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The Effect of Firefighting and Sports Education Course on Physical Performance Development in Civil Defense and Firefighting Students: A Longitudinal Study

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Abstract

This study aims to evaluate changes in physical performance, body composition, and cardiorespiratory endurance parameters of students in the Civil Defense and Firefighting Program following a two-year firefighting and sports education course. Participants' physical and performance measurements, including body weight, skeletal muscle mass, body fat percentage, body mass index (BMI), vertical jump, shuttle run, double-leg jump from the bench, single-handed wall ball throw, 30-meter sprint, and cardiorespiratory endurance (VO_{2max}), were analyzed. During the training process, a 2.55% decrease in body weight (from 78.45±9.63 kg to 76.45±5.45 kg), an 8.68% increase in skeletal muscle mass (from 37.84±2.51 kg to 41.13±3.12 kg), a 19.20% decrease in body fat ratio (from 20.63±2.18 to 16.67±1.87) and a 14.66% decrease in BMI (from 22.64±1.87 kg/m² to 19.32±1.91 kg/m²) were observed. In functional performance tests, significant improvements were recorded in vertical jump (6%), shuttle run (8%), double-footed bench jump (12%), one-handed wall ball throw (30%), and occupational coordination time (11%). A significant increase of 11.17% was observed in cardiorespiratory endurance, while a limited improvement (1%) was observed in 30-m sprint performance ($p = 0.003$). The two-year firefighting and sports training course significantly improved key performance indicators, including muscle mass, body fat percentage, and cardiorespiratory endurance among young firefighter candidates. However, the limited improvements observed in areas that require speed and explosive power suggest that these components should be emphasized more in training programs. This study underscores the importance of interdisciplinary and targeted training programs to optimize professional performance and enhance the physical competence of firefighter candidates.

Keywords: Distance running, Endurance training, Muscular endurance, Resistance training

INTRODUCTION

Firefighting is a complex and challenging profession that plays a crucial role in ensuring public safety. This field involves firefighting, accident and disaster response, search and rescue operations, and the initial response to chemical, biological, radiological, and nuclear (CBRN) threats (Tengilimoğlu & Barutçu, 2024; Marcell-Millet et al., 2023). Firefighters operate in hazardous emergency environments, facing dangers such as high temperatures, smoke, and toxic gases. They perform critical interventions while wearing heavy personal protective equipment (Heydari et al., 2022). Due to the demanding nature of their work, firefighters experience intense physical and psychological stress. During emergency responses, physical attributes such as endurance, strength, agility, and coordination are vital, along with quick decision-making and effective stress management skills (Leduc, 2020; Ras et al., 2023a). Physical fitness is closely linked to the effectiveness of firefighting and rescue operations; inadequate physical capacity increases the risk of injury and diminishes response quality (Jaron, 2023).

The literature highlights the need to regularly assess and enhance firefighters' physical fitness to improve their professional performance. Key parameters include cardiorespiratory endurance, muscle strength, anaerobic capacity, and motor coordination, all of which are critical for success in the profession (Rosner, 2024). Moreover, the personal protective equipment worn during firefighting can restrict mobility and elevate energy consumption, further underscoring the importance of physical fitness (Gledhill & Jamnik, 1992). Occupation-specific physical performance tests are essential for objectively evaluating whether firefighters possess the required skills and capacities for their roles (Stevenson et al., 2019). These tests encompass fundamental physical components such as strength, endurance, agility, and coordination, as well as simulations of tasks encountered in the profession (Sales et al., 2025). Such assessments facilitate monitoring and improving performance during training.

In Turkey, civil defense and firefighting associate degree programs offered at vocational schools include training in physical fitness, alongside theoretical knowledge and professional skills. Within these programs, monitoring changes in students' body composition and biomotor characteristics at the beginning and end of their training is vital for ensuring professional competence (Şipal et al., 2023).

Regularly administering performance tests is essential for enhancing the quality of vocational training and increasing firefighters' work efficiency (Fyock-Martin et al., 2020). International studies in firefighting indicate that developing occupation-specific physical training programs positively impact response times, reduce injury rates, and improve overall health (Michaelides et al., 2011; Barry, 2018). Furthermore, standardizing performance evaluations is critical for tracking individual development and establishing professional standards (Orr et al., 2021).

Therefore, the simultaneous development of physical fitness alongside professional knowledge and skills in firefighting is indispensable for enhancing occupational safety and response effectiveness. Creating scientifically based training and performance evaluations in this field in Turkey is crucial for improving the overall quality of the firefighting profession at the national level. This study aims to contribute to the scientific understanding of the firefighting profession and education in Turkey by examining the changes in body composition and occupation-specific physical performance parameters of students enrolled in associate degree firefighting programs during their training period.

