ผลของโปรแกรมส่งเสริมความปลอดภัยจากอัคคีภัยแบบหลายองค์ประกอบต่อความรู้และพฤติกรรมด้านความปลอดภัยจากอัคคีภัยของบุคลากรมหาวิทยาลัย: การติดตามผลระยะเวลา 12 สัปดาห์

Effects of a Multicomponent Fire Safety Promotion Program on Fire Safety Knowledge and Behaviors among University Personnel: A 12-Week Follow-Up Study

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บทคัดย่อ

อัคคีภัยยังคงเป็นปัญหาสำคัญด้านความปลอดภัยสาธารณะ ซึ่งก่อให้เกิดการบาดเจ็บ การเสียชีวิต ความเสียหายต่อทรัพย์สิน และการหยุดชะงักของการดำเนินงาน การส่งเสริมความรู้และพฤติกรรมด้านความปลอดภัยจากอัคคีภัยในบุคลากรมีความสำคัญต่อการเพิ่มความพร้อมในการรับมือเหตุฉุกเฉินและการลดความเสี่ยงที่เกี่ยวข้องกับอัคคีภัย การศึกษานี้มีวัตถุประสงค์เพื่อประเมินผลของโปรแกรมส่งเสริมความปลอดภัยจากอัคคีภัยต่อความรู้และพฤติกรรมด้านความปลอดภัยจากอัคคีภัยของบุคลากรสำนักวิทยบริการและเทคโนโลยีสารสนเทศ มหาวิทยาลัยราชภัฏพระนครศรีอยุธยา ดำเนินการวิจัยกึ่งทดลองแบบกลุ่มเดียววัดก่อนและหลังการทดลองในบุคลากรมหาวิทยาลัยจำนวน 30 คน ซึ่งเข้าร่วมโปรแกรมส่งเสริมความปลอดภัยจากอัคคีภัยแบบหลายองค์ประกอบ โปรแกรมประกอบด้วยการให้ความรู้ด้านการป้องกันอัคคีภัย การฝึกอบรมการตอบโต้เหตุฉุกเฉิน การปรับปรุงสภาพแวดล้อมด้านความปลอดภัย และการเสริมแรงพฤติกรรมอย่างต่อเนื่องตลอดระยะเวลา 12 สัปดาห์ ประเมินความรู้ด้านความปลอดภัยจากอัคคีภัยในระยะก่อนดำเนินการและสัปดาห์ที่ 4 ขณะที่พฤติกรรมด้านความปลอดภัยจากอัคคีภัยได้รับการประเมินในระยะก่อนดำเนินการ และติดตามผลในสัปดาห์ที่ 4, 8 และ 12 วิเคราะห์ข้อมูลด้วยสถิติเชิงพรรณนา ทดสอบ paired t-tests และ repeated measures analysis of variance ผลการศึกษาพบว่า คะแนนความรู้ด้านความปลอดภัยจากอัคคีภัยโดยรวมเพิ่มขึ้นอย่างมีนัยสำคัญหลังการดำเนินโปรแกรม (ผลต่างค่าเฉลี่ย = 2.54 คะแนน, $p < 0.001$) โดยพบการพัฒนาสูงสุดในด้านความรู้เกี่ยวกับการป้องกันอัคคีภัยและการตอบโต้เหตุฉุกเฉิน พฤติกรรมด้านความปลอดภัยจากอัคคีภัยเพิ่มขึ้นอย่างมีนัยสำคัญตลอดระยะเวลาติดตามผล 12 สัปดาห์ ($p < 0.001$) โดยการพัฒนาสูงสุดพบในด้านการมีส่วนร่วมในกิจกรรมความปลอดภัย การปฏิบัติการตอบโต้เหตุฉุกเฉิน และการเตรียมความพร้อมด้านการอพยพ อย่างไรก็ตาม พฤติกรรมเชิงรุกด้านความปลอดภัย ได้แก่ การระบุอันตราย การตรวจสอบถังดับเพลิงเป็นประจำ และการเรียนรู้ด้วยตนเอง ยังคงมีระดับค่อนข้างต่ำกว่าด้านอื่น ๆ สรุป โปรแกรมส่งเสริมความปลอดภัยจากอัคคีภัยแบบหลายองค์ประกอบสามารถพัฒนาความรู้และพฤติกรรมด้านความปลอดภัยจากอัคคีภัยของบุคลากรมหาวิทยาลัยได้อย่างมีประสิทธิผล การเสริมแรงพฤติกรรมอย่างต่อเนื่องและกิจกรรมติดตามผลมีส่วนช่วยคงไว้ซึ่งพฤติกรรมด้านความปลอดภัยเมื่อเวลาผ่านไป และสนับสนุนการพัฒนาโปรแกรมส่งเสริมความปลอดภัยจากอัคคีภัยที่มีประสิทธิผลในสถาบันอุดมศึกษา

