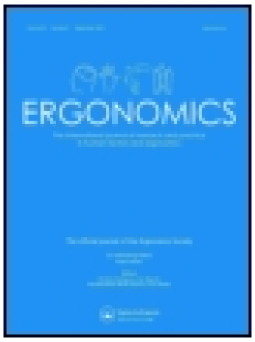

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Comparison of the effect of typical firefighting activities, live fire drills and rescue operations at height on firefighters' physiological responses and cognitive function

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Comparison of the effect of typical firefighting activities, live fire drills and rescue operations at height on firefighters' physiological responses and cognitive function

Abstract

This study examined the impact of various types of firefighting activities on firefighters' physiological responses and cognitive function. Each firefighter was engaged in three conditions: (1) Live-fire activities (LFA), (2) Typical firefighting activities (TFA), and (3) Rescue operations at height (ROH). The effects of various types of firefighting activities on the physiological responses and cognitive function were evaluated by heart rate (HR), temporal artery temperature (TT), and the correct response (CR) on a cognitive test. The results indicated that, compared to the baseline, physiological response increased, while information processing performance decreased after the activity. Furthermore, HR and TT were significantly lower at the end of the firefighting activity in the LFA (149.33 bpm; 38.08 °C) compared with the TFA (152.22 bpm; 38.17 °C) and ROH (159.28 bpm; 38.24 °C) conditions. Also, CR was significantly higher at the end of the activity in the LFA and TFA compared with the ROH condition. The results showed that rescue at height was more intensive than the other firefighting tasks in decreasing physiological and cognitive function capacity after the experiment.

Keywords: cognitive function; firefighting activities; psychophysiological responses

Word count of text: 4730

Practitioner Summary:

We assumed that various types of firefighting activities would have different effects on physiological and cognitive functions during firefighting activities. The Findings suggest that rescue at height operations, performed without the use of special protective equipment, was more influential than other firefighting duties in changing firefighters' physiological and cognitive capacity.

1. Introduction

Firefighting is an occupation that demands high physiological and psychological stamina. Unlike many other professions, firefighters carry out strenuous physical activities, such as suppressing fire, handling hazardous substances, performing various tasks, searching for victims and trying to rescue them, for an unpredictable amount of time (Hemmatjo et al. 2017b). They usually perform their duties in hot and hostile environments while wearing thick and heavy clothing (Barr et al., 2010; Hemmatjo et al., 2017c; Selkirk et al., 2004). Firefighting tasks impose considerable pressures on firefighters' physiological responses. Physiological strain results from multiple factors, including (1) the metabolic heat raised by working muscles, (2) the heavy, thick, non-permeable protective clothing which adds to the metabolic work rate and, in some cases, (3) the radiant heat associated with the fire (Smith et al., 2001a).

The effect of typical firefighting activities, protective clothing and strenuous environments on the physiological responses in firefighters during moderate-intensity activities is well documented (Barr et al., 2011; Hemmatjo et al., 2017a; Larsen et al., 2015). Several studies have reported that physiological responses reach maximal values very quickly and remain high during firefighting activities. Investigations by Larsen et al. (2015) on the effect of heat and simulated typical firefighting activities on firefighters' physiological responses showed that the core temperature was notably higher in the hot condition ($P = 0.001$), reaching 38.2 ± 0.3 °C compared to an average of 37.9 ± 0.3 °C in the control condition. Also, displayed skin temperature reached 37.0 ± 0.5 °C in the hot condition compared to 34.4 ± 0.5 °C in the control environment ($P = 0.001$). Previous research has reported higher heart rate and core temperature after live burn activities when compared to baseline (Colburn et al., 2011). Another study examined the influence of wearing a different firefighting protective clothing on firefighters' physiological responses. The selected participants were involved in a treadmill exercise for at least 20 minutes in an environmental chamber (22°C, 50% RH). Another study focused on physiological responses to wearing different firefighting protection clothing in an environmental chamber, with the results showing increases in heart rate and skin temperature (Williams et al., 2011).

However, there is little information regarding changes in physiological responses as a result of being involved in different tasks in the firefighting operation such as typical firefighting activities, live-fire drills and rescue operations at height. Thus, information on the impact of various types of firefighting activities (including live-fire and rescue at height works) on firefighters' physiological responses are very limited.

On the other hand, despite the number of studies investigating the effect of typical firefighting tasks on firefighters' physiological responses during firefighting activities, limited data exist regarding their cognitive function during such activities (Barr et al., 2010; Greenlee et al., 2014). Previous research has shown that firefighting tasks affect cognitive function (Hemmatjo et al., 2017a; Robinson et al., 2013; Smith and Petruzzello, 1998; Zhang et al., 2014). Kivimäki and Lusa (1994), for example, studied the relation between stress reaction and cognitive function during simulated firefighting and displayed that as the stress reaction during simulated firefighting task increased, the controlled task-focused thinking diminished. They defined firefighters' stress reactions based on changes in their rest and maximal heart rate during the simulated drill. Previous studies have also noted that heat, smoke, and sleep deprivation can have adverse effect on cognitive function and physical capacities (Aisbett et al., 2012). However, there is limited knowledge regarding the impact of various types of firefighting activities on cognitive functions (e.g. attention and information processing).