METHODS

Research Model

The study group consisted of students enrolled in the Civil Defense and Firefighting program at Çankırı Karatekin University. A total of 15 male students enrolled in the program and taking the "Firefighting and Sports Education" course were included in the study. To assess changes in the students' physical fitness levels, measurements were conducted in two stages: at the beginning of the first semester of higher education, in the first week, and at the end of the education period, in the last week of the fourth semester. This approach allows for the objective assessment of physical and performance-based development during the educational process. Participation and exclusion criteria, determined in accordance with scientific ethical standards, were applied during participant inclusion in the study. The prerequisites for participation in the study were as follows: The individual participating in the study must be enrolled in the relevant education program and be an active student; must be in a healthy condition suitable for physical tests and exercise protocols. This eligibility was guaranteed by a comprehensive medical evaluation and approval by experienced healthcare personnel. Participants were required to fully sign the informed consent form after receiving detailed information about the study's purpose, the tests administered, and potential risks. They were required to regularly attend classes and fully participate in the practices throughout the study period. Exclusion criteria focused on factors that could directly affect physical performance: Presence of conditions that limit physical activity due to acute or chronic illnesses (e.g., cardiovascular diseases, respiratory problems, or orthopedic disorders); having had a musculoskeletal injury or surgery within the last six months; inability to complete exercise tests or performance measurements; and failure to regularly participate or maintain consistency in the required practices during the study period. A simple random sampling method was used for participant selection. In this method, students were listed in the order of their program registration and their eligibility was assessed according to established criteria before being included in the study group. During the voluntary participation process, all participants were provided with detailed information about the study's purpose, the tests to be administered, and the procedures to be followed. Participants' rights, confidentiality, and right to withdraw from the study at any time were clearly stated (Mujika et al., 2018). These practices were conducted within the scope of the research ethics committee approval and fully complied with scientific standards. This comprehensive participation procedure enhances the study's internal validity and the reliability of the findings, while also ensuring the protection of participants' safety and rights. It also ensures accurate, objective data on the physical fitness required for the firefighting profession.

Ethics Approval

Ethics committee approval for the study was received by the Bilecik Şeyh Edebali University Non-Interventional Clinical Research Ethics Committee on March 30, 2023 (Decision No: 3/3). Before participating in the study, all participants were provided with a detailed explanation of the study's purpose, methodology, tests to be performed, and potential risks, and they provided written informed consent. Participants' confidentiality, privacy, and voluntariness were meticulously protected. This research was conducted in accordance with the ethical principles outlined in the World Medical Association's Declaration of Helsinki, as updated in 2013.

Procedure

This longitudinal study was conducted with 15 male volunteers using a pretest-posttest design. The measurements and tests applied in this study were conducted at two critical time points: the first week of the first semester of higher education (pretest) and the last week of the fourth semester (posttest). The test administration process was based on the latest protocols and guidelines of the American College of Sports Medicine (ACSM), updated in 2021 (Ratamess, 2021). The measurements were administered by experienced researchers, experts in the field, under controlled conditions in laboratory and field environments, ensuring high internal validity and reproducibility. Taking into account participants' individual physiological characteristics and biological rhythm differences, the tests were scheduled between 8:00 am and 12:00 pm in the morning and 2:00 pm and 4:00 pm in the afternoon. This practice is important to minimize intraday variations in performance and physiological measurements and to maximize standardization of the measurements (Ayala et al., 2021; Drust et al., 2005). Environmental factors such as temperature, humidity, and lighting were maintained within standard ranges in the measurement environment, and participants' resting, nutritional, and hydration status were checked before the test. This increased the reliability of the measurement results and minimized the influence of external biological factors (Chtourou & Souissi, 2012). Furthermore, all testing procedures were conducted in accordance with the ethical and scientific standards recommended by the International Federation of Sports Sciences (ISSA) and the World Anti-Doping Agency (WADA; Ayala et al., 2021). Participants were provided with detailed information before the tests, and written informed consent was obtained

Data Collection Tools

Height: Participants' height was measured to an accuracy of 0.01 m using a Holtaine (UK) stadiometer, in accordance with international anthropometric standards. During the measurement, participants stood barefoot, with heels, hips, and heads aligned, in an upright position. Measurements were repeated twice and averaged. This method offers high accuracy and reliability in current anthropometric practices (Stein et al., 2023).

