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Research Article

The Effect of Physical Fitness on Occupational Performance in Civil Defense and Firefighting Program Students

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Abstract

This research investigated the association between firefighting students' physical fitness characteristics and the duration required to complete simulated occupational tasks. A total of 53 healthy male firefighting trainees voluntarily participated in the study (mean age: 19.81 ± 1.65 years; height: 1.78 ± 0.06 cm; body weight: 77.87 ± 12.09 kg). Fitness assessments included body mass index, handgrip strength, back–leg strength, and VO_2max evaluations. Occupational performance was evaluated through four simulation-based tasks: balance beam walking, forcible entry, hose pulling, and victim rescue. The distribution of the data was assessed for normality using the Shapiro–Wilk test. The relationship between variables was examined using Pearson correlation analysis.Results revealed a moderate, negative, and statistically significant correlation between VO_2max and task completion time ($r = -0.397$, $p = 0.003$). Students with higher aerobic capacity were able to complete tasks more quickly. No significant associations were observed between completion time and other fitness parameters. These findings emphasize that aerobic capacity plays a critical role in firefighting performance. Accordingly, the development of cardiorespiratory endurance should be a priority in training programs for firefighting students. Future research is needed to explore the contribution of muscle strength and other physiological factors to occupational performance in greater depth to establish reference standards.

Keywords: Aerobic Capacity, Cardiorespiratory Endurance, Firefighting, Occupational performance, Physical fitness

Sivil Savunma ve İtfaiyecilik Programı Öğrencilerinde Fiziksel Uygunluğun Mesleki Performansa Etkisi

Öz

Bu araştırma, itfaiyecilik öğrencilerinin fiziksel uygunluk özellikleri ile simüle edilmiş mesleki görevleri tamamlama süresi arasındaki ilişkiyi incelemiştir. Çalışmaya, yaş ortalaması 19,81 ± 1,65 yıl, boy ortalaması 1,78 ± 0,06 m ve vücut ağırlığı ortalaması 77,87 ± 12,09 kg olan toplam 53 sağlıklı erkek itfaiyecilik öğrencisi gönüllü olarak katılmıştır. Fiziksel uygunluk değerlendirmeleri; vücut kütle indeksi, el kavrama kuvveti, sırt–

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bacak kuvveti ve VO_2max ölçümlerini içermiştir. Mesleki performans, denge tahtası üzerinde yürüme, zorla giriş, hortum çekme ve kazazede kurtarma olmak üzere dört simülasyon temelli görev aracılığıyla değerlendirilmiştir. Verilerin dağılımı, normallik açısından Shapiro–Wilk testi ile değerlendirilmiştir. Değişkenler arasındaki ilişkiler, Pearson korelasyon analizi ile incelenmiştir. Sonuçlar, VO_2max ile görev tamamlama süresi arasında orta düzeyde, negatif ve istatistiksel olarak anlamlı bir ilişki olduğunu göstermiştir ($r = –0,397$; $p = 0,003$). Daha yüksek aerobik kapasiteye sahip öğrenciler görevleri daha kısa sürede tamamlamıştır. Görev tamamlama süresi ile diğer fiziksel uygunluk parametreleri arasında anlamlı bir ilişki gözlenmemiştir. Bu bulgular, aerobik kapasitenin itfaiyecilik performansında kritik bir rol oynadığını vurgulamaktadır. Buna göre, kardiyorespiratuvar dayanıklılığın geliştirilmesi, itfaiyecilik öğrencilerine yönelik eğitim programlarında öncelikli bir hedef olmalıdır. Gelecekteki araştırmaların, kas kuvveti ve diğer fizyolojik değişkenlerin mesleki performansa katkısını daha ayrıntılı biçimde incelemesi, referans standartlarının oluşturulmasına katkı sağlayacaktır.

Anahtar Kelimeler: Aerobik Kapasite, Kardiyorespiratuar Dayanıklılık, İtfaiyecilik, Mesleki Performans, Fiziksel Uygunluk

INTRODUCTION

Firefighters encounter physically demanding activities due to the inherent requirements of their profession. Search and rescue operations, fire suppression, traffic accident responses, and similar emergency interventions are all performed while wearing heavy personal protective equipment. Consequently, firefighting represents an occupation that demands exceptional physical strength and endurance. For firefighters to perform their occupational duties safely and effectively, maintaining a relatively high level of cardiorespiratory fitness is imperative. Understanding the contribution of fitness characteristics to firefighting performance will facilitate the appropriate preparation of firefighters to meet job requirements. From this perspective, firefighting can be likened to very high-intensity physical activity. Numerous studies have demonstrated that physical fitness is associated with job performance, including the performance of actual work tasks and simulated firefighting duties (Gledhill & Jamnik, 1992).