The effect of typical simulated firefighting activities on physiological response has been well researched in the fire service context for many years, while few researchers have investigated how various strenuous tasks during firefighting and rescue operation impact physiological and cognitive function capacity. Furthermore, the magnitude of psychological response has not been carefully studied in different tasks during fire and rescue operation. Besides, there is virtually no information available regarding how such strenuous tasks affect cognitive function, particularly the ability of quick and accurate information processing during firefighting activities. Far less is known about the influence of firefighting task types on a range of physiological responses and cognitive functions (e.g., attention, memory). Such information is required to authorize fire service agencies to make informed decisions related to the health and safety of their firefighters.

Therefore it is important to increase our understanding of different firefighting tasks, including the type and duration of duty during fire and life-saving operations, which may increase the risk of physiological strain and impairment of cognitive function.

Based on the available literature, we assumed that typical firefighting activities, live fire drills and rescue operations at height would have different effects on physiological loads and cognitive functions during firefighting activities while wearing firefighting protective clothing. Therefore, the aim of the present study was to evaluate the effect of typical firefighting activities, live fire drills, and rescue operations at height on physiological responses and cognitive function capacity.

2. Methods

2.1. Subjects

Eighteen professional and experienced firefighters were recruited from a Fire Fighting Brigade. Before conducting the study, firefighters' health condition in terms of the thermoregulatory and cardiovascular conditions as well as mental and general health status were monitored by reviewing their medical records and administering General Health Questionnaire (Goldberg and Hillier 1979). Based on this initial examination, healthy firefighters were recruited. Before testing, all firefighters provided written informed agreement indicating that they understood all procedures of the study and that their contribution in the research was voluntary. The testing protocol was approved by the Ethics Committee of Urmia University of Medical Sciences. The mean physical characteristics of the participants were as follows: age 30.0 ± 3.9 years, height 1.79 ± 0.58 m, weight 81.67 ± 14.68 kg, body mass index 25.2 ± 3.0 kg m^{-2}, and body surface area 2.02 ± 0.22 m^2.

2.2. Simulated firefighting tasks

Firefighting activities requires high levels of aerobic fitness, anaerobic capacity, and muscular strength and endurance; however, previous findings show that many firemen do not have high aerobic or anaerobic capacity (Smith 2011, Von Heimburg *et al.* 2006). Commonly, fire and rescue operations are composed of aerobic and anaerobic metabolism, along with remarkable muscular strength and endurance demands (Gledhill and Jamnik 1992, Koide 2015). Based on former research, firefighters perform multiple aerobic and anaerobic tasks at high intensities during fire and rescue operations (Koide 2015). Therefore, the current study simulated various types of firefighting duties, such as typical firefighting activities, live fire drills, and rescue operations at height, which require high levels of aerobic fitness, anaerobic capacity, and muscular strength and endurance. These various types of firefighting activities were selected based on the recommendations provided by the firefighter's commander and previous studies (Hemmatjo et al., 2017c; Perroni et al., 2010; Rhea et al., 2004; Smith et al., 2001b).

All firefighters participated in various types of firefighting operations on three separate occasions:

2.2.1. Live-fire activities (LFA)

The firefighters carried out live fire suppression in a wide and open place. The suite of live-fire tasks included: 1) passing through live-fire 2) extinguishing fire using water 3) shutting off fire with fire extinguisher (Fig. 1).

2.2.2. Typical firefighting activities (TFA)

The firefighters used a smoke-diving room, i.e. an indoor environment with dark and nested rooms for exercising typical firefighting activities (Hemmatjo et al. 2017b). Smoke-diving rooms differ from each other when it comes to their facilities, design, and physical space. The room utilized in this study consisted of an indoor space with black walls. Windows, narrow paths for firefighters' crossing, and escape tunnels were designed in a number of walls. The smoke-diving room also had a separate partition that was used as the control room. Control devices (e.g. monitors) were placed inside the control room and the control room temperature was adjusted using a heating and cooling system (WBGT 22 °C, 50% relative humidity/RH). All participants conducted the same four tasks in the smoke-diving room (WBGT 28-30 °C, 60-65% relative humidity (RH)): 1) hose pulling: as common task performed during firefighting activities, requiring firefighters to carry a 15-m empty hose; 2) ladder handling and climbing: following completion of the hose pulling, the firefighters carried a 13 kg ladder 25 m and then climbed it; 3) passing through narrow routes: after ladder handling, firefighters crossed the narrow 65 to 80 routes that were not familiar to firefighters; and, 4) passing through an escape tunnel (Fig. 1).

2.2.3. Rescue operations at height (ROH)

All firefighters carried out rescue operations at height in an indoor environments (WBGT 27-29 °C, 60-65% relative humidity (RH)) (Fig. 1). In this stage, one person is suspended as a victim at a certain altitude from the ground in the training hall, and a firefighter moves himself upward with the help of special ropes that hung from the horizontal and vertical beams of the ceiling, using a rescue belt to bring down the victim. It should be noted that firefighters do not use protective clothing in their rescue operation.

