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ENHANCING FIREFIGHTER SAFETY THROUGH EQUIPMENT OPERATION TRAINING: A CASE STUDY OF FIRE STATION PERSONNEL

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Abstract: This study evaluates the effect of a structured in-service training program on the equipment operation skills of firefighters and technicians in a real operational environment. The study was conducted as an applied case study and pilot field evaluation using a single-group pre-test and post-test design at an urban fire station. A total of 21 personnel (15 firefighters and 6 technicians) participated in the study, representing the complete eligible workforce of the selected fire station during the study period. Performance-based assessments were carried out for nine categories of firefighting and rescue equipment using a standardized scoring checklist. Pre-test and post-test scores were compared using paired-samples t-tests, and group differences were examined using independent-samples t-tests. The results showed statistically significant improvements in performance scores for all assessed equipment categories after the training program (all $P<0.001$), with large effect sizes observed across all categories (Cohen's d ranging from 1.14 to 1.94). The largest improvements were observed in cutting tools, concrete breakers, and ventilation fans, which had relatively low baseline scores. In addition, performance variability decreased after training, indicating a more standardized skill level among participants. Although technicians achieved higher post-test scores than firefighters in all categories, statistically significant differences between the two groups were observed only for a limited number of tools. Given the single-site design and small sample size, the findings should be interpreted as preliminary evidence from a pilot field evaluation rather than definitive conclusions, and replication in larger multi-site studies is recommended. Despite these limitations, the findings provide a practical foundation suggesting that structured, hands-on in-service training has the potential to lead to measurable improvements in equipment operation skills in fire service organizations.

Keywords: Equipment operation skills, Firefighters, In-service training, Occupational training, Performance evaluation

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1. Introduction

Firefighting and emergency response operations require personnel to perform complex technical tasks under time pressure, hazardous conditions, and high physical and psychological stress. In such environments, operational effectiveness and safety depend not only on the availability of modern equipment but also on the ability of personnel to operate this equipment correctly, efficiently, and in accordance with established safety procedures. Inadequate technical skills and improper equipment use have been identified as important contributing factors to operational errors and occupational injuries in emergency services (Smith and DeJoy, 2014; Li et al., 2025).

From a theoretical perspective, the present study is grounded in training transfer theory, which posits that learning acquired during structured training activities translates into improved job performance in real operational settings (Mehner et al., 2024). In this study, training transfer is evaluated primarily at the individual level, as performance improvements are measured for each participant separately across specific equipment operation tasks. At the same time, the aggregated findings across all station personnel reflect an organizational dimension, as improvements in individual technical competencies collectively contribute to the overall operational readiness and safety performance of the fire station as a unit

In-service training is widely recognized as one of the most important mechanisms for maintaining and improving professional competence in safety-critical occupations. Previous research in the fire service has shown that training, together with management support and safety climate, plays a central role in shaping safety behaviors and compliance with procedures (DeJoy et al., 2017; Smith et al., 2019; Smith et al., 2020). More recent studies have further demonstrated that effective safety