Firefighters are not solely engaged in fire suppression but are also personnel assigned to respond to emergencies such as search and rescue operations, disaster response, and first aid services. Extensive research confirms that firefighting is a physically demanding occupation (Fahy et al., 2012). The uncertainty inherent in firefighting, coupled with the constant sense of time pressure, exposure to extreme heat, dense smoke, toxic gases, excessive workload, and the burden of personal protective equipment—including self-contained breathing apparatus weighing roughly 22.68 kg—induces severe physiological stress responses in firefighters (Kales et al., 2007). According to the most recent U.S. data, sudden cardiac arrest accounted for 51% of firefighter fatalities in 2015 (Smith et al., 2019). Performing duties under such conditions, which involve carrying heavy loads while wearing protective gear, coping with heat stress, and maintaining near-maximal heart rates for prolonged periods, places a considerable strain on the cardiovascular system (Kales et al., 2007; Soteriades et al., 2011).

Health-related physical fitness is commonly characterized by five principal elements: aerobic capacity, body composition, muscular endurance, muscular strength, and flexibility. Of these, cardiorespiratory fitness is consistently identified as a critical factor for firefighters, as it directly relates to their ability to perform tasks under cardiovascular stress and to minimize risk of adverse events (Baur et al., 2011). Cardiorespiratory endurance, frequently termed "aerobic capacity," refers to the ability to maintain extended dynamic activity involving large muscle groups at moderate to high intensity (Mang et al., 2024).

Health-related physical fitness is commonly characterized by five principal components: aerobic capacity, body composition, muscular endurance, muscular strength, and flexibility. While cardiorespiratory fitness is frequently highlighted as a critical determinant of firefighters' ability to perform strenuous tasks under cardiovascular strain (Ras et al., 2023),

recent evidence indicates that occupational performance in firefighting relies on a broader set of physical attributes. In addition to aerobic capacity, muscular strength, power, anaerobic endurance, and agility have been identified as key predictors of job-related performance. For example, grip and back–leg strength are essential for lifting equipment, dragging hoses, and rescuing victims, whereas agility and lower-body power enable firefighters to maneuver efficiently through complex environments or climb stairs while carrying heavy loads (Skinner et al., 2021; Lockie et al., 2024). Muscular endurance also supports sustained physical effort during prolonged operations, and flexibility contributes to mobility and reduces injury risk during dynamic movements. Collectively, these findings underscore the need for a multidimensional approach to firefighter fitness assessment and training, incorporating a comprehensive range of physiological capabilities beyond cardiorespiratory endurance alone.

The National Fire Protection Association (NFPA) has recommended a minimum threshold of approximately 42 ml/kg/min VO_2max for firefighters to execute their occupational duties both effectively and safely Evidence from prior research consistently demonstrates a positive linear association between aerobic capacity and job-related performance in this profession (Phillips et al., 2017). Furthermore, it has been shown that specific physiological factors underlying occupational task performance can be systematically evaluated, and a strong relationship has been reported between overall fitness levels and optimal performance outcomes in firefighting tasks (Rhea et al., 2004; Williams-Bell et al., 2009).

When cardiorespiratory fitness is measured through tests in firefighters, it has been reported that the most challenging firefighting operations average 41.5 ml/kg/min VO_2max (Gledhill & Jamnik, 1992), and that firefighters require cardiorespiratory conditioning of >45 ml/kg/min to safely and successfully complete their duties (Kales et al., 2007). However, it is recommended that firefighters should have a minimum VO_2max level of 38-39 ml/kg/min (Williams-Bell et al., 2009). In a study evaluating physical fitness among firefighters in our country, the average VO_2max level was found to be 41.51 ml/kg/min, while among firefighting students with an average age of 19.6 years, the VO_2max value was found to be 49.1 ml/kg/min following 8 weeks of exercise and training (Arslanoğlu, 2010; Demiralp, 2020).

