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COMPARISON OF RESPIRATORY MUSCLE ENDURANCE AND ANAEROBIC PERFORMANCE BETWEEN YOUNG ADULT SMOKERS AND NON-SMOKERS

SİGARA İÇEN VE İÇMEYEN GENÇ YETİŞKİNLERİN SOLUNUM KAS ENDURANSI VE ANAEROBİK PERFORMANSLARININ KARŞILAŞTIRILMASI

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Abstract
Cigarette smoking negatively affects the structure and function of the diaphragm muscle, as well as aerobic and anaerobic performance. However, the early functional effects of smoking in young adults with relatively short-term smoking exposure remain unclear. This study aims to compare respiratory muscle strength and endurance, pulmonary function, anaerobic power, and fatigue index between smoking and non-smoking university students. Thirty-three university students (15 smokers, 18 non-smokers) aged 18–30 years were included in the study. Pulmonary functions and maximal inspiratory and expiratory pressures (MIP, MEP) were measured using a spirometer. Inspiratory muscle endurance was assessed using an incremental threshold loading test with an inspiratory muscle training device. Anaerobic performance and fatigue index were assessed using the Running-Based Anaerobic Sprint Test (RAST). The demographic characteristics were similar between groups (p>0.05). Although no statistically significant differences were observed in pulmonary function, respiratory muscle strength, or RAST parameters (p>0.05), smokers demonstrated lower mean MIP values, approaching clinical significance, and a tendency toward higher fatigue index compared with non-smokers. The observed tendency for lower MIP values and higher fatigue index results among young university students with low smoking exposure indicates that early functional impairments may develop before measurable clinical deficits become evident. There is a need for longitudinal studies with larger sample sizes to more clearly demonstrate the chronic effects of cigarette smoking on respiratory muscle function and anaerobic capacity.

Keywords: Athletic performance, Cigarette smoking, Maximal respiratory pressures, Pulmonary function tests, Strength

Öz
Sigara içimi diyafram kasının yapısını, fonksiyonunu, aerobik ve anaerobik performansı olumsuz etkilemektedir. Fakat, görece kısa süreli sigara maruziyetine sahip genç yetişkinlerde sigaranın erken dönemdeki fonksiyonel etkileri hâlâ net değildir. Bu çalışma, sigara içen ve içmeyen üniversite öğrencilerinde solunum kas kuvveti ve enduransı, pulmoner fonksiyonlar, anaerobik güç ve yorgunluk indeksini karşılaştırmayı amaçlamaktadır. Çalışmaya 18–30 yaş aralığında, 15'i sigara içen ve 18'i sigara içmeyen toplam 33 üniversite öğrencisi dahil edildi. Pulmoner fonksiyonlar, maksimal inspiratuar ve ekspiratuar basınçlar (MIP, MEP) spirometre kullanılarak değerlendirildi. İnspiratuar kas enduransı, inspiratuar kas eğitim cihazı ile artan eşik yükleme testi kullanılarak değerlendirildi. Anaerobik performans ve yorgunluk indeksi ise Koşuya Dayalı Anaerobik Sprint Testi (RAST) ile ölçüldü. Grupların demografik özellikleri benzerdi (p>0.05). Pulmoner fonksiyonlar, solunum kas kuvveti veya RAST parametreleri açısından istatistiksel olarak anlamlı fark olmamasına rağmen (p>0.05), sigara içenlerde ortalama MIP değerlerinin klinik anlamlılığa yaklaşacak düzeyde daha düşük olduğu ve yorgunluk indeksinin daha yüksek olma eğiliminde olduğu gözlendi. Düşük düzeyde sigara maruziyetine sahip genç üniversite öğrencilerinde

MIP değerlerinin düşük ve yorgunluk indeksinin yüksek olma eğilimi, belirgin klinik bozukluklar ortaya çıkmadan önce erken fonksiyonel bozulmaların gelişebileceğini göstermektedir. Sigara içmenin solunum kası fonksiyonu ve anaerobik kapasite üzerindeki kronik etkilerini daha net ortaya koymak için daha geniş örneklemli ve boylamsal çalışmalara ihtiyaç vardır.