training is positively associated with safety knowledge and the correct use of personal protective equipment among firefighters (Smith et al., 2024). These findings indicate that training is not only an organizational requirement but also a critical factor influencing day-to-day operational performance. Beyond the fire service, the broader training and development literature consistently reports positive effects of systematic training programs on employee performance and organizational effectiveness (Fegade and Sharma, 2023; Hosen et al., 2024). In emergency and high-risk occupations, however, the consequences of insufficient training are more severe, as performance failures may directly result in injuries, loss of life, or major property damage. For this reason, recent research has increasingly focused not only on providing training but also on developing methods to evaluate its effectiveness. For example, Li et al. (2025) proposed technology-based approaches to assess firefighter training outcomes and emphasized that inadequate or irregular training remains an important contributor to operational risk. Although many studies have examined safety climate, leadership, and organizational factors in the fire service (DeJoy et al., 2017; Davis et al., 2020; Smith, 2020), fewer studies have directly evaluated the effect of in-service training programs on specific, practical equipment operation skills using field-based performance measurements. Some applied studies have shown that structured training programs can lead to measurable improvements in physical readiness and task performance (Hollerbach et al., 2019; Rosner, 2024), but in many organizations, especially in developing or resource-constrained contexts, training activities are still implemented without systematic evaluation of their direct impact on technical competencies. In developing and high-workload urban environments, fire departments often face limitations in terms of training time, financial resources, and personnel availability. Under such conditions, it becomes particularly important to ensure that the available training activities produce measurable improvements in practical skills. From a managerial and operational perspective, simple performance-based evaluation methods, such as pre-test and post-test assessments of equipment operation skills, provide a practical way to examine whether training programs achieve their intended objectives and to identify areas requiring further improvement (Mehner et al., 2024; Niemann and Thielsch,2020). Despite the global recognition of training as a critical component of occupational safety in emergency services, the implementation and systematic evaluation of firefighter training programs remain particularly challenging in developing countries, including those in the Middle East and neighbouring regions. In many of these contexts, fire departments operate under significant constraints in terms of budgetary resources, training infrastructure, and the availability of standardized evaluation frameworks, all of which limit the scope and continuity of in-service training activities. Research from developing-country contexts has consistently shown that urban firefighters face substantial occupational challenges related to insufficient training, inadequate personal protective equipment, and limited institutional health support programs factors that directly compromise operational readiness and personnel safety (Bhattarai et al., 2021). In Iran, studies have specifically documented that insufficient investment in occupational safety training and prevention measures contributes to elevated occupational risk among firefighting personnel, and that no comprehensive standards exist for assessing firefighter competency or fitness for duty in the country's fire departments (Heydari et al., 2021). Research conducted within the Tehran Fire Department has further confirmed that firefighters' safety knowledge, attitude, and performance are closely interrelated, and that continuous training plays a pivotal role in strengthening operational competencies in high-workload urban settings (Souri et al., 2019). Similarly, in Turkey, where firefighting organizations face growing demands associated with rapid urbanization and increased emergency response complexity, studies have demonstrated that in-service training is a key determinant of firefighters' knowledge competencies and operational effectiveness, yet significant variation exists in training quality and content across different regions (Safak et al., 2023). Consistent with this, research involving 772 firefighters across Turkey found that disaster risk management performance was significantly higher among those who had received structured training and had regular access to proper personal protective equipment, underscoring the direct relationship between training quality and operational preparedness (Ütük and Baraçlı, 2024). A multi-site study conducted across five major metropolitan fire departments in Turkey further revealed that safety behaviours and operational compliance are shaped not only by organizational factors but also by the quality and continuity of training programs available to personnel (Bakirci et al., 2025). Taken together, these findings from the region highlight the urgent need for practical, field-based evaluations of training effectiveness conducted in real operational environments, and underscore the particular relevance of the present study within this broader regional and international context.

The In metropolitan fire departments, firefighters are generally managed by a centralized human resources unit that establishes standardized criteria for recruitment, training, and professional qualifications applicable to all personnel across the organization. Given that professional and training standards are uniformly applied to all firefighters within the same department, the findings of the present study may, to a certain extent, be considered transferable to the broader organizational context. It is also important to note that an individual fire station, as an independent operational unit, may possess unique sociological and organizational characteristics

shaped by its specific personnel composition, workload, and operational environment. This is precisely why in-service training has received increasing attention worldwide as a mechanism for specializing and standardizing knowledge transfer across fire service organizations, ensuring that competency levels remain consistent across individual stations and operational units. Although the results are limited to a single station and a relatively small sample, the findings may be useful for training planners and administrators in similar contexts when designing and evaluating in-service training programs. The aim of this study is to evaluate the effect of a structured in-service training program on the equipment operation skills of firefighters and technicians in a single urban fire station. Using a pre-test and post-test design, the study has three specific objectives: (1) to assess whether participation in systematic training leads to measurable improvements in practical equipment operation skills, (2) to identify which equipment categories show the greatest training-related improvements, and (3) to compare the effectiveness of the training program between firefighters and technicians. The study focuses on measuring changes in practical performance across nine commonly used firefighting tools and equipment, including cutting tools, welding equipment, milling machines, electric saws, concrete breakers, general tools, hooligan tools, hydraulic jacks, and ventilation fans. This study is presented as an applied case study and a pilot evaluation of a training intervention conducted in a real operational setting. Its main contribution is to provide practical, field-based evidence on how a structured in-service training program can improve measured equipment operation skills within a small and heterogeneous group of emergency service personnel.