คำสำคัญ: การป้องกันอัคคีภัย การแทรกแซงแบบหลายองค์ประกอบ การเปลี่ยนแปลงพฤติกรรม บุคลากรมหาวิทยาลัย ความพร้อมรับมือเหตุฉุกเฉิน

Abstract

Fire incidents remain a significant public safety concern, causing injuries, fatalities, property damage, and operational disruptions. Promoting fire safety knowledge and behaviors among personnel is essential for enhancing emergency preparedness and reducing fire-related risks. This study aimed to evaluate the effects of a fire safety promotion program on fire safety knowledge and behaviors among personnel at the Academic Resource and Information Technology Office, Phranakhon Si Ayutthaya Rajabhat University. A one-group pretest-posttest quasi-experimental study was conducted among 30 university personnel participating in a multicomponent fire safety promotion program. The intervention included fire prevention education, emergency response training, environmental safety improvements, and continuous behavioral reinforcement over 12 weeks. Fire safety knowledge was assessed at baseline and week 4, while fire safety behaviors were evaluated at baseline and followed up at weeks 4, 8, and 12. Data were analyzed using descriptive statistics, paired t-tests, and repeated measures analysis of variance. The findings demonstrated significant improvements in overall fire safety knowledge after the intervention (mean difference = 2.54 points, $p < 0.001$), with the greatest improvements observed in fire prevention and emergency response knowledge domains. Fire safety behaviors also increased significantly throughout the 12-week follow-up period ($p < 0.001$). The greatest improvements were observed in participation in safety activities, emergency response practices, and evacuation preparedness. However, proactive safety behaviors, including hazard identification, routine fire extinguisher inspection, and self-directed learning, remained relatively lower than other domains. The multicomponent fire safety promotion program effectively improved fire safety knowledge and behaviors among university personnel. Continuous reinforcement and follow-up activities may contribute to sustaining safety behaviors over time and support the development of effective fire safety promotion programs in educational institutions.

Keywords: Fire prevention, Multicomponent intervention, Behavior change, University personnel, Emergency preparedness

1. Introduction

Fire incidents represent a major public safety concern worldwide, affecting human life, property, economic activities, and organizational operations. In particular, fires in public buildings, offices, and educational institutions may result in injuries, fatalities, substantial property damage, and prolonged disruptions to organizational operations. According to reports from the National Fire Protection Association (NFPA), fire incidents continue to cause substantial numbers of deaths, injuries, and economic losses each year, while indirect losses resulting from business interruption may be comparable to the physical damage caused to buildings themselves [1], [2]. Furthermore, the International Labour Organization (ILO) and the World Health Organization (WHO) have reported that occupational injuries and diseases not only affect workers' health and safety but also reduce productivity, impair organizational performance, and increase long-term economic costs. The ILO has estimated that occupational injuries and diseases account for approximately 4% of the global gross domestic product (GDP) annually [3]. Similarly, fire incidents continue to occur in Thailand, particularly in public buildings, educational institutions, and

workplaces, highlighting the importance of strengthening fire prevention measures, emergency preparedness, and personnel safety competencies to minimize human and economic losses [4].

Fire incidents occurring within buildings are associated with multiple risk factors, including electrical systems, electronic equipment, combustible materials, and workers' behaviors. Human factors have been widely recognized as critical contributors to workplace accidents and emergency events, encompassing individual, organizational, and environmental factors that influence workers' safety behaviors [5]. Major fire disasters in Thailand, such as the Santika Pub fire, Mountain B Pub fire, and Lat Phrao brewery fire have demonstrated that inadequate preventive measures, insufficient emergency preparedness, and ineffective safety management can lead to catastrophic losses of life and property [6]. In addition, modern office buildings and educational institutions increasingly rely on electrical equipment and information technology systems, which may increase the complexity of fire risk management [7]. Academic resource and information technology centers are particularly vulnerable because they accommodate large numbers of users while operating extensive electrical and information technology infrastructure, emphasizing the need for personnel who possess adequate fire safety knowledge and appropriate emergency response behaviors [8].

Fire safety knowledge is considered one of the essential determinants of safe behavior during fire emergencies. Personnel with adequate knowledge of fire prevention, fire extinguisher use, evacuation procedures, and emergency response are more likely to recognize hazards, respond appropriately during emergencies, and reduce fire-related injuries and losses [9], [10]. According to the health belief model, individuals are more likely to adopt preventive behaviors when they perceive fire as a serious threat, recognize their susceptibility to potential hazards, and believe that preventive actions are effective in reducing risk [11], [12]. Therefore, effective fire safety promotion programs should strengthen not only knowledge but also risk perception and self-efficacy to promote sustained safety behaviors. Several studies have demonstrated that educational interventions and practical fire drills can significantly improve fire safety knowledge, emergency preparedness, and evacuation performance among employees and students [13], [14].

