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Relationship between Body Mass Index, Dynamic Balance, and Core Muscle Endurance in Firefighter Candidates: A Cross-Sectional Study

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Abstract

In physically demanding professions such as firefighting, understanding the impact of Body Mass Index (BMI) on physical performance metrics is crucial for both occupational safety and effectiveness. This study aimed to examine the effects of BMI on dynamic balance and core muscle endurance in firefighter candidates. The study was conducted with 89 firefighter candidates, with a gender distribution of 23.6% female (n=21, age 19.86±1.86 years, height 1.64±0.05 m, weight 59.47±7.26 kg) and 76.4% male (n=68, age 19.82±1.25 years, height 1.78±0.04 m, weight 74.36±12.09 kg). Within the scope of the research, the results of the BMI, balance, and core muscle endurance tests were evaluated. BMI was calculated based on measurements of participant height and weight. Dynamic balance performance was assessed using the Y-Balance Test, while core muscle endurance was measured using the plank test. The performances of the participants in both tests were recorded and subjected to statistical analysis. Pearson correlation analysis and multiple regression models were used to examine the relationships among BMI, dynamic balance, and core muscle endurance. The findings indicated that an increase in BMI has adverse effects on balance and core muscle endurance performance. Specifically, firefighter candidates with higher BMI values exhibited shorter plank durations (females: r=-0.63; p=0.002, males: r=-0.566; p<0.001) and lower scores on balance tests (females: r=-0.508; p=0.019, males: r=-0.435; p<0.001). These observations underscore the necessity of effectively managing BMI to maximize the health and occupational performance of firefighter candidates. The findings of this study that training programs for firefighter candidates should include BMI management, balance training, and core strengthening exercises. In conclusion, this study makes significant contributions toward improving firefighting training and safety standards by presenting methods with the potential to enhance the physical fitness and professional preparedness of firefighter candidates. This study highlights the importance of BMI in the field of firefighting and serves as a valuable resource for developing occupational health and safety practices.

Keywords: Firefighter candidates, Body mass index (BMI), Dynamic balance, Core muscle endurance.

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İtfaiyeci Adaylarında VKİ, Dinamik Denge ve Çekirdek Kas Dayanıklılığı İlişkisi: Kesitsel Çalışma

Özet

İtfaiyecilik gibi fiziksel olarak talepkar bir meslek grubunda, VKİ'nin fiziksel performans ölçütleri üzerindeki etkilerinin anlaşılması hem mesleki güvenlik hem de etkinlik açısından kritik öneme sahiptir. Bu kapsamda bu araştırmada, itfaiyeci adaylarında Vücut Kitle İndeksi (VKİ)'nin dinamik denge ve çekirdek kas dayanıklılığı üzerindeki etkilerini incelemeyi amaçlamaktadır. Çalışma, 89 itfaiyeci adayı üzerinde gerçekleştirilmiş olup, katılımcılar %23,6'sı kadın (n:21, yaşları 19,86±1,86 yıl, boy uzunlukları 1,64±0,05 m ve ağırlıkları 59,47±7,26 kg) %76,4'ü erkek (n:68, yaşları 19,82±1,25 yıl, boy uzunlukları 1,78±0,04 m ve ağırlıkları 74,36±12,09 kg) olarak cinsiyete göre dağılım göstermiştir. Araştırmanın kapsamında, katılımcıların VKİ, denge ve çekirdek kas dayanıklılığı ölçüm testlerine ait sonuçlar değerlendirilmiştir. VKİ, katılımcıların boy ve ağırlıklarına bağlı ölçümlere dayalı olarak hesaplanmıştır. Dinamik denge performansını değerlendirmek için Y-Denge Testi uygulanmıştır. Çekirdek kas dayanıklılığı ise plank testi ile ölçülmüştür. Her iki testte de katılımcıların performansları kaydedilmiş ve bu veriler istatistiksel analizlere tabi tutulmuştur. Verilerin analizinde Pearson korelasyon analizi ve çoklu regresyon modelleri kullanılarak VKİ ile dinamik denge ve çekirdek kas dayanıklılığı arasındaki ilişkiler incelenmiştir. Bulgular, VKİ artışının, özellikle denge ve çekirdek kas dayanıklılığı performansları üzerinde olumsuz etkilere sahip olduğunu göstermiştir. Özellikle, yüksek VKİ değerlerine sahip itfaiyeci adaylarında, plank süresinde kısalma (kadınlar: $r=-0,63$; $p=0,002$, erkekler: $r=-0,566$; $p<0,001$) ve denge testlerinde daha düşük skorlar (kadınlar: $r=-0,508$; $p=0,019$, erkekler: $r=-0,435$; $p<0,001$) gözlemlenmiştir. Bu gözlemler, itfaiyeci adaylarının sağlığını ve mesleki performansını maksimize etmek için VKİ'nin etkin bir şekilde yönetilmesi gerektiğinin altını çizmektedir. Çalışmanın bulguları, itfaiyeci adaylarının eğitim programlarına VKİ yönetimi, denge antrenmanları ve çekirdek bölgesi güçlendirme egzersizlerinin dahil edilmesi gerektiğini öne sürmektedir. Sonuç olarak, bu çalışma, itfaiyeci adaylarının fiziksel uygunluk ve mesleki hazırlıklarını artırma potansiyeline sahip yöntemler sunarak, itfaiyecilik eğitim ve güvenlik standartlarını iyileştirme yönünde önemli bir katkı sağlamaktadır. Araştırmamız, itfaiyecilik alanında VKİ'nin önemini vurgulayarak, mesleki sağlık ve güvenlik pratiklerinin geliştirilmesi için değerli bir kaynak sunmaktadır.