Measuring the actual physiological demands of firefighters during real firefighting situations is difficult and highly complex. Therefore, several studies, including those by Michaelides et al. (2011) and Nazari et al. (2018), have examined physiological responses during simulated occupational activities such as hose dragging and stair climbing with a high-rise pack.

Recent research highlights that firefighting performance is influenced not solely by aerobic capacity but by a combination of multiple physical fitness components, including muscular strength, anaerobic endurance, and agility. Lin et al. (2025) demonstrated that field-based tests such as handgrip strength, back–leg strength, and the 20-meter shuttle run significantly predict completion times in simulated firefighting tasks. Similarly, Chizewski et al. (2021) reported statistically significant associations between fitness parameters particularly muscular strength, aerobic endurance, and agility and job-specific task performance among firefighters. These findings underscore the necessity of adopting a multidimensional physical fitness assessment framework in firefighter training, evaluation, and selection processes.

In line with the hypothesis that there is a significant relationship between physical fitness levels and occupational performance among firefighting students, this study aimed to examine the association between specific physical fitness parameters and the completion times of simulated occupational tasks. This research provides valuable insights into the physical demands of firefighting education and contributes to the scientific understanding of how distinct fitness components influence task performance in firefighting contexts.

METHOD

Research Population and Sample

A total of 53 male students (mean age: 19.81 ± 1.65 years) voluntarily participated in this study. To determine the sample size, a G*Power power analysis test was conducted. The analysis resulted in a total sample size of 34, with a 95% confidence level (α-1), 95% power (β-1), and an effect size of d = 0.5. therefore, conducting the study with 53 participants reinforced the population and sample paradox.

All participants were enrolled in a vocational firefighting training program and had no known musculoskeletal, cardiovascular, or metabolic conditions. None of the participants had a history of involvement in competitive or organized sports. Participant height was assessed using a stadiometer (SECA; Seca Instruments Ltd., Hamburg, Germany) with a precision of ±0.1 mm. During the measurements, participants stood in an anatomical upright position with their heels touching and body weight equally distributed on both feet. Body mass was measured using a digital scale (Tanita BC-545, Tanita Corp., Tokyo, Japan) accurate to ±0.05 kg, while participants were barefoot and dressed in light sportswear (shorts and a t-shirt). Body mass index (BMI) was then determined using the conventional formula: weight in kilograms divided by the square of height in meters (WHO, 2000).

Strength Measurements

For the assessment of muscular strength, both handgrip strength and isometric back–leg strength were evaluated using dynamometers. Handgrip strength is commonly employed as a key marker of overall muscular strength, as it has been linked to functional capacities such as balance and muscle mass, making it a reliable indicator of general strength. Handgrip strength was assessed using a digital hand dynamometer (Takei TKK 5401, Japan) following standardized protocols outlined by the American College of Sports Medicine (ACSM, 2021). Participants were instructed to stand upright with their arms extended along the sides of the body, and to squeeze the dynamometer maximally for 3–5 seconds using the dominant hand. Two trials were conducted with a 30-second rest between attempts, and the highest value (kg) was used for analysis. For determining participants' isometric leg and back strength, a dynamometer (Takei TKK 5402, UK) adjusted to squat position was applied with maximum pulling for 20 seconds using chain length (Koroglu & Koc, 2016). In all applications, two trials were conducted and the best value was recorded in kilograms.

Ethical Approval

This study was approved by the Kastamonu University Social and Human Sciences Scientific Research and Publication Ethics Committee (Meeting No. 6, Decision No. 72, Date: May 21, 2025). Data collection was carried out between May 28 and June 25, 2026. Written informed consent was obtained from all participants, and all procedures were conducted in accordance with the principles of the Declaration of Helsinki.

20-Meter Shuttle Run Test and VO_2Max Calculation

The primary purpose of the 20-meter shuttle run test is to evaluate the participant's aerobic power capacity. The test area was marked with colored adhesive strips to create a 20-meter distance, and cones were used to enhance the visibility of turning lines. Prior to the test, participants completed a standardized 10-minute warm-up protocol consisting of light aerobic exercises and dynamic stretching movements to prepare the body for exertion and reduce the risk of injury. Before the test began, participants were provided with detailed information about the application and shown practical demonstrations to ensure proper test execution. Participants ran back and forth over the designated 20-meter distance, with their speed controlled by a program that emitted signal sounds at specific intervals. Participants began running with the first signal sound and attempted to reach the designated line before the next signal sound. Maximum oxygen consumption (VO_2max) values were calculated using tables developed by Ramsbottom et al. (1997) based on data obtained from the shuttle run test. All test applications were conducted under the supervision of a sports instructor specialized in sports sciences and carried out in

accordance with standard test procedures and scientific measurement criteria.