Body Weight, Body Mass Index, Body Fat, and Skeletal Muscle Mass: In occupations requiring high physical demand, such as firefighting, muscle mass and body fat percentage are critical for determining both performance capacity and injury risk (Looney et al., 2024). While body mass index (BMI) is a widely used metric for assessing obesity and general health risks at the population level, it alone provides limited information in determining occupational performance. Therefore, the use of detailed body composition analyses in addition to BMI allows for a more comprehensive assessment of both occupational competence and health status. Especially in occupations requiring high levels of endurance and strength, monitoring muscle mass and fat percentage independently of BMI is an important approach to improving operational efficiency (Storer et al., 2014). A Tanita BC418 bioelectrical impedance analyzer (Japan) was used in body composition analysis. Measurements were conducted before breakfast, on an empty stomach, without consuming liquids, and without wearing metal jewelry/accessories to minimize variations due to participants' metabolic status and hydration levels (Jagim et al., 2024).

Physical Performance Tests and Protocols

The physical performance tests used in the study were selected based on multidisciplinary and scientific principles, considering the nature of the firefighting profession, which requires high physical endurance, strength, agility, and coordination. The most up-to-date guidelines and meta-analysis results from international sports science literature were taken into account in the application of the tests to ensure objective and reliable performance assessment (Rybicki & Staron, 2025).

Vertical Jump Test

This test, considered the gold standard for determining lower extremity explosive strength, used the Fusion Sport Smart Speed (Australia) digital jump mat. Participants were asked to complete two attempts, and the highest performance was analyzed (Markovic & Mikulic, 2010). Explosive force is the primary indicator of rapid movement and sudden force production in professions requiring emergency response, such as firefighting (Ramirez-Campillo et al., 2023).

3 × 10 m Shuttle Run Test (Anaerobic and Agility-Based Protocol)

The 3 × 10 m shuttle run test is a valid and reliable field test used to assess anaerobic power, agility, and change of direction ability. It should be noted that this test is distinct from the commonly known 20 m shuttle run test, which is primarily designed to evaluate aerobic fitness (i.e., the multi-stage fitness test). The present protocol is a short-distance, time-based shuttle run test that reflects the dynamic and high-intensity physical demands of firefighting, including rapid changes of direction, movement in confined spaces, and repeated high-speed running. Participants started in a ready position behind the starting line between two parallel lines marked on the floor 10 m apart. Upon the researcher's command, participants ran to the opposite line, touched it with their hand, and returned to the starting line, ensuring that one foot crossed behind the line at each turn. This procedure was repeated three consecutive times (3 × 10 m; Savu &Pehoiu, 2018). Completion time was recorded using a Fusion Sport Smart Speed system (Australia), and the fastest time was used for analysis. To ensure reliability, the test was administered at least twice, and the best performance was retained for statistical analysis, consistent with previously established field-testing protocols. Field ‐ based shuttle running and other short distance shuttle tests have been widely utilized in sport and occupational fitness research to measure anaerobic performance and agility outcomes (e.g., shuttle or repeated shuttle runs; Ljach & Witkowski, 2010 ; Gumieniak et al., 2018). Additionally, related shuttle run protocols have demonstrated relevance to firefighter occupational performance assessments and anaerobic fitness modeling (Orr et al., 2021).

Bench Double-Foot Jump Test

The bench double-foot jump test is a valid performance measure for assessing lower extremity muscle strength and the activation capacity of fast-twitch muscle fibers (type II muscle fibers). This test reflects the explosive force capacity required by firefighters during fires, including sudden power generation, equipment handling, and rapid changes of direction (Suchomel et al., 2018). High force production in a short time is considered a critical predictor of occupational efficiency and safety, especially in operational environments. The participant stands in a ready position in front of a bench of standard height (approximately 40–50 cm). In the starting position, both feet are placed parallel to the bench. At the researcher's command, the participant jumped onto the bench with both feet and landed evenly. Then, they returned to the ground in a controlled manner. The test was administered in three repetitions, and the highest jump height was measured using an Optojump device (Microgate, Italy). Participants jumped using only their lower extremity muscle strength, without using their hands, and the highest jump height was recorded.