Anahtar kelimeler: İtfaiyeci adayları, Vücut kitle indeksi (VKİ), Dinamik denge, Çekirdek kas dayanıklılığı.

Introduction

Firefighting is a demanding and hazardous profession that provides critical services, such as fire suppression, rescue, and emergency medical assistance. This occupation entails significant physical and psychological challenges (Lusa et al., 1993; Smith et al., 1996; Von Heimburg et al., 2006; Vujanovic et al., 2021; International Association of Fire Fighters [IAFF], 2008; Demiralp & Demiralp, 2020). In the United States, firefighters sustained approximately 65,000 injuries during duty in 2020 (Campbell & Evarts, 2021; Cornell et al., 2024). A substantial portion of these injuries are musculoskeletal and represent a leading cause of early retirement (IAFF, 2008; Poplin et al., 2012; Demiralp & Demiralp, 2019).

Fire suppression activities are inherently hazardous (Kurlick, 2012). A significant portion (21%) of injuries occurring in fire scenes is associated with falls, slips, and trips (Campbell & Evarts, 2021), indicating that balance ability contributes to injury risk among firefighters (Punakallio et al., 2005). Therefore, implementing balance training interventions may effectively reduce the rates of injury. The National Fire Protection Association (NFPA) emphasizes the importance of balance and dynamic postural control during essential firefighting tasks, such as climbing stairs, descending ladders, and walking on uneven surfaces (NFPA, 2018). Firefighters experience injury rates seven times higher than the general population (Leffer & Grizzell, 2010), which increases the risk of musculoskeletal injuries by 3.8 times (Seabury & McLaren, 2012). These data underscore the importance of safeguarding the occupational health of firefighters.

In this context, enhancing the health and safety of firefighter candidates is of paramount importance due to the physically and psychologically demanding nature of the profession. Firefighter candidates often face significant risks of job-related injuries, which can impact their overall health status and professional lifespan. Current training and preparation programs may not fully address the critical aspects of body composition, dynamic balance, and core muscle endurance that are essential for optimal performance and injury prevention.

Therefore, the primary aim of this research is to evaluate new approaches that can enhance these key areas among firefighter candidates. Specifically, we examined the relationships among body mass index (BMI), dynamic balance, and core muscle endurance to explore how current training and preparation programs can be optimized. A secondary aim of this study is to improve the effectiveness of existing strategies developed for the firefighting profession and to strengthen firefighters' resilience against job-related injuries. These new approaches have the potential to enhance the capacity of firefighter candidates to cope with the physical and psychological demands of this challenging profession, positively impacting their overall health status and extending their

professional lifespan. Consequently, comprehensively designed firefighter training and preparation programs are crucial for reducing individual injury risks and optimizing team responses.

The demanding tasks of firefighting require examination of the correlation between balance and injury. Various studies have explored this relationship, providing insights into the training, balance, and prevention of musculoskeletal injuries. Schmit and DeBeliso (2019) emphasized a strong relationship between firefighters' physical fitness tests and simulated firefighting tasks, highlighting the need for training programs to be structured in a more balanced and comprehensive manner. Balance training is a significant component of injury prevention strategies for firefighters (Sahebozamani & Akoochakian, 2023).

Research indicates that the use of personal protective equipment negatively impacts the dynamic balance performance of firefighters (Brown, 2019; Games, 2019; Games, 2020). This decline in performance becomes particularly evident following physical exertion (Games, 2020). Additionally, the relationship between balance, body composition, lower body strength, and movement quality has been highlighted (Marciniak et al., 2021). These findings underscore the need for proactive injury reduction strategies and balance training programs for firefighters. Çelik and Örer (2023) examined the relationship between core muscle endurance and dynamic balance performance, emphasizing that core muscle endurance is critical for firefighters to perform their duties more effectively and safely.

Obesity impacts over one-third of firefighters (Poston et al., 2011; Soteriades et al., 2008) and correlates with heightened susceptibility to lower back pain (Shiri et al., 2010). Obesity has been associated with diminished performance in physical fitness assessments, including back muscle endurance, and has been identified as a predictor of back pain incidence (Dedering et al., 1999; Mbada et al., 2010; Demoulin et al., 2006). Munir (2012) reported that 65% of firefighters in the United Kingdom are overweight or obese, and this trend is increasing. Goheer (2014) emphasized the necessity of nutrition and exercise interventions to combat obesity. Kales (2007) noted that obese firefighters with cardiovascular diseases have limited exercise capacities and a high risk of cardiovascular events. Hong (2012) examined the relationship between abdominal obesity, workload, job stress, and psychosocial issues and found that abdominal obesity is associated with high job stress and workload.