2. Materials and Methods

2.1. Study Design, Setting, Participants, and Training Program

This study was conducted as an applied case study using a single-group pre-test and post-test design to evaluate the effect of a structured in-service training program on equipment operation skills in a real operational environment. The study was carried out at an urban fire station of the Tehran Fire Department that provides continuous 24-hour emergency coverage and responds to approximately 15 emergency calls per day. The station serves a densely populated area with mixed residential and commercial land use and routinely handles fire suppression, technical rescue, and other emergency response activities.Because of operational and organizational constraints, no separate control group was included. Therefore, the study design is intended as a practical field evaluation rather than a controlled experimental trial, and the results should be interpreted within this limitation.The study population consisted of 21 emergency service personnel working at the selected fire station, including 15 firefighters and 6 technicians.

In the Tehran Fire Department, personnel are assigned to fire stations following their initial recruitment and completion of mandatory pre-service and entry-level training programs, where they begin their duties as operational firefighters. Firefighters are responsible for specific operational tasks, including fire suppression and technical rescue operations, and are required in accordance with Job Performance Requirements (JPR) to maintain physical fitness and both physical and psychological readiness in order to effectively fulfil their operational duties. Firefighting technicians, however, represent a higher occupational grade within the organizational hierarchy. In addition to performing fire suppression and rescue operations, technicians have acquired the necessary qualifications for the operation of specialized and technically complex firefighting equipment. These qualifications may include the operation of light and heavy firefighting vehicles, fire pumps, and specialized technical apparatus. Typically, firefighters may be promoted to the technician grade upon successful completion of designated advanced vocational training courses, which certify their competency in the operation of specialized equipment beyond the standard firefighter role. Participation was voluntary and based on availability during the study period. The mean age of the participants was 32 years (range: 24–40 years), and their mean work experience was 5.7 years (range: 1–13 years). In terms of education, 11 participants (52.4%) held a high school or associate degree, 7 (33.3%) held a bachelor's degree, and 3 (14.3%) held a master's degree. All participants were informed about the purpose and procedures of the study and provided informed consent before participation. The study was conducted in accordance with ethical principles for research involving human participants, and all collected data were analyzed anonymously. It should be noted that the 21 participants represented the complete eligible workforce of the selected fire station during the study period, meaning the study constitutes a census of the available population rather than a selective sample. While this limits generalizability beyond the study site, it ensures that the findings reflect the full range of skill levels present within this operational unit. The intervention consisted of a structured in-service training program focusing on the practical operation of commonly used firefighting and rescue equipment. The training program covered ten equipment categories: (1) hand-held fire extinguishers, (2) debris removal equipment, (3) welding and cutting tools, (4) hydraulic rescue equipment, (5) general firefighting tools, (6) gasoline-powered milling machines, (7) breathing apparatus, (8) emergency generators, (9) tactical ventilation fans, and (10) motorized and electric saws. Training sessions were conducted by shift commanders, who served as instructors based on their operational expertise and familiarity with departmental standard operating procedures. Each session was delivered during the designated in-service training hours from 09:00 to

12:00 on each working shift, providing three hours of instruction per session. Each session combined theoretical explanations with hands-on practical exercises and focused on correct operational procedures, safety precautions, and basic maintenance and handling principles. The pre-test assessment was conducted prior to the commencement of the training program, and upon completion of all training sessions, the same assessment procedure was repeated as the post-test. All participants attended the same training program.

2.2. Assessment Procedure and Data Analysis

To evaluate equipment operation skills, a structured performance-based observation checklist with a standardized grading scale from 0 to 100 points was used for each equipment category. The assessed equipment included cutting tools, welding equipment, milling machines, electric saws, concrete breakers, general tools, hooligan tools, hydraulic jacks, and ventilation fans. For each equipment category, participants were asked to perform predefined operational tasks under standardized conditions, and their performance was scored based on predefined criteria covering correct operating sequence, safe handling, and basic technical proficiency. The same assessment procedure and scoring criteria were used for both the pre-test and the post-test.

The pre-test assessment was conducted immediately before the training program. After completion of the training sessions, the same assessment procedure was repeated as the post-test one month later. To ensure consistency, all assessments were conducted under similar conditions using the same equipment and task scenarios. Because this study was designed as a practical field evaluation, formal psychometric validation of the checklist and inter-rater reliability analysis were not performed. This is acknowledged as a methodological limitation of the study.Statistical analysis was performed using SPSS software. Descriptive statistics (means, standard deviations, frequencies, and percentages) were used to summarize participant characteristics and performance scores. Paired-samples t-tests were used to compare pre-test and post-test scores for each equipment category. Independent-samples t-tests were used to compare post-test scores between firefighters and technicians. Pearson correlation coefficients were calculated to examine the relationship between pre-test and post-test scores. Levene's test was used to assess the homogeneity of variances for between-group comparisons. The level of statistical significance was set at $\alpha = 0.05$. All reported p-values smaller than 0.001 are presented as $P<0.001$.