Occupational Performance Tests

In accordance with previous research by Arslanoğlu (2010), Michaelides et al. (2011), and Nazari et al. (2018), occupational performance tasks were selected based on relevant literature and current field practices in firefighter assessment. The finalized test battery included balance beam walking, forcible entry, hose pulling, and victim rescue simulation, all of which were performed sequentially while participants wore full firefighter personal protective equipment.

All physical fitness assessments (e.g., shuttle run, push-up, and other strength tests) were completed on the first day of testing and were administered by the researchers in an indoor gymnasium. Occupational performance tasks were given a 24-hour rest period to avoid the effects of acute fatigue and to ensure adequate recovery between sessions. This scheduling protocol was followed to ensure the validity and reliability of the performance outcomes. Task completion time was recorded as a single continuous measure for the entire sequence of occupational tasks, rather than for each task individually. Heart rate data, including maximum heart rate (HRmax), were continuously monitored during the simulations using a Voit 9803 heart rate monitor. All physiological and performance-related data were documented in real time and subsequently transferred to a digital database for analysis under standardized scientific protocols.

Balance Beam Walking

This protocol has previously been incorporated into national-level firefighter physical competency evaluations (Arslanoğlu, 2010) and remains in active use within municipal firefighter selection procedures in Turkey (İzmir Municipality, 2023), thereby affirming its operational validity and contextual relevance to firefighting performance standards.

This test was designed to simulate a firefighter's ability to walk on a narrow path while fully equipped during duties. The test aims to evaluate balance and coordination abilities under pressure. Participants walked continuously from the starting point to the finish point on a standard balance beam approximately five meters long and one meter high from the ground. In case of balance loss or falling, participants returned to the beginning of the test and repeated the walk. Participants were instructed to complete their movement as quickly and safely as possible.

Hose Carrying and Pulling

The applied task sequence is similar to protocols previously validated in firefighter performance studies, demonstrating acceptable levels of reliability and operational relevance Chizewski et al. 2021; Lin et al. 2025). In this task, participants carried two coiled hoses approximately 30 meters long to a designated distance and then performed the pulling operation by holding the hose from the connection end. The hose was pulled so that at least one foot of the participant crossed the line at the designated 30-meter distance and was placed on the ground in a controlled manner when the finish line was reached.

Sledgehammer Strike on Tire

This test was designed to simulate power-requiring rescue operations. Participants advanced a tire 10 meters by striking it with a sledgehammer. In this phase, upper body strength, coordination skills, and continuous power application capacity were evaluated.

Mannequin Carrying

The mannequin carrying test used in this study has been previously incorporated into firefighter candidate evaluations to assess job-specific strength, endurance, and rescue performance. Similar protocols have demonstrated acceptable validity and reliability for evaluating functional readiness in both Korean firefighter assessments and standardized physical ability tests such as the Biddle Test (Lockie et al., 2022).

This test was applied to simulate the safe evacuation of an injured or unconscious individual in fire and other emergency scenarios. Participants carried an 80-kilogram mannequin over a 10-meter distance. In this phase, physical strength, appropriate carrying techniques, and the ability to move quickly

and effectively in emergency situations were evaluated.

The occupational course designed to evaluate firefighting personnel's physical endurance, technical skills, and professional competencies includes various challenges. This course aims to simulate the physical and technical tasks that firefighters may encounter in emergency situations and measure their ability to cope with these tasks.