One-Handed Ball Throwing at the Wall Test

The One-Handed Ball Throwing at the Wall Test is used to assess upper extremity muscle strength, endurance, and hand-eye coordination. The test utilizes a flat wall, a 1-kg medicine ball, a stopwatch, and a foot line on the floor 2 m from the wall. Participants completed a 5–8-minute general warm-up protocol before the test, practicing the movement with 2–3 practice throws. During the test, the participant stands behind the line and holds the ball in the hand to be tested, at shoulder level, and with the elbow flexed approximately 90°. On the "Start" command, the stopwatch is started, and the participant throws the ball with the same hand to the target area on the wall for 30 seconds. Catching the ball with the same hand and continuing the throws are all mandatory. Violating the foot line, hitting the wall outside the target area, dropping the ball to the ground, or catching it with both hands are considered invalid repetitions. The number of valid repetitions the participant completes within the 30-second period is recorded as the test score. Two exercises are performed for each hand, and the highest score is considered (Knapik et al., 2004).

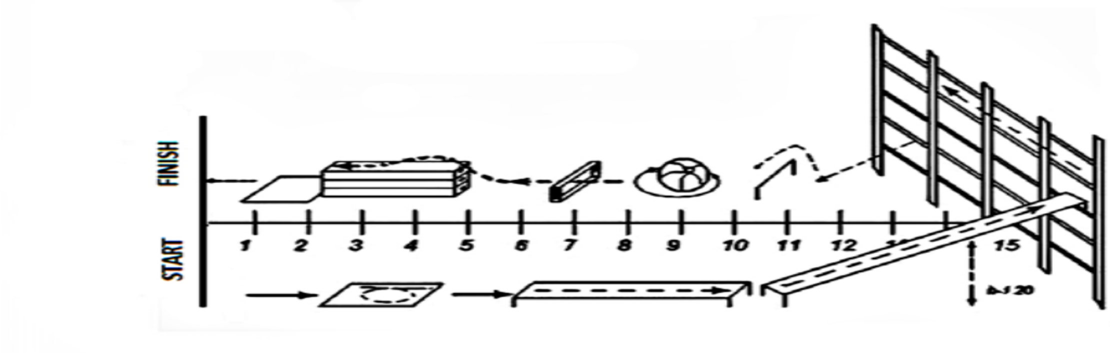
30-Meter Sprint Test

The 30-Meter Sprint Test is administered to determine individuals' maximal speed capabilities. The test is performed on a flat, non-slip surface, preferably in an indoor gym or an open area with minimal wind effects. Participants complete an 8–10-minute general warm-up (light jogging, dynamic stretching, and 2–3 submaximal sprint attempts) before starting the test. The test start line is clearly marked, and the finish line is exactly 30 meters from the start. The participant stands with one foot firmly in front, touching the line. The run is initiated with the commands "Ready" and "Start." The Fusion Smart Speed photocell system (Fusion Sport, Brisbane, Australia) is used for performance measurement. The timer automatically starts the moment the participant crosses the start line and ends when the 30-meter distance is completed. The test is performed at maximum effort with a full sprint. Participants are given at least two attempts, with 3–5 minutes of passive rest between attempts. The best time is recorded as the individual's sprint performance (Ndlomo, 2022; Ras et al., 2023b).

Occupational Coordination Course

The occupational coordination course, which holistically assesses the physical competencies specific to the firefighting profession, covers fundamental performance components such as speed, strength, endurance, agility, and coordination (Michaelides et al., 2008). Before starting the test, participants completed an 8–10-minute general warm-up, which included light jogging, dynamic stretching, and 2–3 submaximal practice shots. Participants waited at the start of the course, completing obstacles and performing task-focused movements at maximum effort levels. These movements included a forward somersault to test flexibility and balance control; a balance board to assess proprioceptive abilities and postural control; a ramp to measure lower extremity strength and balance adaptation; a wall scaffold to test upper and lower extremity coordination; a high-altitude jump to analyze explosive strength and landing control; a hurdle to measure agility and range of motion; and a medicine ball to integrate upper extremity strength, coordination, speed, and balance by crossing under an obstacle, jumping over a vault, and landing into a ring. Course duration was electronically recorded using the Fusion Smart Speed photocell system (Fusion Sport, Brisbane, Australia), and performance measurements were evaluated to reflect the speed, agility, and coordination levels required for occupational tasks (Chizewski et al., 2021). This functional test simulates the movement dynamics of firefighters in real-life work environments, holistically measuring parameters such as explosive strength, anaerobic capacity, and coordination, providing an objective, multidimensional analysis of occupational performance. Since the firefighting profession involves complex movement combinations that place high physical demands and require sudden force production, it is critical that test protocols are supported by scientific data and directly related to occupational requirements (Skinner et al., 2020).

Figure 1
Professional Firefighting Course



Note. This system used in training content.; Nazari et al., 2018.