3. Results

3.1. Descriptive Results and Training Effects

A total of 21 personnel participated in the study, including 15 firefighters (71.4%) and 6 technicians (28.6%). The mean age of the participants was 32 years (range: 24–40 years), and the mean work experience was 5.7 years (range: 1–13 years). In terms of education, 11 participants (52.4%) held a high school or associate degree, 7 (33.3%) held a bachelor's degree, and 3 (14.3%) held a master's degree. The distributions of age and work experience are presented in Tables 1 and 2. Descriptive statistics for pre-test and post-test scores across the nine equipment categories are presented in Table 3.

At baseline, mean pre-test scores ranged from 51.43 (concrete breaker) to 84.29 (general tools), indicating heterogeneous initial skill levels. After the training program, mean scores increased in all equipment categories. The largest improvement was observed for cutting tool operation (from 55.00 to 85.00; mean difference = 30.00 points), followed by concrete breaker operation (from 51.43 to 80.00; mean difference = 28.57 points) and ventilation fan operation (from 65.00 to 90.00; mean difference = 25.00 points). The smallest improvement was observed for hooligan tool operation (mean difference = 8.57 points). In all categories, standard deviations decreased from pre-test to post-test, indicating reduced variability in performance following training. Correlation analysis showed significant positive relationships between pre-test and post-test scores for all equipment categories ($r = 0.599$ to 0.973, all $P<0.01$), indicating that participants generally maintained their relative performance ranking while achieving overall performance improvements (Table 4).

Table 1. Frequency distribution of work experience variable

Work Experience Variable	Frequency	Frequency Percentage	Cumulative Frequency
Less than 4 years	3	14.3	14.3
Between 5 to 10 years	12	57.1	71.4
More than 11 years	6	28.6	100

Table 2. Frequency distribution of employee age variable

Age Variable	Frequency	Frequency Percentage	Cumulative Frequency
Less than 28 years	4	19	19
Between 29 to 32 years	9	42.9	61.9
More than 33 years	8	38.1	100

Table 3. Paired sample statistics

Pair	Variable	Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Cutting 1	55.00	21	24.341	5.312
	Cutting 2	85.00	21	12.247	2.673
Pair 2	Welding 1	57.86	21	23.215	5.066
	Welding 2	79.29	21	11.756	2.565
Pair 3	Milling 1	57.86	21	29.605	6.460
	Milling 2	83.14	21	20.105	4.387
Pair 4	Saw 1	75.00	21	20.494	4.472
	Saw 2	92.14	21	10.556	2.304
Pair 5	Concrete Breaker 1	51.43	21	25.206	5.500
	Concrete Breaker 2	80.00	21	21.389	4.668
Pair 6	Tools 1	84.29	21	12.071	2.634
	Tools 2	95.00	21	8.216	1.793
Pair 7	Hooligan Tool 1	80.00	21	17.321	3.780
	Hooligan Tool 2	88.57	21	12.464	2.720
Pair 8	Jack 1	65.00	21	20.310	4.432
	Jack 2	83.57	21	14.417	3.146
Pair 9	Fan 1	65.00	21	25.836	5.638
	Fan 2	90.00	21	10.607	2.315

Table 4. Correlation of paired statistics

Pair	Variables	N	Correlation	Sig.
Pair 1	Cutting 1 & Cutting 2	21	.843	.000
Pair 2	Welding 1 & Welding 2	21	.599	.001
Pair 3	Milling 1 & Milling 2	21	.886	.000
Pair 4	Saw 1 & Saw 2	21	.901	.000
Pair 5	Concrete Breaker 1 & 2	21	.744	.000
Pair 6	Tools 1 & Tools 2	21	.870	.000
Pair 7	Hooligan Tool 1 & 2	21	.973	.000
Pair 8	Jack 1 & Jack 2	21	.832	.000
Pair 9	Fan 1 & Fan 2	21	.766	.000

The results of the paired-samples t-tests are presented in Table 5. Statistically significant differences between pre-test and post-test scores were observed for all nine equipment categories (all $P<0.001$), and in all cases the 95% confidence intervals did not include zero, confirming the statistical significance of the training effects.