Previous studies have demonstrated that fire safety education programs can improve participants' fire safety knowledge, emergency preparedness, and safety behaviors immediately after training. However, accumulating evidence indicates that the beneficial effects of safety training on knowledge and safety behaviors may gradually decline over time in the absence of periodic reinforcement or refresher training, emphasizing the importance of longitudinal follow-up to evaluate the sustainability of intervention effects [15], [16]. Repeated follow-up assessments are therefore essential to determine whether immediate improvements are maintained over time.

Although previous studies have demonstrated the immediate benefits of fire safety education, evidence regarding the sustained effectiveness of multicomponent fire safety promotion programs with repeated behavioral follow-up among university personnel remains limited, particularly in Thailand. Furthermore, few studies have simultaneously evaluated changes in both fire safety knowledge and safety behaviors over an extended follow-up period. Therefore, this study aimed to evaluate the short-term effectiveness and 12-week sustainability of a multicomponent fire safety promotion program on fire safety knowledge and behaviors among university personnel over a 12-week follow-up period.

2. Materials and methods

2.1. Study design

This study employed a one-group pretest-posttest quasi-experimental design to evaluate the effects of a multicomponent fire safety promotion program on fire prevention and suppression knowledge and fire safety behaviors among personnel at the Academic Resource and Information Technology Office, Phranakhon Si Ayutthaya Rajabhat University. The study was conducted from December 2025 to April 2026. Fire safety knowledge was assessed before and after the intervention, while fire safety behaviors were repeatedly assessed at baseline and at weeks 4, 8, and 12 after the intervention.

2.2. Population and sample

The study population consisted of all 30 personnel working at the Academic Resource and Information Technology Office, Phranakhon Si Ayutthaya Rajabhat University. A total population sampling, or census approach, was used because the study targeted all eligible personnel within this single organizational unit. Therefore, no cluster sampling procedure was applied. A formal sample size calculation was not performed because the entire accessible population was invited to participate. This approach was selected to maximize population coverage and minimize selection bias within the study setting.

Eligible participants were personnel who were employed at the office during the study period, were able to participate in the program and follow-up assessments, and voluntarily provided informed consent. Personnel who planned to resign, transfer, or take extended leave during the 12-week follow-up period were excluded. All 30 eligible personnel agreed to participate, completed the baseline assessment, and were successfully followed up at all assessment time points, with no loss to follow-up.

2.3. Fire safety promotion program

The fire safety promotion program was designed to improve fire safety knowledge and promote fire safety behaviors among personnel. The program was implemented over 12 weeks and consisted of a 4-week core intervention phase followed by an 8-week behavioral follow-up and reinforcement phase. The program integrated four components: fire safety education, practical emergency response training, environmental safety improvement, and continuous behavioral reinforcement. A standardized intervention manual, session plan, presentation materials, activity checklists, and assessment procedures were used throughout the program to ensure consistency and replicability.

In week 1, a 2-hour session was conducted, including an explanation of the study objectives, baseline assessment of fire safety knowledge and behaviors, and training on fire prevention. The training covered causes and risk factors of fire incidents, workplace fire risk assessment, inspection of fire extinguishing equipment, and fire prevention practices in office settings. Instruction was delivered using standardized presentation slides, examples of workplace fire hazards, and a structured fire-risk inspection checklist.

In week 2, a 2-hour session focused on basic fire suppression and emergency response. The content included emergency notification systems, alarm signals, selection of appropriate fire extinguishers according to fire type, demonstration of safe fire extinguisher use, and initial response procedures for early-stage fire incidents. The session included instructor demonstration and supervised hands-on practice using fire extinguishing equipment, allowing each participant to practice the specified response procedures.

In week 3, a 2-hour session addressed emergency preparedness and fire evacuation. The session covered evacuation procedures, assembly points, observation of wind direction and smoke

movement, safe assistance for affected individuals, and site-based inspection of evacuation routes and fire extinguishing equipment locations. Participants completed a structured walk-through of the workplace to identify evacuation routes, emergency exits, assembly points, fire alarm locations, and fire extinguishing equipment.

In week 4, a 2-hour session focused on safety participation and post-intervention assessment. Activities included knowledge review, improvement and communication of safety signs, evacuation routes, and assembly points, as well as encouraging personnel to participate in identifying and reporting fire hazards, inspecting fire extinguishing equipment, and complying with workplace safety measures. Fire safety knowledge and behaviors were reassessed after completion of the core intervention. The session also included feedback on identified workplace hazards and reinforcement of the key practices introduced during the preceding sessions.

All core intervention sessions were delivered by the same instructor, holding in Occupational Health and Safety and completing professional training in fire prevention and emergency response management. The same intervention manual, teaching materials, activity sequence, session duration, and practical checklists were applied to all participants. Attendance was recorded at every session, and completion checklists were used to confirm that each participant received the required intervention activities. All participants attended and completed every scheduled intervention session; therefore, no make-up sessions were required. These procedures were implemented to maintain intervention fidelity and ensure a consistent intervention dosage across participants.