Anahtar Kelimeler: Atletik performans, Kuvvet, Maksimal respiratuar basınçlar, Pulmoner fonksiyon testleri, Sigara içimi

1. Introduction

Cigarette smoking is a global public health problem that causes morbidity and mortality and is a risk factor for various diseases, such as coronary artery disease, peripheral vascular disease, myocardial infarction and stroke (Ezzati & Lopez, 2003; Lee & Chang, 2013). In addition to the well-known negative effects of exposure to cigarette smoke, it is also known to cause structural and functional changes in respiratory muscles, lung functions, and performance (Sheng et al., 2020). These alterations are mainly attributed to toxic substances in cigarette smoke, such as nicotine, o-cresol, phenylacetate (Khattri et al., 2022). Smokers and users of alternative forms of nicotine have higher resistance in small and medium bronchioles (Grudzińska et al., 2024). In addition, increased carbon monoxide in the blood lowers oxygen delivery to muscles and impairs muscle performance (King et al., 1987). As exposure to cigarette smoke increases, the negative impact on respiratory functions and performance increases (Adatia et al., 2021). On the other hand, it has been found that even short-term exposure has acute and reversible effects (Unverdorben et al., 2010). After more than 12 weeks of exposure, particularly in the diaphragm, compensatory changes are replaced by maladaptive alterations in structure and function (Sheng et al., 2020). A previous study emphasized that high body mass and tobacco use in young people increase the risk of developing all diseases examined in later years (Turkiewicz et al., 2025). Considering the direct and indirect adverse effects of cigarette exposure on respiratory muscle function and skeletal muscle function, it is important to evaluate respiratory muscle function and anaerobic performance in young adult smokers. Therefore, the present study aimed to compare respiratory muscle strength and endurance, pulmonary function, and anaerobic performance between young adult smokers and non-smokers. The study tested the hypothesis that young adult smokers would have lower respiratory muscle strength and endurance, reduced pulmonary function, and decreased anaerobic performance compared to non-smokers.

2. Materials and Methods

2.1. Study design and participants

This cross-sectional study was approved (No:2024/151) by the Amasya University Non-Interventional Clinical Research Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Informed consent forms were obtained from the participants. Individuals aged 18-30 who volunteered to participate were included in the study. Individuals who had a diagnosed respiratory, neurological, orthopedic, psychiatric, or cardiac condition, any infection or limitation at the time of evaluation, and who were pregnant or breastfeeding were excluded from the study. Participants' demographic information and smoking history were recorded.

2.2. Data collection

Pulmonary function and inspiratory and expiratory muscle strength (Maximal Inspiratory and Expiratory Pressure, MIP and MEP) were evaluated using a spirometer (Cosmed® Pony Fx, Italy) in accordance with the American Thoracic Society/European Respiratory Society standards. The pulmonary function test parameters including the forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), the FEV_1/FVC, and peak expiratory flow (PEF) were recorded. Measurements were repeated until consistent and acceptable results were achieved. Expected values were calculated using the reference equation, and the measured respiratory function parameters were expressed as percentages of these expected values (Stanojevic et al., 2022).

The MIP and MEP were measured with participants completing at least five trials, and the highest value selected for analysis. Percentages of MIP and MEP values were calculated based on the reference values. The cut-off values were 62 cmH_2O and 83 cmH_2O for PImax, and 81 cmH_2O and 109 cmH_2O for PEmax in females and males, respectively (Lista-Paz et al., 2023).

Inspiratory muscle endurance was evaluated with an inspiratory muscle training device (POWERbreathe, IMT Technologies Ltd., Birmingham, UK). The incremental threshold loading test started at 30% of MIP and was increased by 10% every two minutes until reaching 100%. The test was stopped if participants experienced extreme fatigue, dyspnea, or were unable to take two consecutive deep inspirations. Sustained inspiratory maximal pressure (Pmax) and duration (Tmax) were recorded (Woszezenki et al., 2017).

Anaerobic performance and fatigue index were assessed with the Running-Based Anaerobic Sprint Test (RAST). The RAST protocol includes six maximal 35-meter sprints, each separated by a 10-second recovery period. Anaerobic power was calculated by the formula: weight (kg) × distance^2 (m) ÷ time^3 (s). The fatigue index was determined by calculating (Maximum Power-Minimum Power) ÷ the total time for six sprints (Adamczyk, 2011).

2.3. Statistical analysis

The statistical analyses were performed using Statistical Package for the Social Sciences version 20 (SPSS 20, IBM, Armonk, NY, USA). The normality of the data distribution was tested using "Kolmogorov-Smirnov/Shapiro-Wilk tests". Descriptive analyses were expressed as means ($\bar{x}$) ± standard deviation (SD) for normally distributed variables; median and interquartile range (IQR) for non-normally distributed variables; and as percentages (%) and frequencies (n) for categorical variables. Group comparisons were conducted using the Student's t-test, Mann–Whitney U test, and Chi-square test for normally distributed, non-normally distributed, and categorical variables, respectively. Post hoc statistical power (1 – β) was calculated using the G-Power software (Faul et al., 2007) according to the MIP% values. Level of significance was determined as $p \leq 0.05$.