2.3. Measurements

2.3.1. Measurement of physiological responses

Heart rate was measured prior to the three conditions in the reception room and every minute throughout the trial via a heart rate monitor (Polar V800, Finland). In order to monitor the heart rate every minute, subjects wore a polar heart rate sensor. It is important to be aware before selecting any temperature measurement options what the pros and cons might be for each option. A suitable infrared thermometer should have the following aspects; accurate body temperature measurement, facility for use in a short time, and the absence of potential risks. Previous studies which investigated precision and possibility of infrared temperature measurements have shown that the infrared thermometer meets these aspects. Further, its use in the clinical practice and research purpose appears to be more beneficial than or supplementary to the usual methods (Kocoglu *et al.* 2002, van Staaij *et al.* 2003). Previous work has reported that temporal artery temperature is more accurate than tympanic thermometer (Greenes and Fleisher 2001). Former studies have also reported a correlation coefficient of 0.776 between temporal artery and rectal temperature (Carr *et al.* 2011). In the present study, temporal artery temperature was assessed prior to the experiment and at the end of each experiment using an infrared thermometer (Rossmax, Berneck, Switzerland).

2.3.2. Measurement of cognitive functions

The paced auditory serial addition test (PASAT) aimed at measuring the capacity of information processing and working memory (Fos et al., 2000; Mathias et al., 2004; Tombaugh, 2006). In this test, the participants were seated in a 38–60 cm distance from the computer monitor, with the center of the monitor being 2–5 cm under eye level. They were then asked to listen to 61 single digit numbers (varying from 1 to 9), with a break of 3 second between every two numbers. They should afterward calculate the summation of the last two numbers they had heard from the headphone and loudly declare the result in the microphone. The subjects should say the answer before the following digit was presented to them; otherwise, it would not be considered as a valid response. For example, if 3 and 7 were presented consecutively, the subjects should loudly say

10, which was the correct response (Fig. 2). The computer screen was blank when the participants were taking the trial. The highest score that the subjects could obtain (based on the number of correct answers) was 60. It took three minutes for the subjects to finish the test.

2.4. Experimental design

To assess the effects of strenuous fire and rescue operations on physiological responses and cognitive functions, all firefighters were tested in three separate occasions, namely (1) Live-fire activities (LFA), (2) Typical firefighting activities (TFA), and (3) Rescue operations at height (ROH). Throughout the LFA and TFA experiments, subjects wore firefighting protective clothing (FPC) and basic undergarments, including a T-shirt, underwear, socks, boots, protective gloves, and protective helmet. The total weight of the equipment was 15 to 19 kg. During ROH experiments, firefighters wore work clothes basic undergarments, i.e. a T-shirt, underwear, socks, boots, and protective helmet.

Before the experiment, all firefighters had to be trained how to perform simulated firefighting tasks correctly and run a PASAT test. Therefore, prior to conducting the experiments, the participants attended practice meetings in which they got familiar with the procedure for taking the simulated firefighting tasks. In addition, cognitive test practice meetings were administered to familiarize participants with the PASAT test. It should be noted that training firefighters for the PASAT test continued until firefighters were able to take part in the test using the provided equipment, including computer and the installed software program, without the researchers' assistance. It took about 4 to 6 practice sessions for each participant to learn the PASAT test. In general, the implementation of the PASAT for each firefighter was a very simple task and just required pressing a button upon seeing the target stimulus on the computer screen.

According to the protocol, the firefighters should accomplish the simulated firefighting tasks in the three separate occasions, namely (1) LFA, (2) TFA, and (3) ROH. All firefighters performed three separate conditions as quickly as possible. In the LFA condition, after entering the reception room, each firefighter wore a heart rate sensor, and their basic physiological parameters were measured after 15 minutes of rest in the reception room. Then, PASAT test was administered in the reception room before performing LFA activity. Subsequently, each firefighter performed LFA activity including (1) passing through the live-fire, (2) extinguishing fire using water, and (3) shutting off fire with fire extinguisher (Fig. 3). After that, they again took part in the PASAT test in the reception room. They were asked to perform the drill intensely without competing. It should be noted that the LFA activities were selected with the recommendation of the commander of the firefighters. It took about 20-25 minutes for each firefighter to finish LFA activities and the PASAT test.

In the TFA condition, after entering the reception room, each firefighter wore a heart rate sensor, and their basic physiological parameters were measured after 15 minutes of rest in the reception room. Then, they attended the PASAT test in the reception room before performing the TFA activity. Subsequently, each firefighter performed TFA activities including (1) hose pulling, (2) ladder handling and climbing it up, (3) passing through narrow routes, and (4) passing through escape tunnel (Fig. 1). After that, they again performed the PASAT test in the reception room. They were asked to perform the drill intently without competing. In the current study, TFA activities were selected in the light of the recommendations provided by the fire service commander and previous studies (Larsen et al., 2015; Smith and Petruzzello, 1998). It took about 20-25 minutes for each firefighter to finish TFA activities and the PASAT test.