Effect size calculations indicated large practical significance for all nine equipment categories (Cohen's d ranging from 1.14 to 1.94), confirming that the observed improvements represent meaningful gains in operational performance beyond statistical significance alone. The largest effect sizes were observed for cutting tools (d = 1.94), milling machines (d = 1.68), general tools (d = 1.68), and concrete breakers (d = 1.68), while the smallest, though still large, effect was observed for welding equipment (d = 1.14).

3.2. Comparison between Firefighters and Technicians

Post-test performance comparisons between firefighters and technicians are summarized in Table 6. Technicians achieved higher mean scores than firefighters across all assessed equipment categories. The largest mean differences were observed for concrete breaker operation (90.83 vs. 75.67) and hydraulic jack operation (90.83 vs. 80.67).

The results of the independent samples t-tests and Levene's tests are presented in Table 7. Despite the consistent numerical superiority of technicians, statistically significant differences between the two groups were found only for electric saw operation and general tools usage ($P<0.05$). For all other equipment categories, not statistically significant between-group differences were observed.

Table 5. Paired samples test

Pair	Variables	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval		t	df	Sig.
					Lower	Upper			
Pair 1	Cutting 1-2	-30.000	15.492	3.381	-37.052	-22.948	-8.874	20	
Pair 2	Welding 1-2	-21.429	18.718	4.085	-29.949	-12.908	-5.246	20	
Pair 3	Milling 1-2	-25.286	15.017	3.277	-32.121	-18.450	-7.716	20	
Pair 4	Saw 1-2	-17.143	11.892	2.595	-22.556	-11.730	-6.606	20	
Pair 5	Concrete Breaker 1- 2	-28.571	17.040	3.718	-36.328	-20.815	-7.684	20	
Pair 6	Tools 1 –2	-10.714	6.381	1.392	-13.619	-7.810	-7.695	20	
Pair 7	Hooligan Tool 1 - 2	-8.571	5.946	1.298	-11.278	-5.865	-6.606	20	
Pair 8	Jack 1-2	-18.571	11.526	2.515	-23.818	-13.325	-7.384	20	
Pair 9	Fan 1 - 2	-25.000	18.974	4.140	-33.637	-16.363	-6.038	20	

Table 6. Group statistics

Variable	Position	N	Mean	Std. Deviation	Std. Error Mean
Cutting 2	Firefighter	15	82.33	12.081	3.119
	Technician	6	91.67	10.801	4.410
Welding 2	Firefighter	15	77.00	11.772	3.039
	Technician	6	85.00	10.488	4.282
Milling 2	Firefighter	15	81.47	19.331	4.991
	Technician	6	87.33	23.261	9.496
Saw 2	Firefighter	15	90.67	11.782	3.042
	Technician	6	95.83	5.845	2.386
Concrete Breaker 2	Firefighter	15	75.67	20.077	5.184
	Technician	6	90.83	22.454	9.167
Tools 2	Firefighter	15	94.00	8.904	2.299
	Technician	6	97.50	6.124	2.500
Hooligan Tool 2	Firefighter	15	86.67	12.630	3.261
	Technician	6	93.33	11.690	4.773
Jack 2	Firefighter	15	80.67	14.125	3.647
	Technician	6	90.83	13.571	5.540
Fan 2	Firefighter	15	88.00	11.148	2.878
	Technician	6	95.00	7.746	3.162

Table 7. Independent samples test

Variable	Levene's Test F	Sig.
Cutting 2	2.818	.110
Welding 2	.143	.709
Milling 2	.057	.814
Saw 2	4.452	.048
Concrete Breaker 2	.041	.842
Tools 2	5.128	.035
Hooligan Tool 2	1.289	.270
Jack 2	1.301	.268
Fan 2	2.621	.122

4. Discussion

The present study evaluated the effect of a structured in-service training program on the equipment operation skills of firefighters and technicians using a pre-test and post-test design in a real operational setting. The results demonstrated statistically significant improvements in performance scores for all assessed equipment categories following the training program. These findings are consistent with previous research indicating that systematic training plays a critical role in improving safety-related knowledge, skills, and operational performance in fire and emergency services (DeJoy et al., 2017; Smith et al., 2019; Smith et al., 2024).

The largest performance improvements were observed in equipment categories with relatively low baseline scores, such as cutting tools, concrete breakers, and ventilation fans. This pattern is in line with the general training literature, which suggests that structured training interventions tend to produce the greatest gains in areas where initial competence is limited (Fegade and Sharma, 2023; Hosen et al., 2024). Similar findings have been reported in applied studies in emergency and physically demanding occupations, where targeted training programs resulted in substantial improvements in task-specific performance (Hollerbach et al., 2019; Rosner, 2024).