Limited research has investigated the associations among BMI, dynamic balance, and core muscle endurance in firefighter recruits. These studies highlight the importance of maintaining balance and core muscle endurance for firefighter health and safety, but significant gaps remain in this field. Specifically, the impact of BMI on the balance and core muscle endurance of firefighter

candidates is not fully understood. Understanding this relationship is crucial for optimizing firefighter training programs and ensuring better preparedness for occupational hazards. This gap directs the focus of our study to a detailed examination of the potential effects of BMI on dynamic balance and musculoskeletal health in firefighter candidates.

The primary aim of this study was to investigate the direct effects of Body Mass Index (BMI) on dynamic balance and core muscle strength in firefighter candidates. The hypothesis of this research posits that increasing BMI will lead to decreased dynamic balance and core muscle strength in firefighter candidates and that normal-weight candidates will exhibit better dynamic balance and core muscle strength than obese candidates. This study represents an important step toward enhancing health and safety standards within the firefighting profession and potentially paving the way for new directions in occupational health research. Thus, the results of this study can significantly contribute to the development of evidence-based strategies aimed at optimizing the physical performance of firefighter candidates while reducing the risk of injuries.

Materials and Methods

This study was conducted in strict adherence to the YÖK Scientific Research and Publication Ethics Directive (2012), ensuring that all research procedures and ethical considerations were meticulously followed throughout the study.

Research Design

This study is designed using a descriptive research model, which involves systematically describing the characteristics and behaviors of the subjects without influencing them in any way. Observational research gathers information about participants in their natural environments (Godwin & Chambers, 2009). The descriptive research model focuses on detailed descriptions of measurements such as BMI, dynamic balance, and core muscle strength among participants (Salaria, 2012). An open, uncontrolled research design involves collecting and analyzing data without intervention or manipulation (Ellis & Bochner, 2000). This approach enables the scientific and statistical evaluation of the effects of BMI on dynamic balance and core muscle strength in firefighter candidates.

Population and Sample/Study Group

The study group consists of students enrolled in the Civil Defense and Firefighting program at the Suluova Vocational School in Amasya. During the academic year 2023-2024, a total of 89 healthy students (68 males, 21 females) aged between 18 and 25 years participated in the study after consenting to participate. Participants were selected using a random sampling method and

volunteered to join the research. The exclusion criteria included participants outside the 18-25 age range, those with musculoskeletal, neurological, or orthopedic disorders within the last 3 months before assessment, or those with other medical conditions. Participants were also instructed not to engage in high-intensity activities within 24 hours before assessment and to abstain from alcohol, coffee, caffeinated beverages, and herbal teas the night before participation.

Data Collection Instruments

Demographic information was collected using a form that allowed the participants to provide their gender and other relevant demographic details. Additionally, participants' height was measured using a height scale, and their body weights were measured using a precision scale that was accurate to 0.1 kg. Dynamic balance measurements were then conducted using the Y Balance Test (YBT). The test involved participants reaching distances in three different directions to assess their dynamic balance. Extremity length measurements were also performed during this phase. Core muscle endurance was evaluated using the plank test. During the test, the participants demonstrated their core muscle endurance by maintaining a prone position for as long as possible.

Body Mass Index: The BMI is a measure that estimates body fat based on height and weight. The value was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). BMI values were categorized into specific classifications to assess the participants' conditions. This classification, recommended by the World Health Organization (WHO), defines BMI as follows: $\leq$18.5 kg/m^2 underweight, 18.6-24.9 kg/m^2 normal weight, 25.0-29.9 kg/m^2 overweight, and $\geq$30.0 kg/m^2 obese (WHO, 1995).

Dynamic Balance Measurements: The Y Balance Test (YDT) was applied separately to the right and left legs using three reach lines placed on the floor in the center of a strip meter. To prevent shoe stability, all trials were conducted with the participants barefoot. Participants were instructed to place their hands on their hips and reach forward (Anterior), to the back and side (Posterolateral), and to the back and middle (Posteromedial), while maintaining balance with the opposite foot touching the ground. After reaching the farthest point, the participant returned to the center point, and the maximum reach distance was recorded to the nearest 0.5 mm. After recording the scores, the same test was repeated with the left foot on the ground. Participants were deemed unsuccessful if they removed their hands from their hips, touched the floor, contacted the measuring stick, lifted the heel of the stance leg, or slid the slider for extra distance. Measurements were performed three times after the warm-up trials, and the highest value was recorded. Extremity length was measured from the medial malleolus to the anterior superior iliac spine (Plisky et al., 2009). Subsequently, scores were normalized using the formula (Highest Reach Distance / Leg

Length) x 100 = % Normalized Reach Distance (NRD), as described by Coughlan et al. (2012) and Robinson et al. (2008). This test demonstrated excellent test-retest reliability for the YDT in the anterior (average ICC = 0.88), posterior (average ICC = 0.90), and posteromedial (average ICC = 0.88) reach directions (Picot et al., 2021; Plisky et al., 2009). NRD values were calculated for both legs, and data were recorded by summing and dividing by two to create a balance score. Additionally, injury risk scores were calculated by subtracting the NRD values of the right and left legs.