Yo-Yo IRT 1

Participants' aerobic endurance was evaluated through the Yo-Yo Intermittent Recovery Test, Level 1 (Yo-Yo IRT1), a field-based assessment widely acknowledged for its reliability and validity in estimating intermittent exercise performance (Krustrup et al., 2003). Although laboratory evaluations are often considered the gold standard for assessing physiological capacity, field-based protocols such as the Yo-Yo IRT1 provide a practical, sport-specific alternative for assessing aerobic fitness in athletes (Krustrup et al., 2005).

The maximal oxygen uptake (VO_{2max}) of each participant was estimated from the total distance achieved in the test using the predictive equation proposed by Bangsbo and colleagues (Bangsbo et al., 2008):

$$VO_{2max}\ (ml/kg^{-1}/min^{-1}) = [\text{Yo-Yo IRT1 distance (m)} \times 0.0084] + 36.4$$

Exercise Protocol

This protocol was designed to fully meet the physical and performance requirements of the firefighting profession. The protocol holistically addresses critical parameters, including cardiorespiratory endurance, general and specific strength, explosive power, agility, motor coordination, and occupational functioning. The program was developed using current scientific literature (Ras et al., 2022) and professional standards (NFPA 1582, 2023; Miller et al., 2025). Exercises were conducted during the weekday class period in the fall and spring semesters. Exercises were not conducted during mid-term breaks, summer vacation, or weekends.

Table 1
Weekly Exercise Plan and Application Details

DAY	Training Component	Exercise Content	Sets x Reps / Time
MONDAY	Cardiorespiratory Endurance	High-intensity interval training (HIIT): 4 minutes high (85-90% HR max), 3 minutes low (60-65% HR max), 5 sets	20-30 minutes
	Strength & Core Stability	Functional resistance exercises (push-ups, planks, crunches) – Body weight and elastic bands	3-4 sets x 12-15 reps
	Flexibility & Mobility	Dynamic warm-up and active stretching exercises	10-15 minutes
WENDESDAY	Strength & Explosive Power	Free-weight squats, deadlifts, bench press (progressive overloading)	4 sets x 6-8 reps
	Plyometric and Speed Drills	Vertical/horizontal box jumps, quick foot presses, short sprints	3-4 sets x 8-12 reps
	Coordination and Professional Skills	Firefighting mission simulation (carrying a hose, climbing stairs, crossing an obstacle)	4-6 rounds
	Cool down	light walking and static stretching	10 minutes
FRIDAY	Cardiorespiratory Endurance	Sustained moderate-intensity running (65-75% HR max), running uphill, or climbing stairs	30 minutes
	Explosive Power & Core	Plank variations, quick jumps, and strengthening exercises	3-4 sets x 12 reps

Table 2
Progress and Performance Evaluation Criteria

Performance Criteria	Baseline	Target/Criteria	Evaluation Method
Maximal Strength (Squat, Bench Press)	1RM (Single Repetition Maximum)	3-5% weekly increase, 20% total increase target in 12 weeks	1RM tests
Explosive Power (Vertical Jump)	Height in cm	10-15% increase, shorter reaction time	Digital jump meters
Cardiorespiratory Capacity (VO_{2max})	ml/kg/min	10% increase in 12 weeks	Bruce Protocol, direct or indirect VO_{2max} measurements
Agility & Professional Skills	Course completion time and number of errors	15-20% time reduction, 50% reduction in number of errors	Timing and movement analysis

Protocol Application Content

Warm-up and Cool-down: Each exercise session began with scientifically proven dynamic warm-up protocols to protect student health and optimize performance. Dynamic warm-up increases the elasticity of the muscle-tendon unit and activates neuromuscular connections, thereby minimizing the risk of injury. Post-exercise, the accumulation of metabolites in the muscles must be reduced with static stretching and systematic cool-down activities. Recovery has been promoted by circulation and flexibility, and acceleration (Durand et al., 2011). Loading Principle and Periodic Progression: Exercise intensity and volume were gradually increased systematically and controlled, according to individual adaptation capacity. This principle is critical for preventing overtraining syndrome, decreased performance, and injury risks. Progression was planned based on objective performance indicators and biofeedback, and the balance between loading and recovery was meticulously maintained (Clare et al., 2015). Fatigue and Regeneration: Students' post-exercise fatigue symptoms were regularly monitored, and subjective perception, objective performance data, and biochemical indicators were evaluated together. Optimal recovery was achieved by implementing individual rest periods and regeneration strategies (active rest, sleep hygiene, nutritional support) when necessary (Poston et al., 2011).