The significant positive correlations observed between pre-test and post-test scores indicate that participants generally maintained their relative performance ranking while achieving overall improvement. This suggests that the training program improved performance across the group without fundamentally changing individual differences in skill level. From a practical perspective, this finding supports the view that in-service training contributes to raising the overall competence level of personnel rather than only benefiting a small subset of participants, which is consistent with observations reported in previous safety training research (Smith et al., 2020; Li et al., 2025).

The higher post-test scores consistently achieved by technicians across all equipment categories can be attributed to several interrelated factors. First, differences in daily work routines and task exposure are likely to play a central role, as technicians are more regularly engaged in hands-on equipment maintenance, repair, and technical operations compared to firefighters, whose primary duties are operationally focused on emergency response. This type of role-specific, repeated task exposure is known to consolidate practical skills over time and to lower the cognitive load associated with equipment operation, thereby facilitating faster learning gains during structured training interventions (Fegade and Sharma, 2023; Hosen et al., 2024). Second, educational background may have contributed to the observed differences. Technicians typically enter their roles with vocationally oriented technical education that includes systematic instruction in equipment mechanics and maintenance principles, which provides a stronger prior knowledge base for equipment-related tasks. In line with this, Souri et al. (2019) demonstrated in their study of Tehran Fire Department personnel that education level and job title background were positively and significantly associated with safety knowledge, attitude, and operational performance, suggesting that both formal education and role-specific experience are important determinants of technical competency in fire service contexts. Third, work experience may have further amplified the performance advantage of technicians. Although the overall mean work experience of participants in the present study was relatively modest (mean = 5.7 years; range: 1–13 years), differences in role-specific experience accumulated through daily technical duties are likely to have resulted in greater familiarity with the assessed equipment among technicians, independent of total years of service. Similar role-related and experience-related differences in technical skill levels have been documented in previous studies examining occupational specialization in emergency and industrial settings (Davis et al., 2020; Smith, 2020). Nevertheless, the limited number of statistically significant between-group differences observed in the present study suggests that the structured training program was effective in narrowing practical skill gaps between occupational roles, indicating that well-designed in-service training can partially compensate for differences in prior technical background and daily task exposure."

From a broader organizational perspective, the findings of this study support the argument that regular, structured, and practice-oriented in-service training is a key component of safety management systems in high-risk organizations. Previous studies have emphasized that training, together with management commitment and safety climate, forms a critical foundation for safe and effective operations (DeJoy et al., 2017; Smith et al., 2019; Smith et al., 2024). The present results provide additional field-based evidence that even relatively simple and locally implemented training programs can produce measurable improvements in technical performance.

It is also important to consider the theoretical dimensions of the findings in terms of the level at which training transfer and organizational learning operate. In the present study, training transfer was observed primarily at the individual level, as each participant demonstrated measurable improvements in equipment operation skills following the structured intervention. However, when viewed collectively, these individual-level gains reflect an organizational outcome namely, a more standardized and elevated competency level across the entire station workforce. This distinction is theoretically significant because it suggests that organizational learning in fire service contexts may function as a moderating factor in the relationship between structured training and operational performance. Specifically, organizational factors such as

management support, safety climate, and the institutionalization of regular training practices are likely to influence the degree to which individually acquired skills are retained, reinforced, and applied in real operational settings (DeJoy et al., 2017; Smith et al., 2019). Strengthening these organizational conditions may therefore amplify the long-term effectiveness of in-service training programs beyond what can be captured in a single pre-test and post-test evaluation. Future studies examining the moderating role of organizational learning and safety climate on training transfer outcomes would further strengthen the theoretical contribution of this line of research.