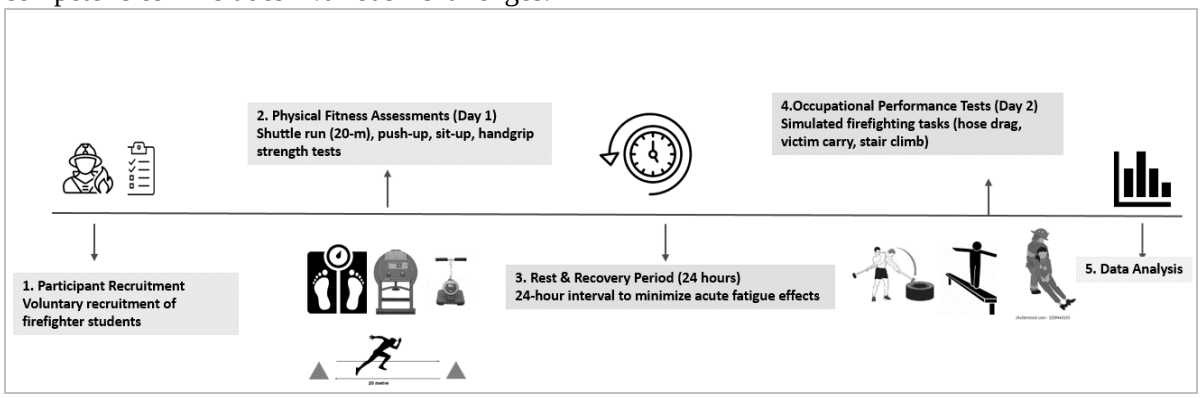

Figure 1. Schematic representation of the study design and procedural timeline

Statistical Analysis

Data analysis was carried out using IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive results were presented as mean (X) ± standard deviation (SD), with percentages and medians provided when appropriate. The distribution of the data was evaluated using the Shapiro–Wilk test, as well as visual assessments through histograms and Q–Q plots. As the findings confirmed normality, relationships between variables were investigated using Pearson's correlation test. Statistical significance was set at $p < 0.05$.

RESULTS

Table 1. Descriptive Statistics of Participants' Physical Fitness Parameters

Variable	***Mean ± SD***	***Min - Max***
Age (years)	19.81 ± 1.65	18 – 25
Height (m)	1.78 ± 0.06	1.54 – 1.95
Body weight (kg)	77.87 ± 12.09	60.9 – 123.6
Body mass index (kg/m²)	24.35 ± 3.41	19.44 – 33.52
Body fat percentage (%)	19.88 ± 5.54	12.5 – 29.9
Waist circumference (cm)	82.66 ± 8.65	70 – 107
Hip circumference (cm)	98.92 ± 6.58	84 – 119
Handgrip strength (kg)	45.26 ± 6.39	33 – 62
Leg strength (kg)	134.05 ± 41.03	68 – 285
Back strength (kg)	129.18 ± 27.50	59.5 – 189.5
VO_2max (ml/kg/min)	32.63 ± 6.07	22.2 – 50.3

Mean ± SD: Mean ± Standard Deviation

As shown in Table 1, participants' average height was determined as 1.78 ± 0.06 m, body weight as 77.87 ± 12.09 kg, and body mass index (BMI) as 24.35 ± 3.41 kg/m². According to BMI classification, 60.4% (n=32) of participants were in the normal category, 35.8% (n=19) were overweight, and 3.8% (n=2) were obese. Body fat percentage was determined as an average of 19.88 ± 5.54%, while waist circumference was

measured as 82.66 ± 8.65 cm and hip circumference as 98.92 ± 6.58 cm.

When muscle strength parameters were evaluated, hand-wrist strength was calculated as 45.26 ± 6.39 kg, back strength as 129.18 ± 27.5 kg, and back-leg strength as 134.05 ± 41.03 kg. The VO_2max value, indicating aerobic capacity, was measured as 32.63 ± 6.07 ml/kg/min in participants.

Table 2. Correlations Between Physical Fitness Parameters and Obstacle Course Completion Time

Variable	Weight	BMİ	Hand Grip Strength	Back Strength	Leg Strength	VO_2max	Course Time
Weight		0.827**	0.150	0.228	0.210	-0.230	0.126
BMİ			0.057	0.353**	0.303*	-0.290*	0.225
Hand Grip Strength				0.480**	0.470**	0.223	-0.212
Back Strength					0.830**	0.158	-0.127
Leg Strength						0.195	-0.242
VO_2max							-0.397**

Correlations significant at the $p < 0.05$ level are marked with *, and correlations significant at the $p < 0.01$ level are marked with **.

Table 2 shows that body mass index (BMI) is positively and significantly correlated with back strength ($r = 0.353$, $p < 0.01$) and leg strength ($r = 0.303$, $p < 0.05$). This finding suggests that individuals with higher BMI may generally possess greater muscular strength. Hand grip strength demonstrated positive and significant correlations with both back strength ($r = 0.480$, $p < 0.01$) and leg strength ($r = 0.470$, $p < 0.01$), indicating a direct association between upper extremity strength and overall body strength.