After the 4-week core intervention, behavioral follow-up and reinforcement were conducted during weeks 5-12. These activities included communication of fire safety information, reminders to comply with safety measures, encouragement to identify and report unsafe conditions, and follow-up on inspection of fire extinguishing equipment and evacuation routes. Standardized fire safety messages and reminders were delivered through the LINE application once a week throughout the 8-week follow-up period. In addition, educational infographics and motivational messages promoting fire safety practices were shared, and participants were encouraged to ask questions and report potential fire hazards through the LINE. Environmental improvements, including updated safety signs, clearly displayed evacuation routes, and visible assembly-point information, remained in place throughout the follow-up period as continuous environmental cues. Fire safety behaviors were reassessed at weeks 8 and 12 to evaluate behavioral trends and maintenance after the intervention.

2.4. Research instruments and quality assessment

The research instruments were developed based on a literature review and previous studies related to fire safety knowledge and behaviors. The instrument consisted of three sections, with a total of 30 items.

The first section included five items on demographic and occupational characteristics: sex, age, educational level, work experience, and history of occupational injury.

The second section was a 10-item fire prevention and suppression knowledge test using true–false questions. It was divided into three domains: fire prevention knowledge (4 items), fire suppression knowledge (2 items), and emergency response and evacuation knowledge (4 items). Correct answers were scored as 1, while incorrect answers were scored as 0.

The third section was a 15-item fire safety behavior questionnaire using a four-point rating scale. It consisted of four domains: fire prevention

behavior (4 items), safety communication and participation (4 items), emergency response behavior (3 items), and emergency preparedness and evacuation behavior (4 items).

Content validity was evaluated by three experts with expertise in occupational health and safety, fire prevention, emergency management, and research methodology. Each expert assessed the relevance and congruence of individual items with the study objectives and operational definitions. The Index of Item–Objective Congruence (IOC) ranged from 0.67 to 1.00. Item analysis of the fire safety knowledge test demonstrated acceptable psychometric properties, with item difficulty indices ranging from 0.30 to 0.80 and item discrimination indices ranging from 0.20 to 0.67. The knowledge test showed satisfactory reliability (KR-20 = 0.81), while the fire safety behavior questionnaire demonstrated acceptable internal consistency (Cronbach's alpha = 0.85).

2.5. Data collection

Data were collected sequentially. The researcher explained the study objectives, procedures, and participant rights. Participants then completed the fire safety knowledge test and fire safety behavior questionnaire before the intervention. The fire safety promotion program was then implemented over four weeks. After completion of the core intervention, fire safety knowledge was reassessed at week 4, while fire safety behaviors were assessed at weeks 4, 8, and 12 to examine behavioral changes and maintenance after the intervention.

The dates of all assessments were scheduled in advance in coordination with the participating unit. Participants received follow-up reminders through LINE approximately 3 days before each assessment. The researcher also coordinated with the unit representative to confirm participant availability and promptly reschedule assessments when necessary. These procedures were used to minimize attrition and ensure completion of all repeated assessments. Participant attendance and completion status were monitored using a follow-up tracking form. No participant resigned, transferred, withdrew, or was lost to follow-up during the 12-week study period; therefore, complete data were available for all 30 participants at each assessment time point.

The study was approved by the Human Research Ethics Committee of Phranakhon Si Ayutthaya Rajabhat University, approval number ARU-REC 022/2025, dated January 21, 2026.

2.6. Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, Version 26.0. Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to describe participant characteristics. Paired t-tests were used to compare fire safety knowledge scores between baseline and week 4. Mean differences, 95% confidence intervals, and Cohen’s d were also reported. Changes in fire safety behavior scores at baseline and weeks 4, 8, and 12 were analyzed using repeated measures analysis of variance. Mauchly’s test was used to assess sphericity, and the Greenhouse-Geisser correction was applied when necessary. F statistics, degrees of freedom, p-values, and partial eta squared were reported. Bonferroni-adjusted pairwise comparisons were conducted for significant overall effects.

Statistical significance was set at $p < 0.05$. Absolute and relative changes were calculated, and item-level mean scores at week 12 were ranked to identify the highest- and lowest-performing behaviors. Subgroup analyses by age and work experience were not conducted because the subgroup distributions were highly imbalanced and insufficient for reliable comparison.