Beyond individual performance outcomes, it is important to consider training within the broader organizational context in which it takes place. The effectiveness of in-service training is not solely determined by the content and delivery of the training program itself, but is also shaped by the relationship between the organization and its employees, including the degree of management commitment, organizational support for learning, and the extent to which training activities are embedded within a coherent safety management system. Previous research has consistently demonstrated that training effectiveness in fire service organizations is closely linked to organizational factors such as safety climate, transformational leadership, and management support for safety practices (DeJoy et al., 2017; Smith et al., 2019; Smith et al., 2020). In this sense, the improvements observed in the present study should be understood not only as a product of the training intervention itself, but also as a reflection of the organizational commitment to structured, practice-oriented professional development within the participating fire station. Organizations that systematically invest in regular in-service training and create supportive conditions for skill development are more likely to sustain and build upon the performance gains observed following individual training interventions (Smith et al., 2024). The operational nature of fire stations, particularly those in high-activity urban environments such as capital cities, inherently imposes constraints on research design and data collection. Several limitations of the present study should therefore be considered when interpreting the findings. The study was conducted within a single fire station with a relatively small sample size and without a control group, which limits the generalizability of the results and the strength of causal inferences. Furthermore, the performance assessment checklist was developed as a practical field instrument and was not subjected to formal psychometric validation. These methodological constraints are not uncommon in applied research conducted in emergency and safety-critical contexts, where operational demands frequently restrict the degree of experimental control achievable (Li et al., 2025; Mehner et al., 2024; Niemann and Thielsch, 2020).

Future research should seek to address these limitations across several important directions. Multi-center studies involving multiple fire stations or departments across diverse urban contexts would substantially improve the generalizability of findings and enable more robust comparisons across organizational settings, staffing compositions, and training program structures. Additionally, incorporating repeated follow-up assessments at defined intervals following training completion such as three, six, and twelve months would allow researchers to evaluate whether performance gains are sustained over time or whether skill decay occurs in the absence of continued practice. Future studies would also benefit from examining training effectiveness within a broader organizational framework, integrating measures of management support, safety climate, and employee-organization relationships alongside individual performance outcomes. Finally, the application of Multi-Criteria Decision Making (MCDM) methods could provide a structured and systematic approach to prioritizing training needs across equipment categories, weighting performance criteria according to operational importance, and supporting evidence-based decision making in the planning and evaluation of in-service training programs within fire service organizations.

Despite these limitations, the present study contributes to the applied literature by providing field-based evidence from a real operational environment on the effectiveness of structured in-service training in improving practical equipment operation skills. The findings extend existing research on safety training and workforce development in fire and emergency services, and may help organizational decision-makers in designing, implementing, and evaluating in-service training programs in similar high-risk operational contexts.

5. Conclusion

This study examined the effect of a structured in-service training program on the equipment operation skills of firefighters and technicians using pre-test and post-test design in a real operational setting. The results showed statistically significant improvements in performance scores for all assessed equipment categories after the training, indicating that the program was effective in enhancing practical technical skills. The largest gains were observed in equipment with lower initial performance levels, and performance variability decreased after training, suggesting a more standardized skill level among participants. Although technicians generally achieved higher post-test scores than firefighters, significant differences were limited to only a few tools, indicating that the training benefited both groups. Despite limitations related to the single-site design, small sample size, and lack of a control group, the preliminary findings from this pilot evaluation suggest that structured, hands-on in-service training has the potential to lead to measurable improvements in operational skills in fire service environments, and provide a basis for larger-scale, multi-site investigations.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	N.F.	S.H.H.
C	50	50
D	50	50
S	50	50
DCP	30	70
DAI	50	50
L	70	30
W	80	20
CR	50	50
SR	80	20
PM	80	20

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

References

Bakirci, A. E., Demirel, N., Sar, V., & Cetin, A. (2025). Post-traumatic stress disorder and post-traumatic growth in firefighters: Examining the moderating effects of resilience on occupational safety behaviors. *BMC Public Health*, *25*, Article 1745. https://doi.org/10.1186/s12889-025-22908-9

Bhattarai, S., K.C., P., Gyawali, A., Lamichhane, A., Giri, & Kakchapati, S. (2021). Urban firefighting: Qualitative exploration of occupational challenges faced by firefighters of Kathmandu valley, Nepal. *International Journal of Occupational Safety and Health*, *11*(2), 72–79. https://doi.org/10.3126/ijosh.v11i2.35982

Davis, A. L., Allen, J., Shepler, L., Resick, C., Lee, J., Marinucci, R., & Taylor, J. A. (2020). Moving FOCUS – The fire service organizational culture of safety survey – From research to practice. *Journal of Safety Research*, *74*, 233–247. https://doi.org/10.1016/j.jsr.2020.06.011

DeJoy, D. M., Smith, T. D., & Dyal, M. A. (2017). Safety climate and firefighting: Focus group results. *Journal of Safety Research*, *62*, 107–116.