A very strong positive correlation was observed between back strength and leg strength ($r = 0.830$, $p < 0.01$), suggesting that these two strength components complement one another, and that individuals with higher back strength tend to also exhibit higher leg strength. Moreover, maximal oxygen consumption (VO_2max) was negatively and significantly correlated with BMI ($r = -0.290$, $p < 0.05$) and obstacle course completion time ($r = -0.397$, $p < 0.01$).

Table 3. Regression Analysis of Fitness Parameters Predicting Course Completion Time

Variables	B (Unstandardized Coefficient)	Standard Error	Beta (Standardized Coefficient)	t	p	95% Confidence Interval (Lower–Upper)
Constant	1.161	0.276	-	4.207	<0.001	0.606 – 1.716
VO_2max	-0.018	0.006	-0.397	-3.089	0.003	-0.029 – -0.006
BMİ	0.018	0.011	0.225	1.652	0.105	-0.004 – 0.039
Leg Strength	-0.003	0.002	-0.404	-1.641	0.107	-0.006 – 0.001
Back Strength	0.003	0.002	0.284	1.147	0.257	-0.002 – 0.008
Hand Grip Strength	-0.007	0.007	-0.158	-1.011	0.317	-0.020 – 0.007

Coefficients significant at the $p < 0.05$ level are indicated in bold.

Table 3 presents the results of the multiple regression analysis examining the relationships between firefighting candidates' occupational course completion time and their physiological and anthropometric variables. VO_2max demonstrated a statistically significant and negative effect on course time ($B = -0.018$, $p = 0.003$). This finding indicates

that each unit increase in VO_2max is associated with a reduction in course completion time, meaning that individuals with higher aerobic capacity are able to complete the course more quickly.

Body mass index (BMI) showed a positive coefficient (B = 0.018), but this relationship was not statistically significant (p = 0.105). This suggests that BMI is not a direct determinant of course performance. Similarly, leg strength exhibited a negative coefficient (B = -0.003), implying a tendency for shorter course times with greater lower-limb strength; however, this effect did not reach statistical significance (p = 0.107).

Back strength and handgrip strength also did not exert significant effects on course completion time (p > 0.05). Overall, VO_2max emerged as the strongest and most significant independent predictor in the model, underscoring aerobic capacity as a critical determinant of occupational performance in firefighting candidates.

DISCUSSION and CONCLUSIONS

This research sought to investigate the association between the physical fitness profiles of firefighting students and the duration required to complete simulated occupational tasks. The results highlight that physical fitness serves as a key determinant of job performance, with aerobic capacity (VO_2max) in particular showing a strong and consistent relationship with occupational task completion.

In the present study, VO_2max was determined as 32.63 ± 6.07 ml/kg/min. According to correlation analysis, a moderate negative and significant relationship (r = -0.397, p = 0.003) was found between VO_2max and course completion time. This finding reveals that students with higher aerobic capacity can complete occupational tasks in shorter durations. Regression analysis supports this finding, demonstrating that VO_2max maintains a significant effect on course completion time even when other physical fitness parameters are controlled (B = -0.018, p = 0.003).

Previous research has consistently shown that firefighting is an occupation requiring exceptional levels of physical fitness, with higher fitness capacities being closely linked to superior job performance in firefighters (Rhea et al., 2004; Williams-Bell et al., 2009). The nature of firefighting tasks places heavy physiological demands on the body, often requiring prolonged high-intensity exertion that may reach or even approximate maximal aerobic capacity during emergency situations.

Cardiorespiratory endurance, body composition, muscle strength, muscular endurance, and flexibility are crucial parameters for firefighters to perform their duties throughout their careers. Studies have shown that cardiorespiratory endurance is one of the most important factors for firefighters to safely perform their professional duties (Porto et al., 2024).

Examination of studies conducted in this field indicates that firefighters require cardiorespiratory conditioning of >45 ml/kg/min VO_2max to safely and successfully complete their duties (Gledhill & Jamnik, 1992; Kales et al., 2007). Furthermore, the recommended minimum VO_2max standard for firefighter candidates has been specified as 45 ml/kg/min, and published reports recommend that firefighters should have a minimum VO_2max level of 38-39 ml/kg/min (Williams-Bell et al., 2009). In a study evaluating physical fitness among firefighters in our country, the average VO_2max level was found to be 41.51 ml/kg/min, while among firefighting students with an average age of 19.6 years, the VO_2max value was found to be 49.1 ml/kg/min following eight weeks of exercise and training (Arslanoğlu, 2010; Demiralp, 2020).