Core Muscle Endurance: Participants were instructed to assume a prone plank position, maintaining contact with the mat only through their elbows and toes, with their bodies elevated off the ground. The test commenced as soon as the participant lifted their body, at which point the test administrator started the timer using a stopwatch. Participants received verbal encouragement to hold the position for as long as possible, but no feedback regarding the elapsed time was provided. If the participant could not maintain the position, they were given up to two verbal prompts to correct their posture. If the position could not be maintained despite the prompts, the test was terminated, and the duration for which the participant successfully held the position was recorded in seconds. The plank test, which evaluates lumbar spine stabilization, is a validated and reliable measure of isometric core muscle endurance (Schellenberg et al., 2007).

Data Analysis

All statistical analyses were conducted using IBM SPSS Statistics 23.0 (IBM Corp., Armonk, NY, USA). The normality of the data distribution was confirmed using the Kolmogorov-Smirnov test. Continuous variables are presented as mean ± standard deviation, whereas categorical variables are presented as frequencies and percentages. The independent sample t-test was used to assess categorical differences. The relationships between BMI and the results of the balance and plank tests were examined using Pearson correlation analysis. Additionally, linear regression analyses were performed to determine the predictive power of BMI on balance and plank test results. A significance level of $p < 0.05$ was used as the threshold for statistical significance in all tests.

Research Ethics

According to the evaluation report submitted by the Amasya University Non-Interventional Clinical Research Ethics Committee on May 29, 2024 (decision number 2024/62, the study was found to be ethically appropriate and approved. The ethical aspects of the research were meticulously addressed in full compliance with the principles outlined in the Helsinki Declaration (2013). Fundamental ethical principles such as obtaining participant consent, ensuring

confidentiality and protection of personal information, respecting participants' rights and welfare, and full compliance with the YÖK Scientific Research and Publication Ethics Guidelines (2012) were strictly adhered to. Potential risks were thoroughly explained to participants in advance, and their voluntary informed consent was obtained in writing. Furthermore, participants were informed about the significance of their voluntary participation in the study and their right to withdraw at any time without facing adverse consequences.

Results

A total of 89 firefighter candidates participated in the study, including 21 (23.6%) females and 68 (76.4%) males. The demographic characteristics and measurement results of the participants are presented in Tables 1 and 2.

Table 1 Comparison of Demographic and Physical Characteristics between Female and Male Participants

Variable	Gender	n	$\bar{x}$	SS	*t*	*p*
Age (years)	Female	21	19.86	1.38	0.104	0.91
	Male	68	19.82	1.25		
Height (m)	Female	21	1.64	0.05	-10.427	0.00**
	Male	68	1.78	0.04		
Weight (kg)	Female	21	59.47	7.26	-5.340	0.00**
	Male	68	74.36	12.09		
BMI (kg/m^2)	Female	21	21.92	2.37	-1.851	0.06
	Male	68	23.45	3.53		
Right Anterior (cm)	Female	21	59.38	3.26	-2.254	0.02*
	Male	68	62.36	5.77		
Right Posterolateral (cm)	Female	21	88.04	7.66	-3.830	0.00**
	Male	68	96.85	9.62		
Right Posteromedial (cm)	Female	21	86.28	9.02	4.788	0.00**
	Male	68	97.26	9.23		
Left Anterior (cm)	Female	21	57.23	4.61	-6.219	0.00**
	Male	68	64.52	4.72		
Left Posterolateral (cm)	Female	21	89.90	8.35	-3.546	0.00**
	Male	68	97.82	9.11		
Left Posteromedial (cm)	Female	21	88.95	8.23	-3.712	0.00**
	Male	68	96.7	8.4		
Lower limb length (cm)	Female	21	83.76	4.42	-4.175	0.00**
	Male	68	88.66	4.78		
Plank Duration (sec)	Female	21	102.38	14.99	2.218	0.02*
	Male	68	112.5	19.14		
Right Absolute	Female	21	77.9	5.74	-4.317	0.00**
	Male	68	85.49	7.38		
Right NRD	Female	21	93.14	7.07	-1.621	0.1
	Male	68	96.63	9.06		
Left Absolute	Female	21	78.69	6.62	4.678	0.00**
	Male	68	86.35	6.53		

Left NRD	Female	21	94.04	7.41	-1.698	0.09
	Male	68	97.64	8.81		
Balance Score	Female	21	93.58	6.98	-1.697	0.09**
	Male	68	97.14	8.76		
Injury Score	Female	21	-0.9	3.84	0.124	0.90
	Male	68	-1.01	3.51		

Note: Significant differences are denoted as **p < 0.01 and *p < 0.05.