3. Results

3.1. Characteristics of participants

The demographic and occupational characteristics of the study participants. Of the 30 participants included in the study, the majority were female (76.7%), aged between 41 and 50 years (80.0%), and had attained at least a bachelor's degree (93.3%). Most participants had more than 10 years of working experience (96.7%). Only one participant (3.3%) reported a history of occupational injury (Table 1)

Table 1 Characteristics of study participants (n=30)

Characteristics	n	%
Sex		
Male	7	23.3
Female	23	76.7
Age group (years)		
31–40	2	6.7
41–50	24	80.0
≥51	4	13.3
Education		
Below bachelor's degree	2	6.7
Bachelor's degree or higher	28	93.3
Working experience		
<10 years	1	3.3
≥10 years	29	96.7
Previous occupational injury		
No	29	96.7
Yes	1	3.3

3.2. Changes in fire safety knowledge after intervention

Table 2 presents changes in fire safety knowledge before and after the multicomponent fire safety promotion program. Overall knowledge increased significantly from 6.07 ± 1.73 at baseline to 8.61 ± 1.21 at week 4, with a mean difference of 2.54 points (95% CI: 1.97-3.11; Cohen's d = 1.70; $p < 0.001$). Significant improvements were also observed in fire prevention knowledge, emergency response and evacuation knowledge, and fire suppression knowledge. The estimated effect sizes ranged from moderate to large, indicating that the improvements were meaningful in practical terms.

Figure 1 illustrates the study design and participant flow throughout the intervention period. All eligible participants completed the baseline assessment, participated in the four-week safety promotion program, and were successfully followed up at weeks 4, 8, and 12, resulting in no loss to follow-up (Figure 1).

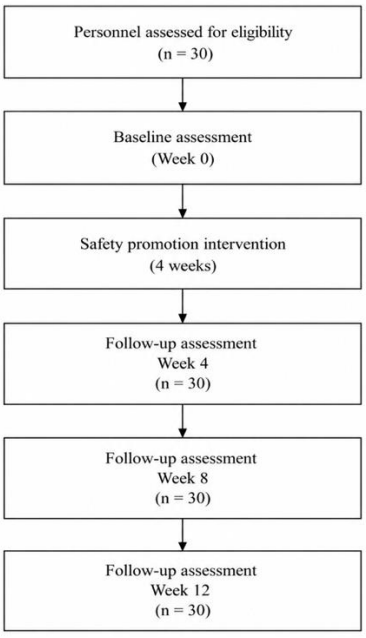


Figure 1 Study flow diagram

3.3. Longitudinal changes in fire safety behavior

Table 3 presents longitudinal changes in fire safety behaviors over the 12-week follow-up period. The overall fire safety behavior score increased significantly from 2.23 ± 0.77 at baseline to 2.84 ± 0.32 at week 12 ($F = 27.91$, $df = 3,87$, partial $\eta^2 = 0.49$, $p < 0.001$), corresponding to a relative improvement of 27.4%, indicating a large intervention effect. Among

Table 2 Changes in fire safety knowledge after intervention (n=30)

Knowledge domain	Baseline score (Mean ± SD)	Week 4 score (Mean ± SD)	Mean difference	95% CI of mean difference	% Improvement	Cohen's d	p
Fire prevention	2.42 ± 0.98	3.50 ± 0.62	1.08	0.76-1.40	44.6	1.32	<0.001**
Fire suppression	1.19 ± 0.68	1.63 ± 0.49	0.44	0.21-0.67	37.0	0.74	0.014*
Emergency response	2.45 ± 0.91	3.48 ± 0.67	1.03	0.73-1.33	42.0	1.29	<0.001**
Overall	**6.07 ± 1.73**	**8.61 ± 1.21**	**2.54**	**1.97-3.11**	**41.8**	**1.70**	**<0.001****

Note: Values are presented as mean ± standard deviation. Mean differences were calculated as week 4 minus baseline scores. P-values were obtained by paired-samples t-tests.

Table 3 Longitudinal changes in fire safety behavior following the safety promotion intervention

Behavioral domain	Baseline	Week 4	Week 8	Week 12	Relative improvement (%)	Repeated measures ANOVA
Preventive safety	1.77 ± 0.92	2.34 ± 0.80	2.55 ± 0.63	2.73 ± 0.44	+54.2	F = 24.68, df = 3,87, η^2p = 0.46, p < 0.001**
Safety communication and participation	2.51 ± 0.70	2.77 ± 0.44	2.79 ± 0.42	2.89 ± 0.32	+15.1	F = 8.95, df = 3,87, η^2p = 0.24, p < 0.001**
Emergency response	2.48 ± 0.63	2.68 ± 0.54	2.81 ± 0.35	2.87 ± 0.18	+15.7	F = 5.87, df = 3,87, η^2p = 0.17, p = 0.002*
Evacuation and preparedness	2.22 ± 0.83	2.36 ± 0.72	2.59 ± 0.57	2.86 ± 0.34	+28.8	F = 15.34, df = 3,87, η^2p = 0.35, p < 0.001**
Overall	**2.23 ± 0.77**	**2.54 ± 0.63**	**2.69 ± 0.49**	**2.84 ± 0.32**	**+27.4**	**F = 27.91, df = 3,87, η^2p = 0.49, p < 0.001****

Note: Values are presented as mean ± standard deviation. Statistical significance was assessed using repeated measures analysis. *p<0.05, **p<0.001

the behavioral domains, preventive safety behavior exhibited the greatest improvement (+54.2%), followed by evacuation and preparedness behavior (+28.8%).