In the ROH condition, after entering the reception room, each firefighter wore a heart rate sensor, and their basic physiological parameters were measured after 15 minutes of rest in the reception room. Then, the subjects completed the PASAT test in the reception room before performing the ROH activities. Subsequently, each firefighter performed ROH activity (Fig. 1). After that, they again attended the PASAT test in the reception room. They were asked to perform the drill intently without competing. ROH activities were selected based on the typical procedures used in previous studies. It took about 20-25 minutes for each firefighter to finish ROH activities and the PASAT test.

2.5. Statistical analysis

The collected data were analyzed by Statistical Package for the Social Sciences IBM SPSS 21 (IBM, Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess the normality of the data. Firefighters' physiological responses and cognitive functions before and after exercise in the various types of firefighting activities were compared using a paired samples t-test. The effects of various types of firefighting activities on all measurements were tested by a repeated measures analysis of variance (ANOVA) for each of the dependent variables to determine if there were any significant differences during firefighting activities. The level of statistical significance was set to $p < 0.05$.

3. Results

3.1. Physiological responses

Compared to the baseline, heart rates increased significantly following the three types of firefighting activities (Fig. 3). Throughout the exercise periods, significant differences were observed between pre and post experiments in the heart rate mean scores ($P < 0.05$). The subjects' heart rate mean scores before and after doing the firefighting activities were (69.8 ± 6.2 vs. 149.3 ± 3.7 bpm), (69.8 ± 5.7 vs. 152.2 ± 3.9 bpm), and (70.0 ± 5.9 vs. 159.2 ± 4.1 bpm) for LFA, TFA and ROH respectively.

The firefighters' temporal artery temperature (TT) scores before and after the three types of firefighting activities are displayed in Fig. 4. As shown in this figure, mean TT scores were remarkably different between pre and post experiments throughout the exercise periods. Before and after the three types of firefighting activities, mean TT values were (37.1 ± 0.12 vs. 38.0 ± 0.07 °C), (37.1 ± 0.1 vs. 38.1 ± 0.09 °C), and (37.1 ± 0.09 vs. 38.2 ± 0.08 °C) for LFA, TFA and ROH respectively. The results of paired samples t-test revealed a significant difference in temporal temperatures between the beginning and the end of the simulated firefighting tasks in the three types of firefighting activities ($P < 0.05$).

Table 1 displays the results of pairwise comparisons of the impact of three types of firefighting activities on physiological responses. The repeated measure analyses of variance revealed significant differences in heart rate among the three types of firefighting activities. The LSD post hoc test was used for pairwise comparisons to examine the effect of various types of firefighting activities on physiological responses. According to the table, there was a significant difference in heart rate between LFA and TFA ($P < 0.05$). Furthermore, the heart rate values significantly increased for the ROH compared to the LFA and TFA conditions ($P < 0.05$). In addition, there was a small rise in TT in various types of firefighting activities; however, the LSD post hoc revealed significant differences in temporal artery temperature among the three types of firefighting activities ($P < 0.05$).

3.2. Paced Auditory Serial Addition Tests (PASAT)

Fig. 5 illustrates the effect of various types of firefighting activities on PASAT scores (Correct Response/CR). Before and after the experimental period, the mean PASAT scores were (50.3 ± 1.1 vs. 48.6 ± 1.2 CR), (50.2 ± 1.1 vs. 47.7 ± 1.2 CR), and (50.4 ± 1.5 vs. 47.0 ± 1.1 CR) for LFA, TFA and ROH respectively. The results of paired samples t-tests demonstrated a significant difference in PASAT scores (CR) between pre and post experiments ($P < 0.05$).

Pairwise comparisons of the effect of various types of firefighting activities on information processing performance and working memory are demonstrated in Table 2. The results of repeated measures analyses of variance revealed significant differences in PASAT scores among the three types of firefighting activities. The LSD post hoc test was used for pairwise comparisons to examine the influence of various types of firefighting activities on information processing performance and working memory. There was a significant difference in PASAT scores between LFA and TFA ($P < 0.05$). There was also a significant difference in PASAT scores between LFA and ROH ($P < 0.05$) either. Furthermore, a measurable discrepancy was detected in PASAT scores between TFA and ROH ($P < 0.05$).

4. Discussion

Fire and rescue operations are commonly intermittent, and contain an array of activities of varying severity (Hemmatjo et al., 2017c; Perroni et al., 2010; Phillips et al., 2011; Rhea et al., 2004; Smith et al., 2001b). Hence, participants in the present study were exposed to various types of firefighting tasks. As expected, firefighters experienced considerable increase across all measures of physiological responses, namely heart rate and core temperature, after completing the three types of firefighting activities. The results of the present survey are in line with previous studies, which have shown that firefighting activities cause notable physiological strain. Faff and Tutak (1989) studied changes in cardiovascular strain and body temperature under controlled laboratory conditions in a hot humid environment (dry bulb temperature: 39 ± 1 °C, relative humidity: 70 ± 5 %). They reported that heart rate and rectal temperature values rose significantly throughout the exercise on a cycle ergometer. In some subjects, the heart rate went up to near maximal level. In many cases, the rectal temperature exceeded 39 °C. In the current study, the results obtained with regard to physiological response, especially maximum heart rate responses, are similar to those reported after being involved in simulated firefighting (Barr et al., 2009; Smith et al., 1997).