Based on the findings presented in Table 1, an independent samples t-test was used to compare the demographic and physical characteristics of female and male participants. The average ages between the two genders were very close, with females averaging 19.86±1.38 years and males averaging 19.82±1.25 years, indicating no significant age difference between them (t=0.104, p=0.91). Male participants were found to be significantly taller with an average height of 1.78±0.04 m compared to females with an average of 1.64±0.05 m (t=-10.427, p<0.01**). The mean weight was 74.36±12.09 kg for males and 59.47±7.26 kg for females, showing a significant difference (t=-5.340, p<0.01**).

The average BMI of women was calculated as 21.92 ± 2.37 kg/m², and for men it was 23.45 ± 3.53 kg/m². Although not statistically significant at first glance (t = -1.851, p = 0.06), this finding suggests a trend toward differences between genders. Anterior, posterolateral, and posteromedial measurements: Men exhibited significantly higher values in these measurements compared to women. For instance, the mean for right posteromedial was 97.26 ± 9.23 cm in men and 86.28 ± 9.02 cm in women (t = 4.788, p < 0.01**). Lower limb length: This measurement was recorded as 88.66 ± 4.78 cm in male participants and 83.76 ± 4.42 cm in female participants, indicating a significant difference (t = -4.175, p < 0.01**). Plank Duration: Women maintained the plank position for an average of 102.38 ± 14.99 seconds, which was significantly shorter than men who averaged 112.5 ± 19.14 seconds (t = 2.218, p = 0.02*).

Table 2 *Distribution of Participants According to Sex and Obesity Status*

		Frequency	Percentage (%)
Gender	Female	21	23.6
	Male	68	76.4
	Total	89	100
Obesity	Underweight	3	3.4
	Normal	61	68.5
	Overweight	21	23.6
	Obese	4	4.5
	Total	89	100

Note: This table displays the frequency, percentage, and cumulative percentage of gender and obesity status for a total of 89 participants.

Upon examining Table 2, it is evident that the majority of the 89 participants are men (76.4% n=68), while women constitute 23.6% (n=21) of the total. Regarding obesity status, most participants (68.5% n=61), fall within the normal weight range, reflecting an overall healthy weight status. The proportion of overweight participants was 23.6% (n=21), whereas those classified as obese accounted for 4.5% (n=4) of the total. Additionally, the percentage of participants classified as underweight is quite low at 3.4% (n=3).

Table 3. *Correlations between Body Mass Index, Plank Duration, Balance Score, and Injury Scores*

Variables	**Pearson Correlation (Females n=21)**	**Pearson Correlation (Males n=68)**
BMI-Plank	-0.63** (p = 0.002)	-0.566** (p < 0.001)
BMI-Balance	-0.508* (p = 0.019)	-0.435** (p < 0.001)
BMI-Injury	0.096 (p = 0.678)	-0.194 (p = 0.112)
Plank-Balance	0.649** (p = 0.001)	0.476** (p < 0.001)
Plank- Injury	-0.050 (p = 0.830)	0.278 (p = 0.022)
Balance-Injury	-0.093 (p = 0.688)	0.072 (p = 0.559)

*p < 0.05 **p < 0.01

The results of the correlation analysis are presented in Table 3. In women, a strong negative correlation was found between BMI and plank duration ($r = -0.63$; $p = 0.002$, $p < 0.01$), indicating that an increase in BMI is associated with a decrease in plank duration. There was also a moderate negative correlation between BMI and balance score ($r = -0.508$, $p = 0.019$, $p < 0.05$), that females with higher BMI values exhibit poorer balance performance. Furthermore, a strong positive correlation was observed between plank duration and balance score in the female participants ($r = 0.649$, $p = 0.001$, $p < 0.01$), indicating that an increase in plank duration is associated with improved balance performance. Similarly, for males, a strong negative correlation was found between BMI and plank duration ($r = -0.566$, $p < 0.001$, $p < 0.01$), as well as a negative correlation between BMI and balance score ($r = -0.435$, $p < 0.001$, $p < 0.01$). A moderate positive correlation was found between plank duration and balance score ($r = 0.476$, $p < 0.001$, $p < 0.01$) in males; however, no statistically significant correlations were observed in other relationships ($p > 0.05$).

Table 4. Investigation of the Effect of Body Mass Index Differentiated by Gender on Plank Duration, Balance, and Injury Risk through Regression Analysis

	Variable	R^2	Coefficient b	*Standard Error SE*	95% confidence interval (CI)		*t*	*p*
					LL	*CL*		
Females	**Constant**		189.76	24.69	138.09	241.44	7.68	0.000
	Plank	0.40	-3.98	1.12	-6.32	-1.64	-3.55	0.002
	Constant		126.28	12.8	99.48	153.08	9.86	0.000
	Balance	0.25	-1.491	0.581	-2.707	-0.276	-2.568	0.019
	Constant		-4.309	8.137	-21.340	12.721	-0.530	0.603
	Injury	0.009	0.155	0.369	-0.617	0.928	0.421	0.678
Males	**Constant**		184.400	13.038	158.370	210.431	14.144	0.000
	Plank	0.32	-3.066	0.550	-4.163	-1.968	-5.576	0.000
	Constant		122.417	6.518	109.403	135.431	18.781	0.000
	Balance	0.18	-1.078	0.275	-1.626	-0.529	-3.921	0.000
	Constant		3.520	2.848	-2.166	9.206	1.236	0.221
	Injury	0.038	-0.193	0.120	-0.433	0.047	-1.609	0.112