When examining the findings of this study, VO_2max values are lower than literature values; however, when examining the relationship between VO_2max and course completion time, the findings demonstrate parallelism with literature findings. This discrepancy between measured values and established standards highlights the critical need for enhanced cardiovascular conditioning programs within firefighting education curricula.

The physiological mechanisms underlying this low VO_2max can be understood more deeply within the framework of the Fick equation (VO_2max = Cardiac Output × Arteriovenous Oxygen Difference). Maximal oxygen uptake is primarily limited by two main components: (1) Central Factors, which include the heart's capacity to pump blood (cardiac output, stroke volume) and the blood's oxygen-carrying capacity; and (2) Peripheral Factors, which relate to how effectively the working muscles can extract and utilize oxygen from the bloodstream (Bassett & Howley, 2000; Joyner & Dominelli, 2021; Wolsk et al., 2019). Low VO_2max values typically stem from inefficiency in one or both of these systems. For instance, an inadequate cardiac output results in insufficient delivery of oxygenated blood to the muscles during exercise, while poor peripheral adaptations (such as low mitochondrial or capillary density) prevent the effective utilization of the oxygen delivered by the blood (Hellsten & Nyberg, 2016).

A recent systematic review and meta-analysis demonstrated that absolute VO_2max (r = -0.75) has a stronger relationship with firefighting task performance compared to relative VO_2max (r = -0.64) (Martin et al., 2025). This finding is significant as it reflects the absolute physiological demands of firefighting tasks. Furthermore, the personal protective equipment (PPE) that firefighters are required to wear, which adds an extra load of approximately 17-25 kg, severely restricts the body's ability to dissipate heat, creating additional thermal stress on the cardiovascular system (Agostinelli et al., 2024). This condition leads to a decrease in stroke volume and a compensatory increase in heart rate, thereby reducing cardiac efficiency and further limiting VO_2max.

Previous research has emphasized that one of the most important physiological factors affecting firefighters' occupational performance is cardiorespiratory fitness. In a study conducted by Rhea et al. (2004), significant relationships were found between various physical fitness measures and occupational performance, including total physical fitness (r = -0.62), bench press strength (r = -0.66), handgrip strength (r = -0.71), and 400-meter sprint time (r = 0.79). Similarly, in a review conducted by Morris and Chander (2018), it was noted that firefighters work at levels approaching their maximal aerobic capacity during firefighting tasks, requiring high cardiorespiratory fitness. The sustained nature of firefighting operations, combined with the additional physiological stress imposed by personal protective equipment and environmental conditions, creates extraordinary demands on the cardiovascular system.

Although handgrip strength, back strength, leg strength, and body mass index did not demonstrate statistically significant associations with course completion time, a negative trend observed between leg strength and task duration suggests that greater lower-limb strength may still support occupational performance. Previous studies have highlighted the importance of muscular strength in tasks such as hose dragging, stair climbing, and victim rescue (Michaelides et al., 2011; Nazari et al., 2018). The absence of statistical significance in the current findings may stem from methodological factors, such as sample homogeneity or the limited specificity of isometric strength assessments.

Studies indicate that firefighters need high levels of aerobic and anaerobic capacity, as well as muscle strength and endurance (Phillips et al., 2017). Numerous studies in the literature emphasize the need for this occupational group to possess high physical performance capacity. These studies have reported that parameters such as maximal oxygen consumption (VO_2max), body composition, muscular strength, and muscular endurance are crucial for firefighters to perform their duties (Knappett & Haines, 2023; McAllister et al., 2022)

The lack of statistical significance of this relationship in our study can be explained in the context of energy systems and task characteristics. Firefighting duties involve a variety of actions that rely on different dominant energy systems. For example, explosive actions requiring high power, such as breaking down a door or momentarily lifting heavy equipment, depend heavily on anaerobic energy pathways (ATP-PC and

glycolytic systems) (Perroni et al., 2010). In contrast, more prolonged and rhythmic actions like stair climbing, carrying debris, or dragging a hose predominantly utilize the aerobic energy system. The simulated course in our study, when evaluated by its overall completion time, is inherently an endurance task and thus relies heavily on the aerobic energy system.