In the current study, at the end of various types of firefighting activities, heart rate and temporal artery temperature increased in the LFA, TFA and ROH situations. The remarkably increased heart rate and temporal artery temperature responses that were obvious during the rescue at height operation were not detected during the other experimental conditions. Heart rate is a physiological response tightly related with physical activity and thermal stress. It is considered a fast physiological response to strenuous physical activity (Davis and Gallagher, 2014; Perroni et al., 2014; Smith et al., 1995). The results of this study displayed that being involved in different types of firefighting activities will cause variations in physiological responses. In the present research, a smaller increase in heart rate was observed following the firefighting activities in the LFA compared with the TFA condition. On the other hand, increases in HR were more dramatic for the ROH compared with the LFA and TFA conditions. The results of the repeated measures analyses of variance further revealed significant differences in heart rate among the three types of firefighting activities. The findings also showed that, at the end of the firefighting activities, temporal artery temperature increased in the LFA, TFA, and ROH conditions relative to baseline. Additionally, a greater increase was detected in temporal artery temperature for the ROH compared with the LFA and TFA conditions, after performing the experiment.

The results of the present work support former ones reporting simulated typical firefighting activities are effective in increasing the physiological responses during experiments while wearing firefighting protection clothing (Barr et al., 2011; Smith and Petruzzello, 1998). Previous research has shown higher heart rates when performing strenuous firefighting drills (Smith et al., 2001a). Former studies have also reported that performing typical firefighting activities imposes notable physiological stress on the firefighters' body (Chiou et al., 2012; Horn et al., 2015; Watt et al., 2016). These studies, however, did not specify which types of firefighting tasks and physical activities are more effective in fostering physiological responses across all firefighting operations. Moreover, existing studies have often used physical tasks, such as treadmill or cycle exercise, to simulate multiple firefighting tasks. These physical tasks, nevertheless, are improper because firefighters accomplish typical firefighting tasks during fire and rescue operations (Chou et al., 2008; Giesbrecht et al., 2007; Zhang et al., 2014).

These results demonstrate that rescue at height is more strenuous than live-fire and typical firefighting activities in reducing the cognitive function impairments during fire and rescue operations. While performing fire and rescue tasks, firefighters need to work in hot, rigorous, and unpredictable environments for a long time. Former research has indicated that heat, smoke, sleep deprivation, and deficiency can have adverse effect on cognitive functions (Aisbett et al., 2012). The evaluation of cognitive functions is a serious matter for firefighters since the failure of a firefighter to make accurate decisions could have irreparable consequences. Due to lack of experimental studies, little is known concerning changes in information processing performance and working memory during fire and rescue operations (Barr et al., 2011; Zhang et al., 2014). Prior research projects have surveyed cognitive functions, like sustained attention, by visual continuous performance test during simulated firefighting tasks (Greenlee et al., 2014; Smith et al., 2001a). Morley et al. (2012) studied non-firefighter subjects' cognitive functions with PASAT test following treadmill trial in a heated room (33–35 °C) while wearing firefighting protective clothing (FPC) and SCBA, reporting declines in information processing performance working memory after exercise. Another study investigated the effect of dehydration caused by thermal stress on mental performance outside the fire service agencies, with the results demonstrating that a 2% and 3% level of primary dehydration would lead to a considerable decrease in mental function (Sharma et al., 1986). Former studies have reported impairment in information processing performance when performing strenuous firefighting drills (Hemmatjo et al., 2017c).

In this study, firefighters' information processing impairments were remarkably higher following various types of firefighting activities compared to those prior to the experiment. As noted above, the passed auditory serial addition test is applied to evaluate information processing performance. It is thus argued that reductions in PASAT scores after being involved in various types of firefighting activities reveal impairment in cognitive functions. Comparison of mean changes in PASAT scores showed differences between the three experiments. According to the obtained results, cognitive function impairment was greater for ROH condition at the end of the experiment. The results of the repeated measures analysis of variance also showed a significant difference between the LFA and TFA conditions. There was also a significant difference between the TFA and ROH trials. It is thus concluded that rescue at height has more impact on firefighters' information processing and working memory than live-fire and typical firefighting activities when conducting fire and rescue operations. Various tasks that firefighters perform cause physiological and psychological stress (Hemmatjo et al. 2017d). In the present study, physiological response values increased throughout the experiment. During firefighting operations, the physiological responses and stress level goes up, making it necessary for the body to deal with them. This may cause reduction in the capacity of information processing performance (Barr et al. 2010). According to the results, cognitive function impairment increased following firefighting activities. It is thus deduced that the rise of physiological strain negatively impacts firefighters' cognitive function.

The results of this study indicated decrements in PASAT scores after conducting firefighting activities as compared with the baseline. Former research has reported that firefighter's cognitive functions deteriorate following simulated firefighting activities (Greenlee et al., 2014). Also, Zhang et al. (2014) argued that cognitive functions change following treadmill exercise in the environmental chamber. There is evidence that performing simulated firefighting tasks may reduce the cognitive function capacity. Previous work has reported that performing typical firefighting tasks cause notable cognitive impairments (Smith et al., 2001a). These studies have however failed to demarcate the firefighting tasks and physical activities that have a stronger effect on cognitive function changes across all of firefighting operations.