Data Analysis

Statistical analysis of the data obtained in the study was conducted using SPSS 23 (SPSS Inc., Chicago, IL, USA). In the first stage, the data were checked for homogeneity of variance using the Levene Test, and the suitability for a normal distribution was analyzed in detail using the Shapiro-Wilk Test. The results showed that the data did not meet the assumptions of the parametric tests. Therefore, the Wilcoxon Signed Rank Test, a non-parametric statistical method, was used for within-group comparisons. In addition, a post-hoc power analysis was conducted to assess the statistical power of the study and the adequacy of the sample size. The analyses showed a power level above 80%, indicating sufficient statistical sensitivity and supporting the reliability of the study's findings and the generalizability of the results. The significance level in the analyses was set at $p < 0.05$, and all statistical results were interpreted using this threshold. The findings were comprehensively reported to test the study's hypotheses and reliably demonstrate changes in physical performance parameters.

RESULTS

The results of our research findings are presented below. An examination of Table 3 reveals that the age (n = 15), height, body weight, and body mass index values of the female volunteers participating in the study were 19.67 ± 1.50 years, 177.13 ± 6.16 cm, 78.45 ± 9.63 kg, and 22.64 ± 1.87 kg/m², respectively. These findings indicate that the participants were in the young adult age group and that their physical structures were consistent with general population norms. Furthermore, the low standard deviations of the anthropometric measurements indicate that the individuals in the sample were similar and homogeneous. These demographic and anthropometric data constitute an important basis for the physical performance analyses within the scope of the study to yield reliable and reliable results.

Table 3
Descriptive Statistics of the Volunteers Participating in the Study Comparison of Anthropometric Measurement Parameters of Training Groups

Variables	n	$\bar{X}$ ± sd	Median	Min - Max
Age (year)	15	19.67 ± 1.50	20	18 – 22
Height (cm)	15	177.13 ± 6.16	177	165 – 188
Body Weight (kg)	15	78.45 ± 9.63	79.2	62.3 – 92.5
Body Mass Index (kg/m²)	15	22.64 ± 1.87	22.5	19.8 – 25.9

Note. *: $p< 0.05$

Table 4 compares participants' physical performance and body composition parameters before and after the two-year training program. According to the Wilcoxon Signed-Rank Test, significant improvements were observed in all variables ($p < 0.05$). Specifically, increases in skeletal muscle mass and cardiorespiratory endurance (estimated VO_{2max}) and significant decreases in body fat percentage and body mass index demonstrate the program's effectiveness. Shorter times measured in timed performance tests (3x10m shuttle run, 30m sprint, occupational coordination) indicate improvements in endurance and agility. These findings support the fact that the firefighting and sports training program significantly increased the participants' physical capabilities.

Table 4

Comparison of Body Composition and Physical Performance Parameters of Civil Defense and Firefighting Program Students in Pre and Post Tests

Variables (n = 15)	Pre-Test ($\bar{X}$ ± sd)	Final Test ($\bar{X}$ ± sd)	z	p	% Change
Body Weight (kg)	78.45 ± 9.63	76.45 ± 5.45	-2.56	0.010*	-2.55
Skeletal Muscle (kg)	37.84 ± 2.51	41.13 ± 3.12	-3.41	<0.001*	+8.68
Body Fat Percentage (%)	20.63 ± 2.18	16.67 ± 1.87	-3.41	<0.001*	-19.20
Body Mass Index (kg/m²)	22.64 ± 1.87	19.32 ± 1.91	-3.41	<0.001*	-14.67
Vertical Jump (cm)	37.75 ± 4.47	39.85 ± 4.12	-3.35	<0.001*	+5.57
3x10m Shuttle Run (sec)	9.77 ± 0.83	8.97 ± 0.86	-3.41	<0.001*	-8.19
Double Leg Jump on Bench (reps)	19.13 ± 1.40	21.40 ± 1.50	-3.51	<0.001*	+11.86
One-Handed Ball Throwing at the Wall (reps)	6.40 ± 1.35	8.33 ± 0.97	-3.37	<0.001*	+30.16
30m Sprint (sec)	3.86 ± 0.20	3.82 ± 0.21	-2.93	0.003*	-0.04
Occupational Coordination (sec)	1.21 ± 0.13	1.08 ± 0.18	-3.41	<0.001*	-10.74
VO_{2max} (ml/kg/dk)	38.50 ± 4.20	42.80 ± 4.35	-3.41	<0.001*	+11.17

Note. p: Wilcoxon Signed Rank Test; *: statistically significant

DISCUSSIONS

In this study, significant improvements were observed in the physical performance, body composition, and cardiorespiratory endurance parameters of students in the Civil Defense and Firefighting Program at the end of the two-year firefighting and sports training program (Table 4). These improvements demonstrate the effectiveness of the training in helping young firefighter candidates achieve the physical capacity appropriate to their professional requirements. Our findings are consistent with the results of many previous studies demonstrating the high physical fitness requirements of the firefighting profession (Poston et al., 2011; Ras et al., 2023c).