The isometric strength measurements we used (applying maximal force in a static position) may not fully reflect the dynamic, repetitive, and endurance-based muscle contractions required by the tasks. As noted in the literature, the relationship between isometric strength and dynamic task performance is not always linear, and the specificity of the task is of great importance (Johnson et al., 2022; Stone et al., 2022). Therefore, the fact that muscle strength did not emerge as a significant factor in this study does not imply that strength is unimportant, but rather may stem from a mismatch between the type of strength measured (isometric) and the overall characteristic of the course (endurance). Indeed, recent studies have shown that higher muscle strength and endurance enhance performance in specific occupational tasks (Ras et al., 2024).

Future research should incorporate dynamic, task-relevant strength measures and consider the biomechanical and physiological demands of firefighting activities to better elucidate the role of muscular strength in occupational settings. The complex nature of firefighting tasks requires a multifaceted approach to physical conditioning. While cardiovascular fitness emerges as the primary determinant, the integration of strength training, particularly for the lower extremities, should not be overlooked in comprehensive training program design.

Certain limitations must be considered when interpreting these results. The modest number of participants may have reduced the ability to identify statistically meaningful associations between strength measures and occupational task performance. Additionally, the simulated nature of the occupational tasks, while representative of firefighting activities, may not fully capture the complexity and unpredictability of real-world emergency scenarios.

Future research should consider longitudinal study designs to examine the effects of targeted training interventions on both physical fitness parameters and occupational performance outcomes. Multi-site studies incorporating larger, more diverse populations would enhance the generalizability of findings and provide more robust evidence for training program recommendations.

The findings of this study have direct implications for firefighting education and training program development. The establishment of minimum cardiovascular fitness standards, aligned with occupational performance requirements, should be considered a priority in firefighting education curricula. Regular fitness assessments and progressive training protocols can ensure that firefighting students achieve and maintain the physical readiness necessary for safe and effective job performance. Furthermore, the development of standardized occupational performance assessments, incorporating the tasks evaluated in this study, may provide valuable tools for evaluating training program effectiveness and individual readiness for firefighting duties.

In conclusion, this study has revealed that the aerobic capacity of firefighting students is a critical determinant in terms of occupational performance. It is considered that adding exercises aimed at increasing cardiorespiratory endurance to physical fitness programs during the education process will enable firefighters to work more effectively and safely in the field.

Additionally, multi-subject, multi-repetition studies are needed to examine the effects of lower extremity strength and general muscle strength on occupational performance in more detail. The integration of such scientific research into education programs is anticipated to serve as an important complementary element in meeting the physical fitness standards required by the firefighting profession.

The evidence presented supports the critical importance of cardiovascular fitness in firefighting performance and underscores the

need for evidence-based training program development. As the demands of firefighting continue to evolve, maintaining a scientific approach to physical fitness assessment and training will be essential for ensuring the safety and effectiveness of firefighting personnel.

Future research should continue to explore the complex relationships between various physical fitness components and occupational performance, with particular attention to the development of comprehensive training protocols that address the multifaceted demands of modern firefighting operations.

Author's Statement of Contribution to the Article

Idea/Concept: Nuray Demiralp, Hürmüz Koç; Article design: Nuray Demiralp, Büşra Umay, Hürmüz Koç; Consulting: Hürmüz Koç; Data Collection and Processing: Nuray Demiralp, Büşra Umay, Ahmet Gür; Analysis/Comment: Nuray Demiralp, Hürmüz Koç; Literature review: Nuray Demiralp, Kemal Demiralp, Ahmet Gür; Article writing: Nuray Demiralp, Hürmüz Koç; Analysis: Nuray Demiralp, Hürmüz Koç; Source/Material: Nuray Demiralp, Hürmüz Koç; Article Submission Corresponding Author: Nuray Demiralp

Conflict of Interest

The authors have no conflict of interest to declare.

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Ethics Committee Approval

This study is in line with the Declaration of Helsinki. This study was approved by the Kastamonu University Social and Human Sciences Scientific Research and Publication Ethics Committee (Meeting No. 6, Decision No. 72, Date: May 21, 2025).

Peer Review

After the blind review process, it was found suitable for publication and accepted.

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