Advantages and limitations of the present study

In this study, professional and experienced firefighters were recruited. They performed simulated fire and rescue operations in an advanced and well-equipped smoke-diving room (e.g. nesting and dark rooms as well as specialized UV cameras) and training hall that resembles real fire and rescue scenarios. In the current study, we compared the effect of various types of fire and rescue operations on physiological loads and cognitive functions. Nevertheless, we could not measure the physiological responses, such as firefighters' recovery heart rate, cortisol, blood lactate levels, and blood Adrenocorticotropic hormone (ACTH) at the end of various types of firefighting duties. Further research is required to compare the effect of various types of fire and rescue operations on firefighters' physiological response.

5. Conclusion

These findings indicate that various types of fire and rescue operations have notable impact on a firefighter's physiological responses. The results also showed that rescue at height was more effective than the live-fire and typical firefighting activities in raising physiological response indices following the experiment. Our results also propose that cognitive functions, such as information processing and working memory, change as a result of conducting various types of firefighting activities. The results further demonstrate that rescue at height operation was more effective than the other firefighting tasks in decreasing cognitive function capacity after the experiment. Therefore, it is recommended that safety managers recruit and train firefighters for rescue at height operations who have the appropriate physiological and cognitive capacity.

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Conflicts Of Interest

There are no conflicts of interest.

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Figure captions

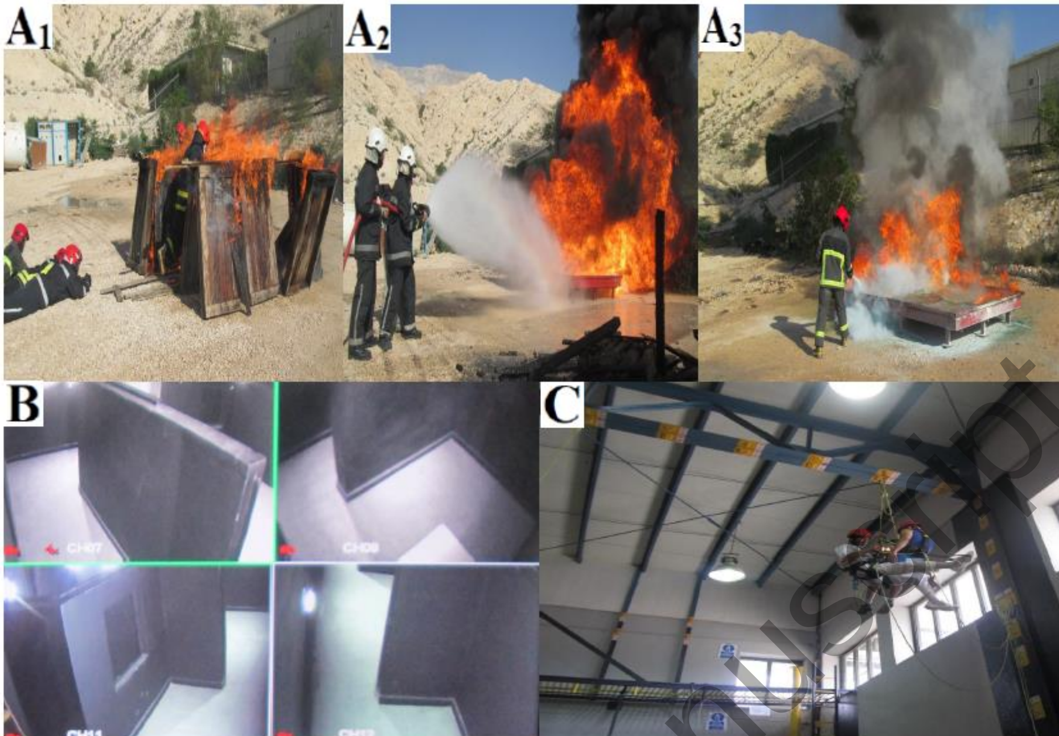
Fig. 1. A_1) Passing through the live-fire, A_2) Extinguishing fire using water, A_3) Shutting off fire with fire extinguisher, B) smoke-diving room, C) Rescue operations at height.

Fig. 2. The pattern of performing paced auditory serial addition test (PASAT).

Fig. 3. Heart rate mean scores before (pre HR) and after (post HR) activity in the three experimental conditions namely (1) Live-fire activities (LFA), (2) Typical firefighting activities (TFA) and (3) Rescue operations at height (ROH).

Fig. 4. Temporal artery temperature mean scores before (pre TT) and after (post TT) activity in the three experimental conditions namely (1) Live-fire activities (LFA), (2) Typical firefighting activities (TFA) and (3) Rescue operations at height (ROH).

Fig. 5. Mean PASAT scores before (pre PASAT) and after activity (post PASAT) in three experimental conditions namely (1) Live-fire activities (LFA), (2) Typical firefighting activities (TFA) and (3) Rescue operations at height (ROH).