Fegade, T. K., & Sharma, P. (2023). Exploring the impact of employee training and development on organizational efficiency and effectiveness: A systematic literature review. *IOSR Journal of Business and Management*, *25*(4), 56–63. https://doi.org/10.9790/487X-2504015663

Heydari, A., Ostadtaghizadeh, A., Ardalan, A., Ebadi, A., Mohammadfam, I., & Khorasani-Zavareh, D. (2022). Exploring the criteria and factors affecting firefighters' resilience: A qualitative study. *Chinese Journal of Traumatology*, *25*(2), 107–114. https://doi.org/10.1016/j.cjtee.2021.06.001

Hollerbach, B. S., Jahnke, S. A., Poston, W. S., Harms, C. A., & Heinrich, K. M. (2019). Examining a novel firefighter exercise training program on simulated fire ground test performance, cardiorespiratory endurance, and strength: A pilot investigation. *Journal of Occupational Medicine and Toxicology*, *14*, Article 12. https://doi.org/10.1186/s12995-019-0232-2

Hosen, S. H., Hamzah, S. R., Ismail, I. A., Alias, S. N., Aziz, M. F. A., & Rahman, M. M. (2024). Training & development, career development, and organizational commitment as the predictor of work performance. *Heliyon*, *10*(1), Article e23903. https://doi.org/10.1016/j.heliyon.2023.e23903

Li, Y., Han, Q., Cui, G., & Bai, K. (2025). Evaluation of firefighter training effectiveness based on human physiological signals and improved transfer learning. *Fire Technology*, *61*(1), 1779–1807. https://doi.org/10.1007/s10694-024-01662-1

Mehner, L., Rothenbusch, S., & Kauffeld, S. (2024). How to maximize the impact of workplace training: A mixed-method analysis of social support, training transfer and knowledge sharing. *European Journal of Work and Organizational Psychology*, *34*(2), 201–217. https://doi.org/10.1080/1359432X.2024.2319082

Niemann, L., & Thielsch, M. T. (2020). Evaluation of basic trainings for rescue forces. *Journal of Homeland Security and Emergency Management*, *17*(3), Article 20190062. https://doi.org/10.1515/jhsem-2019-0062

Rosner, B. (2024). *The impact of human performance initiatives in improving physical readiness and resiliency in firefighters* (Publication No. 6307) [Doctoral dissertation, Liberty University]. Liberty University Digital Commons. https://digitalcommons.liberty.edu/doctoral/6307/

Safak, I., Okan, T., & Karademir, D. (2023). Perceptions of Turkish forest firefighters on in-service trainings. *Fire*, *6*(2), Article 38. https://doi.org/10.3390/fire6020038

Smith, T. D. (2020). Examination of safety climate, affective organizational commitment, and safety behavior outcomes among fire service personnel. *Disaster Medicine and Public Health Preparedness*, *14*(5), 559–562. https://doi.org/10.1017/dmp.2019.117

Smith, T. D., & DeJoy, D. M. (2014). Safety climate, safety behaviors and line-of-duty injuries in the fire service. *International Journal of Emergency Services*, *3*(1), 49–64. https://doi.org/10.1108/IJES-04-2013-0010

Smith, T. D., DeJoy, D. M., & Dyal, M. A. (2020). Safety specific transformational leadership, safety motivation and personal protective equipment use among firefighters. *Safety Science*, *131*, Article 104930. https://doi.org/10.1016/j.ssci.2020.104930

Smith, T. D., DeJoy, D. M., Dyal, M. A., Pu, Y., & Dickinson, S. (2019). Multi-level safety climate associations with safety behaviors in the fire service. *Journal of Safety Research*, *69*, 53–60. https://doi.org/10.1016/j.jsr.2019.02.005

Smith, T. D., Mondal, K., Lemons, K., Mullins-Jaime, C., Dyal, M. A., & DeJoy, D. M. (2024). Relationships between effective safety training, safety knowledge and personal protective equipment related behaviors among firefighters. *Journal of Safety Research*, *90*, 137–143. https://doi.org/10.1016/j.jsr.2024.06.010

Souri, A., Ghiyasi, S., & Heidari, M. (2019). Investigation on safety knowledge, attitude, and performance (Safety-KAP) among firefighters of operating units in Tehran. *Jundishapur Journal of Health Sciences*, *11*(3), Article e86749. https://doi.org/10.5812/jjhs.86749

Ütük, A., & Baraçlı, H. (2024). Evaluation of the knowledge and awareness of firefighters in Turkey in disaster risk management. *Sustainability*, *16*(9), Article 3720. https://doi.org/10.3390/su16093720