Improvements in safety communication and participation (+15.1%) and emergency response behavior (+15.7%) were also observed. These results demonstrate sustained behavioral changes following the implementation of the safety promotion intervention (Table 3).

The progressive increase in behavioral scores throughout the follow-up period suggests that the intervention not only improved participants' knowledge but also facilitated long-term adoption of fire safety practices.

The mean overall fire safety behavior score increased progressively over time, rising from 2.23 at baseline to 2.54 at week 4, 2.69 at week 8, and 2.84 at week 12. The observed upward trend indicates sustained improvements in fire safety practices following the intervention. The relatively small error bars observed after the intervention suggest consistent improvements in fire safety behavior among participants throughout the follow-up period (Figure 2).

3.4. Summary of intervention outcomes

The magnitude of changes in fire safety knowledge and behaviors following the intervention. Overall fire safety knowledge increased by 41.8%, with the greatest improvements observed in fire prevention knowledge (44.6%) and emergency response and evacuation knowledge (42.0%). Fire safety behaviors also improved substantially, with the largest relative increase observed in fire prevention behavior (54.2%), followed by emergency preparedness and evacuation behavior (28.8%). These findings indicate that the multicomponent fire safety promotion program produced meaningful improvements in both knowledge and safety behaviors among participants. (Table 4).

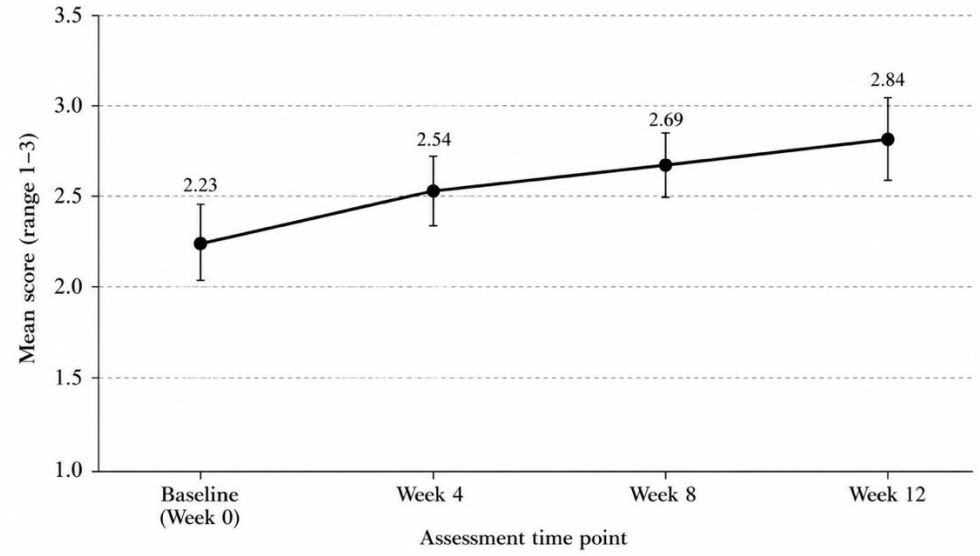


Figure 2 Longitudinal changes in overall fire safe behavior scores

(Values are mean ± standard deviation. Error bars represent standard deviation)

Table 4 Summary of intervention outcomes

Outcome	Baseline	Follow-up	Absolute Change	Relative Change (%)
Overall knowledge	**6.07**	**8.61**	**+2.54**	**+41.8**
- Fire prevention knowledge	2.42	3.50	+1.08	+44.6
- Fire suppression knowledge	1.19	1.63	+0.44	+37.0
- Emergency response and evacuation knowledge	2.45	3.48	+1.03	+42.0
Overall behavior	**2.23**	**2.84**	**+0.61**	**+27.4**
- Fire prevention behavior	1.77	2.73	+0.96	+54.2
- Safety communication and participation	2.51	2.89	+0.38	+15.1
- Emergency response behavior	2.48	2.87	+0.39	+15.7
- Emergency preparedness and evacuation behavior	2.22	2.86	+0.64	+28.8

Note: Absolute change was calculated as the difference between follow-up and baseline scores. Relative change (%) was calculated as the percentage increase relative to baseline values.

Figure 3 presents the relative improvement in fire safety behaviors across behavioral domains from baseline to week 12. Preventive safety behavior demonstrated the greatest improvement (+54.2%), followed by evacuation and preparedness behavior (+28.8%). Smaller but meaningful improvements were observed in emergency response behavior (+15.7%) and safety communication and participation (+15.1%). These findings indicate that the intervention was particularly effective in promoting proactive fire prevention practices

3.5. Highest and lowest performing fire safety behavior

To provide a more detailed interpretation of behavioral outcomes, individual questionnaire items were ranked according to their mean scores at week 12. The three highest- and three lowest-performing indicators are presented in Table 5.