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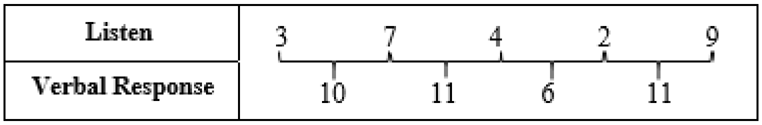

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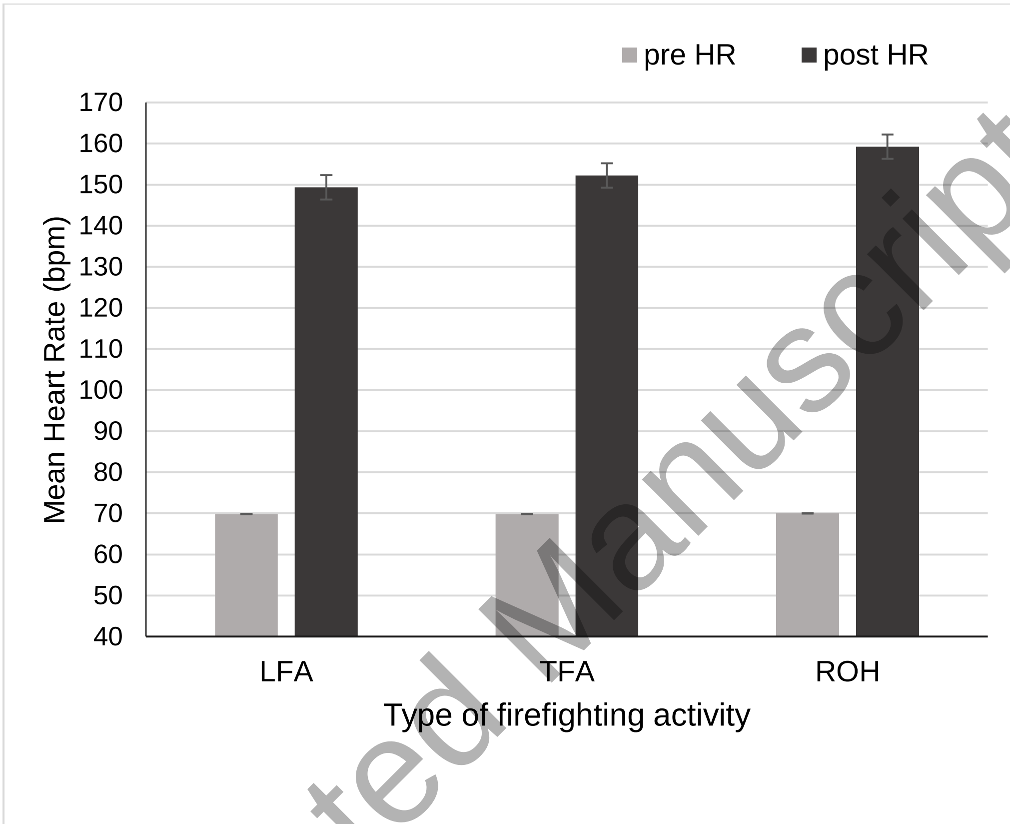

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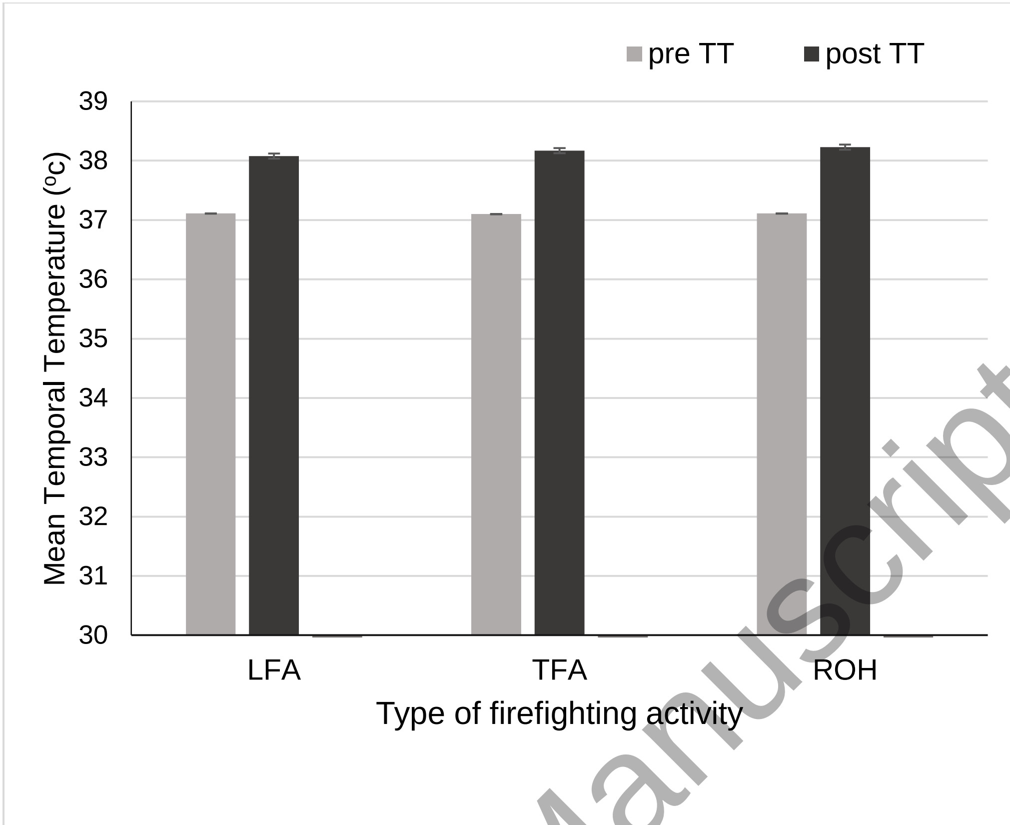