Body Composition

Our study reveals significant improvements in body composition in young firefighting cadets. These findings are reflected in a 2.55% decrease in body weight, a 19.20% significant decrease in body fat percentage, and an 8.68% increase in skeletal muscle mass. These changes are critical not only for general health indicators but also for occupational performance and the physical demands of duty. The literature indicates that high body fat percentage increases the risk of cardiovascular disease, metabolic disorders, and musculoskeletal injuries in firefighters (Munir et al., 2012; Clark et al., 2022; Bucala & Sweet, 2019). The significant decrease in body fat percentage observed in our study provides strong evidence that these risks can be reduced. An increase in skeletal muscle mass directly contributes to the development of strength and endurance required during duty (Wilkinson et al., 2014; Tsismenakis et al., 2009; Jahnke et al., 2013). However, the literature emphasizes that Body Mass Index (BMI) reflects body composition only to a limited extent, whereas the muscle-to-fat ratio is a more reliable determinant (Vincente et al., 2021). In our study, a 14.66% decrease in BMI was observed, accompanied by decreases in fat mass and increases in muscle mass. This result suggests that young firefighting cadets have a healthier, more functional, and more professionally competent physical profile.

However, high muscle mass can increase the risk of injury, particularly by increasing the mechanical load on joints. Therefore, integrating training components targeting flexibility, mobility, and balance into physical preparation programs is critical for maintaining performance and minimizing injury risk (Post et al., 2011). Overall, our findings indicate that improving body composition is decisive not only for health and aesthetics but also for professional performance, task effectiveness, and safety. This highlights the importance of holistic, evidence-based approaches that consider muscle-fat ratio and functional capacity in the design of physical preparation programs for the fire service profession.

Functional Performance

Improvements in physical performance parameters are critical to enhancing firefighters' professional competence. In our study, a 5.58% increase in vertical jump indicates a significant improvement in explosive power capacity; this finding demonstrates the potential for firefighters to enhance their performance in operational tasks requiring sudden power (Andrews et al., 2019; Beach et al., 2014). The 8.19% reduction in shuttle run time reflects improvements in anaerobic endurance and agility; These parameters directly affect task success, especially in occupational scenarios requiring high intensity and rapid changes of direction (Beaton et al., 2022). An 11.85% increase in the number of double-footed bench jumps reveals a significant improvement in lower and upper extremity strength, while a 30.16% improvement in the one-handed wall ball throw test indicates a significant improvement in coordination, hand-eye dexterity, and explosive upper extremity power. These improvements are essential for increased performance in high-physical demand tasks such as firefighting, rescue, and emergency response (Butle et al., 2013; de la Motte et al., 2013). In contrast, only a 1.04% improvement in 30-m sprint time was observed, suggesting that the current training program does not sufficiently develop high-speed anaerobic capacity. The literature emphasizes that specific speed training is critical in improving sprint and high-speed anaerobic performance, and that including these practices in the program significantly improves performance (Baur et al., 2012; Henderson et al., 2007). Accordingly, it is recommended that future physical preparation programs include specific training targeting sprint, agility, and anaerobic capacity. In addition, the 10.74% improvement in occupational coordination time is a significant development, increasing the success rate on complex tasks and reducing the risk of injury. The development of coordination skills supports firefighters' safe and effective work in high-stress and dynamic duty conditions (Lee & Jun, 2019). Overall, these findings show that improvements in physical performance parameters have a holistic effect, increasing not only individual capacity but also occupational task effectiveness and safety. The study emphasizes the importance of multidimensional assessment of physical performance among young firefighting students, from the perspectives of professional competence and safety. The findings suggest that physical preparation programs for the fire service profession should be designed using holistic, evidence-based approaches that target muscular strength, explosive power, anaerobic capacity, agility, and coordination. This approach not only increases task effectiveness but also supports long-term professional sustainability by reducing the risk of injury.