4. Discussion

The present study demonstrated that the fire safety promotion program significantly improved fire prevention and suppression knowledge among personnel at the Academic Resource and Information Technology Office. Overall fire safety knowledge scores increased significantly following the intervention, with relative improvements of 41.8% in overall knowledge, 44.6% in fire prevention knowledge, and 42.0% in emergency response and evacuation knowledge. These findings may be explained by the use of active learning strategies, group discussions, and context-specific learning activities that enabled participants to engage with realistic workplace situations and apply newly acquired knowledge to their own work environment. Previous studies have reported that active learning approaches and experiential safety training can improve knowledge retention and learning outcomes more effectively than traditional lecture-based instruction alone [10], [13]. These findings are also consistent with the health belief model, suggesting that increased knowledge may enhance awareness of fire-related risks and strengthen motivation to adopt appropriate preventive behaviors, thereby facilitating subsequent behavioral change.

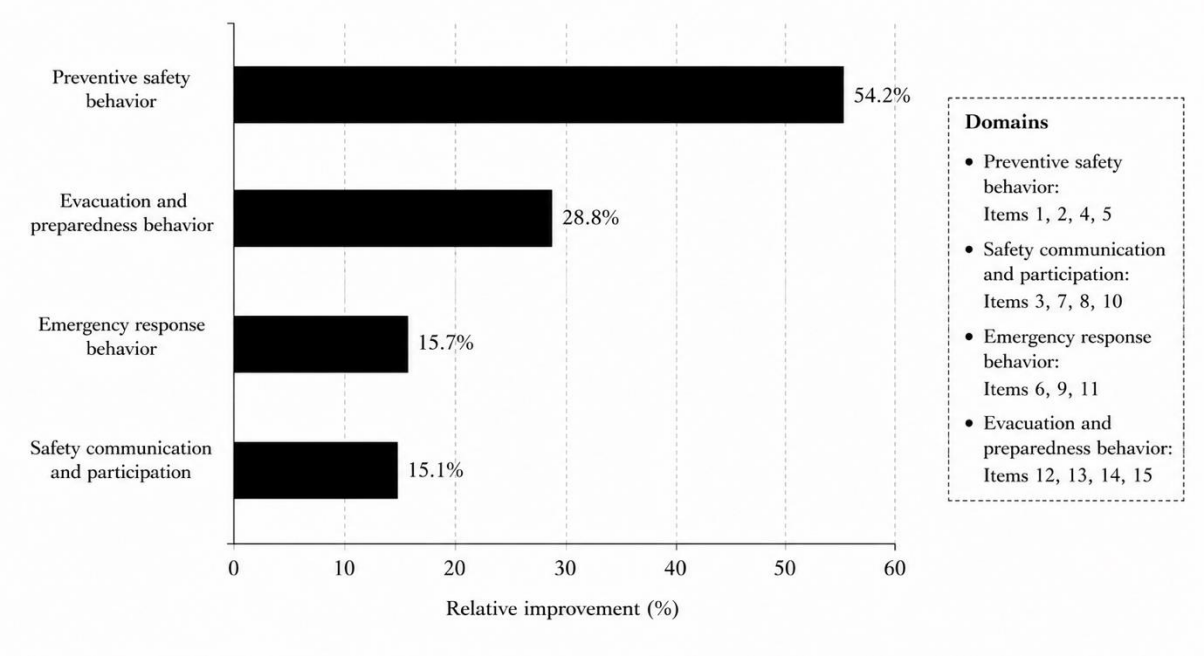


Figure 3 Relative improvement in fire safety behavior by domain from baseline to week 12

(Relative improvement (%) = (week 12 mean - Baseline mean) / Baseline mean x 100)

Table 5 Highest and lowest performing fire safety behavior indicators at 12-week follow-up

Category	Indicator	Week 12 (Mean ± SD)
Highest	Participation in fire safety training and drills	2.93 ± 0.25
	Responding appropriately to small fire incidents	2.90 ± 0.31
	Immediate evacuation following emergency alarms	2.86 ± 0.34
Lowest	Identification of fire hazard areas	2.37 ± 0.70
	Routine inspection of nearby fire extinguishers	2.60 ± 0.54
	Self-directed learning on fire prevention and suppression	2.72 ± 0.60

The findings of this study are consistent with previous studies demonstrating that workplace safety training and safety promotion programs can effectively enhance safety knowledge, risk perception, and emergency response capabilities among participants. Multicomponent safety interventions that combine educational activities, practical exercises, and continuous reinforcement have been shown to improve safety-related competencies more effectively than single-component interventions [17], [18]. Therefore, the findings of this study support the concept that systematic safety promotion programs can contribute substantially to improving personnel preparedness for fire emergencies. The large effect sizes observed in the present study further suggest that the intervention produced not only statistically significant improvements but also meaningful practical benefits for workplace fire safety.