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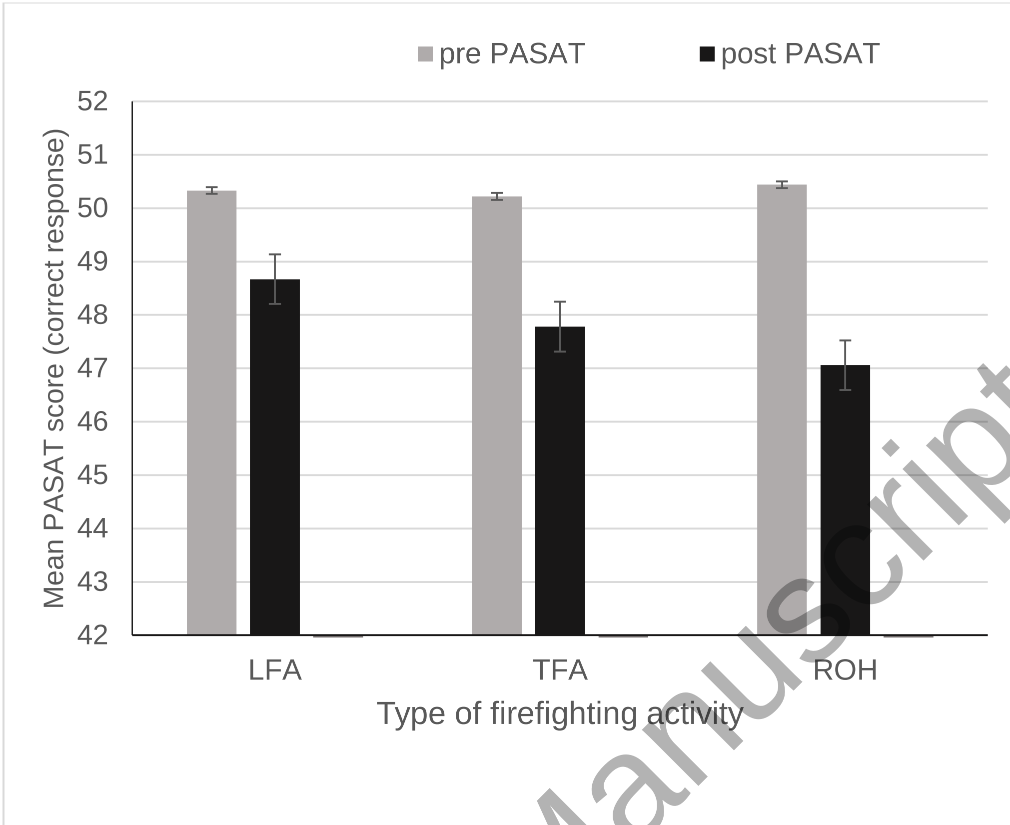

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List of tables

Table 1. Pairwise comparison of the effect of various types of firefighting activities on physiological responses

Firefighting activities	HR (bpm)				TT (°C)			
	MD	95% CI		P-value	MD	95% CI		P-value
		Lower	Upper			Lower	Upper	
(LFA vs. TFA)	2.89	0.09	5.68	0.04	0.08	0.04	0.13	0.001
(LFA vs. ROH)	9.94	7.89	11.99	<0.001	0.15	0.10	0.19	<0.001
(TFA vs. ROH)	7.05	4.43	9.67	<0.001	0.06	0.01	0.11	0.01

Abbreviations: HR, heart rate; TT, temporal temperature; MD, mean difference; CI, confidence interval for difference; LFA, live fire activities; TFA, typical firefighting activities; ROH, rescue operation at height.

Table 2. Pairwise comparison of the effect of various types of firefighting activities on the PASAT

firefighting activities	PASAT			
	MD	95% CI		P-value
		Lower	Upper	
(LFA vs. TFA)	0.88	0.16	1.61	0.02
(LFA vs. ROH)	1.61	0.92	2.29	0.001
(TFA vs. ROH)	0.72	0.06	1.38	0.03

Abbreviations: PASAT, passed auditory serial addition test; MD, mean difference; CI, confidence interval for difference; LFA, live fire activities; TFA, typical firefighting activities; ROH, rescue operation at height.