Cardiorespiratory Endurance

In our study, the 11.17% increase in VO_2max values indicates a significant improvement in cardiorespiratory endurance. A high VO_2max is a critical determinant for the sustainability of long-duration, high-intensity occupational tasks (Heimburg et al., 2013). Conversely, high cardiovascular capacity increases firefighters' resilience to the extreme physical stress and heat load they experience during their occupational tasks, while also reducing the risk of occupational injuries and cardiovascular events (Raines et al., 2020; Seyedmehdi et al., 2016; McGill et al., 2013). The findings indicate that the integrated firefighting and sports training program is effective in improving multidimensional physical fitness in young candidates. The program improved key components that directly support professional performance, such as strength, endurance, and coordination (Poplin et al., 2014). However, limited improvements in speed and anaerobic performance suggest that the program presents deficiencies in these areas. The literature emphasizes that the firefighting profession requires high explosive power and speed, making it essential to include specific anaerobic and speed training in the program (Mier & Gibson, 2004;

Tierney et al., 2010). The literature also indicates that the firefighting profession involves high psychological stress, and these factors are decisive for both professional performance and long-term health (Rexhepi & Brestovci, 2014). Therefore, it is recommended that future training programs address both physical and psychological components holistically through a multidisciplinary approach. The study findings demonstrate that integrated firefighting-sports training programs can significantly improve cardiorespiratory fitness and multidimensional physical fitness in young candidates, but they emphasize the need for optimized, multidisciplinary programs that encompass all dimensions of performance.

Limitations

This study has several limitations. First, the relatively limited number of participants in the study group and the limited demographics (students of the Civil Defense and Firefighting Program) may limit the generalizability of the findings. Furthermore, VO_{2max} values were measured using indirect methods, and the absence of gold-standard methods, such as direct gas analysis, is another limitation that may affect measurement accuracy. Furthermore, the training program did not assess key biopsychosocial factors, including psychological resilience, stress management, and sleep quality. In this respect, the program's limited scope to physical parameters prevented a fully holistic assessment of occupational performance.

Future studies are recommended to conduct long-term follow-up in real-world settings with larger, more heterogeneous participant groups. Furthermore, enriching training programs with a multidisciplinary approach to improve speed, anaerobic capacity, and psychological endurance will support firefighters' occupational performance and health in a more holistic manner. Finally, using gold-standard measurement techniques will increase the accuracy and reliability of the findings.

CONCLUSION

This study demonstrates that students in the Civil Defense and Firefighting Program achieved significant improvements in physical fitness and performance parameters during the two-year integrated firefighting and sports training.

Improvements in cardiorespiratory endurance (VO_{2max}) and functional performance tests demonstrate that young firefighters possess the physiological capabilities to perform their professional duties both effectively and safely. However, limited improvements in performance tests requiring speed and explosive power, such as the 30-meter sprint, indicate that current training programs are inadequate in these areas and lack specific anaerobic and speed-focused training.

This highlights the importance of integrating intensive, targeted training programs focused on speed, explosive power, and anaerobic capacity into future training models, while accounting for professional requirements.

Furthermore, programs should not be limited to physical components alone. It significantly improves candidates' physical and functional capacities, but multidisciplinary approaches need to be expanded to encompass both physical and psychological components. Future research encompassing diverse demographic groups and monitoring performance and health parameters over the long term under real-world occupational conditions is critical for optimizing program effectiveness and enhancing professional competence. Therefore, continuous updating and evidence-based holistic design of firefighting training programs are essential for occupational safety and sustainable performance.

PRACTICAL IMPLICATIONS

The findings of this study indicate that integrated firefighting and sports training programs are effective in developing the physical capacities required for professional firefighting. The observed improvements in body composition underscore the importance of using functional indicators, such as the muscle–fat ratio, rather than relying solely on body mass index in occupational fitness evaluations.

Improvements in functional performance measures demonstrate that task-specific, short-distance field tests are valuable tools for performance monitoring and training prescription. However, the limited development of speed and anaerobic capacity highlights the need to incorporate targeted training components addressing these abilities. In addition, the increase in VO_2max underscores the critical role of aerobic endurance in sustaining performance during prolonged and physically demanding firefighting tasks. Overall, these findings support the adoption of holistic, evidence-based training models that integrate aerobic, anaerobic, and neuromuscular components, and that are continuously updated to align with occupational demands and long-term professional sustainability.

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Authors' Contribution

All authors contributed equally to the conception and design of the study, data collection, data analysis and interpretation, drafting the article and/or its critical revision, and final approval of the version to be published.

Declaration of Conflict Interest

There is no conflict of interest among the authors.

Ethics Statement

Ethics committee approval for the study was received by the Bilecik Şeyh Edebali University Non-Interventional Clinical Research Ethics Committee on March 30, 2023 (Decision No: 3/3).

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