3. Results and Discussion

Thirty-three university students participated in the study, including 15 smokers and 18 non-smokers. The demographic and anthropometric characteristics of the participants were similar between the groups (p>0.05, Table 1). The comparison of respiratory muscle strength, endurance, pulmonary function, and anaerobic capacity between groups is shown in Table 2. No statistically significant differences were observed between smokers and non-smokers in respiratory and anaerobic performance parameters (p>0.05, Table 2). The mean MIP values (1– β=0.59) tended to be lower, approaching clinical significance, while the fatigue index tended to be higher in smokers. Figure 1 illustrates the radar chart comparing respiratory muscle strength and fatigue index between the two groups.

This study provides a comparison of respiratory muscle strength and endurance, pulmonary function, and anaerobic performance parameters including anaerobic power and fatigue index between smokers and non-smokers.

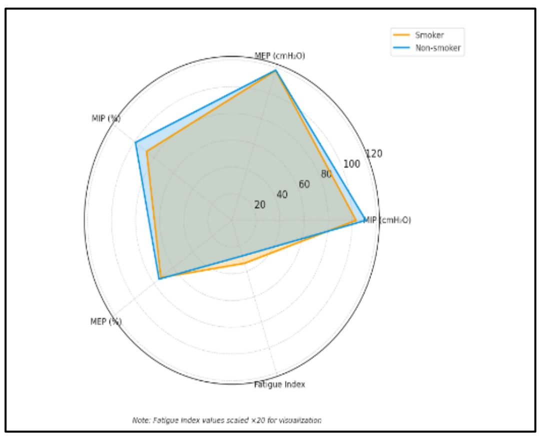
While no statistically significant differences were observed between the two groups, these physiological assessments may help explain the findings and support the possible clinical and functional effects of smoking on respiratory and exercise performance. The results contribute to the existing literature by providing important insight into how exposure to cigarette smoke may affect respiratory mechanics and energy metabolism during exercise, even in apparently healthy university students.

Table 1. Demographic and anthropometric characteristics of the groups

Variable	Smoker (N = 15) Mean ± SD	Non-smoker (N = 18) Mean ± SD	*p* value
Gender(n/%)			
Females	7 (46.7%)	13 (72.2%)	0.135
Males	8 (53.3%)	5 (27.8%)	
Age (y)	22.53 ± 0.92	22.28 ± 3.18	0.748
Height (cm)	171.6 ± 9.06	168.78 ± 9.35	0.388
Weight (kg)	66.12 ± 14.04	63.26 ± 13.39	0.554
Body Mass Index(kgm^{-2})	22.34 ± 3.46	22.08 ± 3.66	0.838
Smoking exposure (pack-years)	3.35 ± 1.97	-	

*y, years; cm, centimeters; kg, kilograms; kg m^{-2}, kilogram per square meter; %, percentage; SD, standard deviation

Figure 1. Radar chart comparing respiratory muscle strength and fatigue index between smokers and non-smokers.



Exposure to cigarette smoke condensate, which includes toxic agents such as nicotine, o-cresol, phenylacetate, and decanoic acid, leads to dysfunction in muscle mitochondria by decreasing respiratory activity and mitochondrial coupling efficiency (Khattri et al., 2022). In our study, although the mean smoking exposure among the university students who smoked was approximately 3.5 pack-years and no statistically significant differences were found between the groups, the MIP values of smokers were tended to be lower than those of non-smokers, approaching clinical significance (Beaumont et al., 2023).

Table 2. Comparison of respiratory muscle performance and anaerobic capacity

Variable	Smoker (*N* = 15) Mean ± SD Median (IQR)	Non-smoker (*N* = 18) Mean ± SD Median (IQR)	*p* value
MIP (cmH_2O)	103.27 ± 26.92	111.39 ± 23.93	0.366
MEP (cmH_2O)	117.73 ± 32.48	118.13 ± 54.77	0.981
MIP (%)	87.63 ± 24.67	99.08 ± 16.43	0.121
MEP (%)	72.97 ± 18.39	74.82 ± 23.48	0.812
FVC (%)	96.29 ± 14.75	101 ± 12.54	0.344
FEV_1 (%)	93.5 ± 9.31	100.56 ± 12.68	0.091
FEV_1/FVC (%)	97.71 ± 7.14	101.28 ± 10.53	0.286
PEF (%)	84.14 ± 22.22	89.97 ± 11.08	0.340
Tmax (min)	360 (240-567)	337 (240-720)	0.824
Pmax (cmH_2O)	52.8 (38.6-90)	52.5 (40-92.5)	0.681
Anaerobic power (W)	142.1 (130.8-353.45)	175.8 (117.05-322.33)	0.834
Fatigue index ($W{\cdot}s^{-1}$)	1.69 (0.79-5.14)	1.4 (0.95-4.23)	0.895