However, knowledge related to the selection and use of fire extinguishers remained relatively lower than other knowledge domains despite participation in training activities. This finding may indicate that knowledge involving practical decision-

making and equipment selection requires hands-on practice and experiential learning rather than passive information acquisition alone. Previous studies have demonstrated that simulation-based and experiential training approaches can improve practical decision-making skills, confidence, and the ability to apply knowledge in real emergency situations more effectively than didactic teaching methods [19], [20]. Another possible explanation is that the selection and inspection of fire extinguishers may be perceived as the responsibility of facility management personnel rather than individual employees, reducing opportunities for routine engagement with fire safety equipment. Furthermore, participants may still experience uncertainty regarding fire classification and the appropriate selection of fire extinguishers, suggesting that additional practical training and simulation exercises should be incorporated into future fire safety promotion programs.

The present study also found that fire safety behaviors significantly improved throughout the 12-week follow-up period. The greatest improvements were observed in fire prevention behaviors, followed by emergency preparedness and evacuation behaviors. These findings suggest that safety promotion programs incorporating educational activities, environmental modifications, and continuous behavioral reinforcement can effectively facilitate behavioral change. Previous studies have demonstrated that multicomponent safety interventions and behavior-based safety approaches are effective in improving workplace safety behaviors and promoting sustainable behavioral change [17], [21]. Moreover, theories of health behavior change and occupational safety behavior suggest that sustainable safety behaviors require knowledge acquisition, risk perception, organizational support, and continuous reinforcement [14]. The large intervention effects observed across repeated assessments further indicate that these improvements were not only statistically significant but also meaningful in practical workplace settings.

Another important finding was that safety behavior scores continued to increase from week 4 through week 12, indicating the maintenance of behavioral changes following the intervention. This sustained improvement may be attributed to the multicomponent intervention approach, which combined education, safety communication, environmental improvements, and continuous behavioral reinforcement. Such approaches provide repeated exposure to safety-related information and facilitate long-term behavioral adaptation. In addition, regular safety reminders and visible environmental cues, such as evacuation signs and assembly-point information, may have reinforced safe practices by encouraging participants to consistently apply what they had learned in their daily work. These findings are consistent with previous studies indicating that behavioral follow-up, feedback, and reinforcement are essential components for maintaining safety behaviors and improving the effectiveness of workplace safety promotion programs [22], [23].

When examining individual safety behaviors, participation in safety activities, emergency response actions during minor fire incidents, and emergency evacuation practices demonstrated the highest scores. In contrast, proactive safety behaviors, such as hazard identification, routine fire extinguisher inspections, and self-directed learning, remained relatively lower than other safety behaviors. These findings suggest that behaviors requiring personal initiative and proactive safety monitoring continue to present challenges in organizational safety management. Previous studies have shown that proactive safety behaviors require not only individual motivation and risk perception but also strong organizational support and an established

safety culture [24], [25]. In addition, employees may perceive routine fire extinguisher inspection as the responsibility of designated safety or facility personnel, while routine work demands may reduce opportunities for self-directed fire safety learning. Therefore, future fire safety promotion programs should emphasize the development of safety culture and encourage personnel participation in continuous hazard identification and risk management activities [26], [27]. Encouraging greater individual ownership of workplace safety may further strengthen proactive fire safety behaviors beyond participation in scheduled training activities.

The strengths of this study include the implementation of a multicomponent fire safety promotion program combined with a 12-week follow-up period, allowing for the evaluation of both knowledge improvement and the maintenance of safety behaviors over time. However, several limitations should be acknowledged. First, the study employed a one-group quasi-experimental design without a control group, which limits the ability to establish causal relationships. Second, the relatively small sample size may affect the generalizability of the findings. Third, safety behaviors were assessed using self-reported questionnaires, which may have been influenced by social desirability bias. Fourth, because the study was conducted in a single university office, the findings should be generalized to other organizational settings with caution. Finally, participants were aware that they were participating in the study, and therefore the Hawthorne effect may have contributed to improvements in self-reported safety behaviors. Therefore, future studies should consider using controlled study designs, larger sample sizes, and objective behavioral assessments, such as observational methods, to further strengthen the evidence regarding the effectiveness of fire safety promotion interventions.

5. Conclusion

This study demonstrated that a multicomponent fire safety promotion program significantly improved fire safety knowledge and behaviors among university personnel. The program increased overall fire safety knowledge by 41.8% and achieved a sustained 27.4% improvement in overall fire safety behaviors throughout the 12-week follow-up period. The intervention produced sustained improvements in safety behaviors throughout the 12-week follow-up period, suggesting that the integration of education, practical training, environmental modifications, and continuous behavioral reinforcement may effectively promote long-term fire safety practices. These findings suggest that the multicomponent approach may provide a practical model for strengthening fire safety culture and emergency preparedness in higher education institutions. Future research should employ controlled designs and longer follow-up periods to further investigate the sustainability of fire safety promotion interventions.

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