Note: N(female) = 21, N(male) = 68; independent variable, BMI

According to the regression analysis results presented in Table 4, the impact of BMI on dependent variables varied according to sex. For women, BMI negatively affects plank performance ($\beta = -3.98$, $p = 0.002$) and balance performance ($\beta = -1.491$, $p = 0.019$), with decreases of 40% and 25%, respectively. However, BMI did not significantly affect the injury rate ($\beta = 0.155$, $p = 0.678$). In males, BMI negatively influences plank performance ($\beta = -3.066$, $p = 0.000$) and balance performance ($\beta = -1.078$, $p = 0.000$), with reductions of 32% and 18%, respectively, but shows no significant effect on injury rate ($\beta = -0.193$, $p = 0.112$). These findings that BMI is a significant determinant of plank and balance measures independent of sex, but it does not markedly impact injury risk.

Discussion and Conclusion, Recommendations

Our study provides a comprehensive analysis of the relationships among BMI, dynamic balance, and core muscle endurance among firefighter candidates. This analysis offers valuable insights and proposes significant recommendations for enhancing physical training programs for firefighter candidates. These findings underscore the importance of including critical factors, such as BMI, dynamic balance, and core muscle strength, in the development of these programs because they directly impact firefighters' ability to cope with the physical demands of their profession.

The primary aim of this study was to determine the relationship between BMI and dynamic balance as well as core muscle endurance in firefighter candidates. Our analysis, conducted on a total of 89 firefighter candidates, revealed substantial differences in physical characteristics between female (23.6%) and male (76.4%) participants. Although the average ages of the female and male participants are similar, significant disparities are observed in height, weight, BMI, and specific

physical measurements. These findings highlight gender as a significant variable, particularly in terms of physical performance. Accordingly, the design of gender-specific training programs should play a central role in fire departments' physical preparedness strategies.

The gender differences observed in our study may necessitate the customization of physical training programs to equally benefit both genders, potentially enhancing program effectiveness and reducing the risk of injury. We found that males exhibited significantly greater height and weight compared to females, whereas females demonstrated shorter plank test durations. Furthermore, the relationships between BMI and plank duration, balance score, and injury rates varied by sex, emphasizing that BMI is a crucial determinant of physical performance independent of sex and has no significant impact on injury risk. This underscores the importance of BMI as a critical indicator of health and safety programs for firefighter candidates.

The direct influence of BMI on health and performance should be a pivotal factor in determining individual health goals during firefighter candidates' training processes. These findings indicate that evaluations of firefighter candidates' physical preparedness and health programs should consider gender and BMI as fundamental factors.

Our study demonstrated significant differences in physical characteristics between female and male firefighter candidates, extending beyond basic metrics, such as height, weight, and Body Mass Index (BMI), to include plank duration, balance scores, and lower extremity measurements. The relationship between BMI and dynamic balance varies according to sex. Previous studies have supported the effects of BMI on physical performance and injury risk, and these findings are consistent with the outcomes of our study. Studies have indicated that higher BMI values are associated with decreased performance in balance tests (Mocanu & Murariu, 2022; Swarnalatha et al., 2018). Therefore, our findings reinforce existing trends in the literature, highlighting BMI as a significant factor that influences the physical abilities of firefighter candidates.

Mocanu and Murariu (2022) reported that individuals with higher BMI exhibited lower performance in dynamic balance tests compared to a control group with lower BMI, consistent with our results showing a negative impact of BMI on dynamic balance among firefighter candidates. This finding underscores the crucial health indicator of BMI. Swarnalatha et al. (2018) demonstrated that BMI is a determinant of overall physical performance. These findings support our findings regarding the effects of BMI on both plank duration and balance scores. Specifically, our study found that male candidates, despite having higher BMI values, exhibited longer plank test durations compared with females, BMI alone can be a complex indicator of performance.

Gender differences play a role in dynamic balance, and significant disparities between men and women have been observed (Silva et al., 2016). The findings of Silva et al. (2016) demonstrate that gender has a significant impact on dynamic balance, highlighting differences in balance performance between men and women. Our study parallels these findings; male firefighter candidates exhibited different dynamic balance scores, highlighting the need for physical training curricula that consider gender differences. However, when it comes to maintaining body balance, gender does not significantly affect the effectiveness of the sensory system in young and healthy individuals (Olchowik et al., 2015). Olchowik et al. (2015) found that gender did not influence body balance in young and healthy individuals.

Interestingly, our study found pronounced gender differences in the relationship between BMI and balance. The effects of BMI on dynamic balance may vary by gender, emphasizing the need for detailed consideration of these factors when training firefighter candidates. Additionally, a study focusing on young female students found that BMI levels affect balance performance, with underweight and normal-weight individuals generally outperforming those who are overweight in various balance tests (Mocanu & Onu, 2022). Therefore, BMI, gender, and balance performance appear to be interconnected factors that should be considered when assessing the physical performance of youth.