*MIP, Maximal inspiratory pressure; MEP, Maximal expiratory pressure; FEV_1, Forced expiratory volume in the first second; FVC, Forced vital capacity; FEV_1/FVC, Forced expiratory volume in the first second/forced vital capacity; PEF, Peak expiratory flow; mm, millimeter; cmH_2O, centimeters of water; W, watt; min, minute; s, second; IQR, interquartile range

Our findings on respiratory muscle strength are consistent with findings of Formiga et al., who compared inspiratory muscle performance between former smokers and non-smokers. They emphasized that although sustained inspiratory performance differed by sex, no significant difference was found in maximal inspiratory pressure (Formiga et al., 2018). In addition, Adatia et al (2021) divided smokers into different groups based on their smoking exposure duration. Similar to our study, no significant decreases in lung function, muscle strength, or exercise capacity were observed in individuals with less than 10 pack-years of exposure. However, when compared with groups with higher exposure, adverse effects such as narrowing of the small airways and decreased diffusing capacity were observed. These findings suggest that smoking exposure has a dose-dependent effect on lung function and exercise capacity (Adatia et al., 2021).

In our study, the mean values of pulmonary function test parameters including FVC, FEV_1, FEV_1/FVC, and PEF were lower in smokers, although the differences were not statistically significant. Similarly, Unverdorben et al. (2010) demonstrated that short-term exposure to cigarette smoke causes acute and reversible impairment in airway function. Although lung volumes remained within normal limits in our study, the observed trend toward lower values may be related to early functional changes that occur before significant pulmonary dysfunction develops.

Cigarette smoke exposure has been shown to negatively affect skeletal muscle structure and function through oxidative stress, mitochondrial dysfunction, and changes in muscle fiber composition. Sheng et al. (2020) investigated the effects of 12 and 24 week cigarette smoke exposure on diaphragm structure in rats and found that short-term (12-week) exposure causes adaptive compensatory changes in the diaphragm muscle, whereas prolonged (24-week) exposure resulted in maladaptive alterations characterized by reduced mitochondrial density, abnormal mitochondrial morphology, and impaired contractile function. In our study, there were no differences between the groups in terms of respiratory muscle endurance parameters, including the maximal duration and pressure achieved during the endurance test. Considering that our sample consisted of university students with relatively short smoking exposure due to their young age, it may be early to observe the long-term detrimental effects of smoking on respiratory muscle performance and structure. Furthermore, the participants' young age and active lifestyle may have contributed to the preservation of their respiratory endurance capacity and dynamic lung volumes. Further studies with longer durations and longitudinal designs are needed to clarify better the chronic effects of smoking on respiratory muscle endurance and function.

Cigarette smoking increases plasma oxidative stress and can exacerbate reactive oxygen species during intense exercise (Taito et al., 2013). Borrelli et al. demonstrated that smoking negatively impacts cardiorespiratory and metabolic responses during maximal incremental exercise even in young physically active individuals. Furthermore, even in individuals with short-term smoking exposure, oxygen consumption, expiratory ventilation, and mechanical power during exercise are reduced, and recovery time is prolonged (Borrelli et al., 2024). In our study, the fatigue index averages calculated as a result of the RAST test tended to increase in the smoking group, although the exposure levels were relatively low compared to the studies in the literature. In line with these findings, Lee et al. (2013) conducted an intermittent sprint test in healthy university students and found that while peak power and total work did not differ between smokers and non-smokers, smokers showed a greater decline in average power during later sprints and a higher fatigue index, indicating faster fatigue development even in young, physically active individuals. Evidence suggests that smoking, even at low exposure levels, may impair resistance to fatigue during intense activity.

4. Conclusion

Although no statistically significant differences were found between smokers and nonsmokers, the trends toward lower MIP values and higher fatigue index results suggest that early functional impairments may emerge before measurable clinical impairments become apparent. These results emphasize the potential for even short-term cigarette smoking to negatively impact exercise performance and respiratory mechanics in university students. However, this study has several limitations: the relatively small sample size and low cumulative smoking exposure among participants may have limited our ability to detect long-term effects. Future longitudinal studies with larger cohorts and higher exposure levels are needed to better explain the chronic effects of smoking on respiratory muscle and exercise performance.

Author Contributions

EYK: Literature Search, Study Design, Data Collection, Statistical Analysis, Manuscript Preparation, Reviewing; ZÇ: Study Design, Data Collection, Statistical Analysis, Data Interpretation, Manuscript Preparation, Reviewing.

Conflicts of interest

The authors declare no conflict of interest.

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