal link has not been firmly established, the current findings—limited to participants with BMI values below 25 kg/m^2—support the hypothesis that even modest increases in adiposity may contribute to headache burden, particularly among non-smokers (Saintila et al., 2024). Proposed mechanisms include sympathetic nervous system dysregulation and inflammatory processes, which warrant further investigation (Haywood et al., 2021; Saintila et al., 2024).

In this study, the identification of pulmonary function parameters as significant predictors of headache impact in non-smokers may be partially explained by environmental influences (Kasparoğlu et al., 2018; Saracco et al., 2022; Yağcı, 2019). The research was conducted at Yalova University, a region characterized by a mild climate and green spaces, yet also subject to air and marine pollution. Prior studies have reported elevated allergen concentrations in this area, which may contribute to respiratory symptoms even in non-smoking individuals (Kasparoğlu et al., 2018; Yağcı, 2019). Therefore, environmental exposures could account for the unexpectedly reduced pulmonary function observed among non-smokers in the sample.

In this study, carbon monoxide (CO) levels were significantly higher among smokers compared to non-smokers. Elevated CO exposure in smokers may contribute to their higher prevalence of headaches, as CO interferes with oxygen delivery and has been implicated in vascular and neurological dysfunction. While no significant differences were found between the groups in terms of physical activity, FEV_1, FVC, or BMI, CO levels emerged as a distinct risk factor potentially associated with headache burden. Conversely, higher levels of sedentary behavior observed among non-smokers may also play a role in the differing health outcomes between the groups.

The study did not assess muscle tension, sleep quality, or psychological stress among participants. However, the associations among physical activity, pulmonary function, and headache impact were examined using objective and validated tools. These findings suggest practical strategies for improving health among university students (Langford et al., 2014; Saracco et al., 2022). Based on the results, being female, leading a sedentary lifestyle, and having high CO levels appear to be unfavorable conditions. More detailed analyses of sedentary patterns among female students are warranted, and interventions should aim to reduce smoking and sedentary behavior in this population.

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Anecdotal observations during the study indicated that several participants became more conscious of their health status after viewing their CO and pulmonary function values. Some students even inquired about resources for smoking cessation. While not systematically measured, these informal reactions suggest that the study may have contributed to increased health awareness among participants. By employing objective tools to assess CO exposure and pulmonary capacity, the study was able to communicate the physiological consequences of smoking in a tangible and comprehensible manner (Jeong et al., 2020).

Saez et al. (2021) reports that university students often face barriers such as fatigue and lack of time, limiting their engagement in physical activity (Sáez et al., 2021). They emphasize the need for further research to promote healthy lifestyles in this population. Future studies should incorporate assessments of muscle tension, sleep, and psychological distress. Interventions such as aerobic exercise, yoga, and breathing techniques can improve pulmonary function and reduce headache triggers. Addressing posture through physiotherapy or ergonomic education may alleviate neck and shoulder tension, a known source of tension-type headaches. Moreover, mindfulness and stress management strategies may reduce headache frequency. Adequate hydration, balanced nutrition, and regular sleep also contribute to headache prevention (Heneweer et al., 2021; Li et al., 2023; Silva et al., 2020).

Flynn et al. (2022) emphasize that a holistic approach is considered the gold standard in pain management (Flynn et al., 2022; Dresler et al., 2019). In addition to pharmacological treatments, behavioral strategies such as regular sleep and relaxation are well-supported in the literature (Al-Natour et al., 2021; Dresler et al., 2019).

About one-fifth of headache-related studies note a bidirectional relationship between migraine and mental health disorders (Dresler et al., 2019). Promoting physical activity not only improves mental health but also academic performance. Given the multiple factors affecting university students' health, interventions to manage headaches must address broader lifestyle and environmental contributors (Al-Natour et al., 2021; Dresler et al., 2019; Li et al., 2023).

A review of the literature reveals no other study that has examined pulmonary function, physical activity, CO exposure, and headache impact simultaneously in a university student population (Langford et al., 2014). In this regard, our study is comprehensive and novel.

This study, however, has limitations. The cross-sectional design precludes causal inferences, as only one point was assessed. Thus, it cannot be determined whether smoking causes headaches or whether shared underlying factors explain both. While the power analysis was based on detecting medium effect sizes for individual associations, we acknowledge that the inclusion of multiple covariates in regression models may reduce statistical power and increase the risk of type II errors. This limitation has been considered when interpreting nonsignificant predictors. In addition, we did not assess all potential confounding variables, such as headache subtype, socioeconomic status, smartphone use, sleep, stress, caffeine intake, and diet (Langford et al., 2014; Savcı et al., 2006; Silva et al., 2020). Despite these limitations, the findings underscore the importance of including nurses and physiotherapists in smoking cessation efforts. Darabseh et al. recommend a multidisciplinary approach to smoking-related health interventions (Al-Natour et al., 2021; Dresler et al., 2019; Langford et al., 2014). Our research team included two physicians, two nurses, and one physiotherapist, reflecting this approach.

CONCLUSION

This study identified FEV_1 as a significant predictor of headache impact in both smokers and non-smokers. Additionally, BMI was associated with headache burden among non-smokers. CO levels and sedentary behavior emerged as key distinguishing variables between the two groups. Among university students who smoke, factors such as physical activity, psychological well-being, and nutrition likely interact to influence headache risk. To our knowledge, this is the first study to examine pulmonary function, physical activity, CO exposure, and headache impact within a single framework. These findings provide a valuable foundation for future research and inform health interventions aimed at reducing headache burden in young adult populations.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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