Understanding the relationship between dynamic balance and body mass index (BMI) enables the development of specialized training programs tailored to the demanding physical requirements of firefighters. These findings are consistent with our study findings on the effects of BMI and underscore that BMI is a significant variable for improving physical performance parameters regardless of gender. Finally, there is an increasing emphasis in the literature on the importance of designing gender-specific exercise programs to maximize the physical readiness of firefighter candidates. In this context, developing personalized and gender-specific strategies is crucial for optimizing firefighter candidates' physical preparedness. Pawlak et al. (2016) reported that customized training programs based on firefighters' gender-specific physical and physiological profiles could enhance workforce performance, supporting the practical application of our study findings.

Relationship Between BMI and Dynamic Balance

Dynamic balance refers to the ability to maintain an upright position while moving the body or shifting from one foot to another. It is crucial for daily activities and athletic performance. Findings from previous studies have shown a significant relationship between BMI and dynamic balance. It has been observed that increasing BMI negatively impacts dynamic balance by affecting

the ability to maintain stability during movement (Bhave et al., 2021; Arslan et al., 2017; El-Basatiny & El-Kafy, 2014; Roshan et al., 2021; Nascimento et al., 2017; Hussain, 2023).

High BMI is associated with instability and increased risk of falls, especially among elderly individuals. It is understood that increased weight can shift the body's center of mass, thereby challenging postural stability. A study by Hue et al. (2007) demonstrated negative effects on postural balance among participants with high and low BMI values. The relationship between balance and BMI among firefighters involves complex interactions influenced by various factors. Hue et al.'s (2007) reported that excessive body fat negatively affects dynamic balance in individuals awaiting bariatric surgery. This finding that weight gain can alter the body's center of mass, thereby potentially challenging postural stability. These findings are consistent with the findings of our study, particularly highlighting how high BMI adversely affects dynamic balance in firefighter candidates.

Research indicates that greater dynamic balance ability among firefighters is associated with lower body mass index, increased functional movement, and greater lower body strength (Marciniak et al., 2021). However, the impact of obesity on movement efficiency among firefighters is less significant than that in other populations, with no significant differences identified in movement efficiency measures across BMI categories (Cornell et al., 2016). Additionally, obese firefighters have been found to exhibit less postural sway, particularly when their postural control systems are compromised, suggesting a compensatory mechanism to reduce slip and fall risks (Davis et al., 2009). These findings underscore the importance of collectively considering BMI, movement efficiency, and postural balance when designing effective training programs to enhance overall performance and reduce injury risks among firefighters. Additionally, regular bicycle use has been shown to be an effective method for reducing BMI and improving overall physical balance (Elveren & Çelebi, 2024).

Research has utilized various assessment methods such as the Y Balance Test, Balance Error Scoring System, Star Excursion Balance Test, and Time Up and Go test to evaluate dynamic balance in relation to BMI (Cerón-Lorente et al., 2019). In this study, the Y Balance Test, which is a reliable and valid method for assessing dynamic balance, was employed. Studies have indicated that lean mass plays a smaller role in dynamic balance than fat mass, with higher fat mass predicting lower performance in dynamic balancing tests (El-Basatiny and El-Kafy, 2014). Furthermore, the relationship between dynamic balance and BMI has been investigated across different populations, including elderly adults, young obese individuals, and sedentary obese young adults, consistently showing detrimental effects of higher BMI on dynamic balance abilities (Widyaswari, 2024; Hussain, 2023; Nascimento et al., 2017). These findings underscore the

importance of considering BMI as a factor that affects dynamic balance performance in interventions intended to improve balance and reduce fall risks across diverse demographic groups. Our study demonstrated a significant effect of BMI on dynamic balance performance. Specifically, an increase in BMI was found to decrease dynamic balance performance, which is particularly noticeable in women. Similarly, among men, increasing BMI was associated with decreased dynamic balance performance. These results confirm the negative effects of BMI on postural balance and highlight its detrimental impact on dynamic balance performance.

Relationship between Body Mass Index and Core Muscle Endurance

BMI is a widely used measure for classifying weight status and is a parameter directly affecting athletic performance. For instance, a strong correlation has been found between BMI and running performance, highlighting BMI as a critical factor determining athletes' speed and overall performance (Sedeaud et al., 2014; Thuany et al., 2023). Various studies have explored the relationship between BMI and core muscle endurance. In a study involving young adults, a significant association was identified between BMI and core muscle endurance, although muscle strength and overall physical activity levels also played significant roles (Fallahasady et al., 2022). A study on firefighters revealed no significant correlation between BMI and plank duration; however, a higher BMI was observed to be associated with lower core muscle endurance in individuals experiencing back pain (Sanregret et al., 2023).

The impact of BMI on core muscle endurance is significant. The plank test is commonly used to assess core strength and endurance. Individuals with higher BMI values may need to exert more effort to support extra body weight, which theoretically could adversely affect plank duration. Research has highlighted the crucial role of core muscle endurance in stabilizing the torso and maintaining proper posture (Pathak et al., 2023). Studies have established plank test standards based on the lean body mass-fat mass ratio, indicating that individuals with lower lean body mass-fat mass ratios are more likely to have lower core muscle endurance, potentially affecting balance and spinal health (Laurson et al., 2022).

Furthermore, research among firefighters has shown a negative association between BMI, body fat percentage, and back and core muscle endurance, emphasizing the importance of considering obesity when designing exercise programs to prevent back pain (Mayer et al., 2012). These findings underscore the importance of maintaining a healthy BMI and adequate core strength endurance for maintaining overall musculoskeletal health. Implementing regular core strengthening exercises for firefighter candidates, alongside health programs focusing on BMI management, could help prevent occupational injuries.

Our findings are consistent with those of the existing literature, supporting the adverse effects of high BMI on plank duration. The observations that individuals with higher BMI expend more effort to support extra body weight, potentially compromising core muscle endurance, align with previous research highlighting the significance of BMI in musculoskeletal health. Therefore, enhancing core muscle endurance is crucial for preserving spinal health and improving overall musculoskeletal health, particularly for individuals with high BMI.

Limitations

This study has several limitations that should be considered when interpreting its findings. The primary limitation is the restricted demographic diversity of the participants in terms of gender, age, and experience in firefighting. The study includes firefighter candidates from specific geographic locations and training institutions, which may constrain the generalizability of the findings. Therefore, future studies involving a broader participant group from different geographic regions with varying levels of firefighting experience are needed to enhance the scope and impact of the findings.

Additionally, the measurements of BMI, balance, and core muscle endurance used in this study focused on a limited number of physical performance parameters, which may not fully encompass the entire spectrum of physical fitness profiles. Methodological limitations, such as the limited number of participants and data collection from a single center, could also restrict the generalizability of the results. Therefore, future studies that incorporate participants from diverse cultural and geographical backgrounds—thereby increasing demographic diversity—will provide an opportunity to test the generalizability of our findings.

The cross-sectional design of the study may also have hindered our ability to understand changes over time in BMI and physical performance criteria, as well as causal relationships. Finally, this study does not directly address specific types of injuries, such as the risk characteristics identified during firefighter candidates' performances.

Addressing these limitations through future research with a more diverse participant base, broader measurement of physical fitness parameters, longitudinal designs, and direct consideration of specific injury types will further advance our understanding of this field.

Recommendations for Future Research

Future studies should aim to broaden demographic factors by including a more diverse participant group from various fire academies and geographic locations. This approach enhances the

generalizability of research findings and provides more representative results. Longitudinal studies are crucial to understand how the relationship between BMI and physical performance criterion evolves and to elucidate potential causal relationships. In future research, additional physical performance measures such as cardiovascular endurance, maximum oxygen consumption (VO2max), and muscle strength should be examined to comprehensively assess the impact of BMI on overall physical fitness among firefighter candidates.

Furthermore, longitudinal studies examining the long-term effects of specific training programs on BMI, dynamic balance, and core muscle endurance are needed to provide in-depth insights into this area. Monitoring the effects of tailored interventions within firefighting training curricula on balance and core muscle endurance could yield valuable practical insights. These studies could inform the development of strategies for BMI management and enhance the physical performance and occupational safety of firefighter candidates.

These recommendations aim to enhance both the health and safety of firefighter candidates and improve physical standards within the firefighting profession. These findings serve as a foundation for exploring these areas in more depth in future research.

Conclusion

Our findings demonstrate that BMI has a significant impact on balance and core muscle endurance among firefighter candidates. Specifically, higher BMI values were associated with shorter plank durations and decreased balance scores, indicating that increased BMI negatively affects physical performance parameters. In contrast, normal-weight firefighter candidates exhibited better balance and core muscle endurance than their heavier counterparts, confirming that BMI is an important health and performance indicator for the physically demanding profession of firefighting.

These findings underscore the importance of designing firefighter candidate training and preparation programs with consideration of BMI. Moreover, the findings indicate that BMI management strategies can positively influence the occupational success and safety of firefighter candidates. In particular, integrating BMI management and core strengthening exercises into firefighter training programs can significantly enhance firefighters' physical readiness and job safety. This approach lays the groundwork for providing individualized training and health guidance to firefighter candidates, allowing each individual to perform at their best within their physical limits and abilities.

The insights provided by our study can guide efforts to enhance the physical health and professional competencies of firefighter candidates. By aiming to improve fitness standards in the

firefighting profession, this research makes a significant step toward enhancing health, safety, and performance outcomes.

Ethics Committee Approval

Ethics Committee: Non-Interventional Clinical Research Ethics Committee (Decision No. 2024/62)

Date of the ethics evaluation document: 29/05/2024

Number of the ethics evaluation documents: E-76988455-050.04-196321

Author Contributions Statement

This research was conducted by one researcher. All stages of the research (conceptualization, data collection, analysis and interpretation, writing, and finalization) agent independently by the researcher.

Conflict of Interest Statement

The author(s) declare(s) no conflicts of interest related to the research reported in this article.

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