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Original Article

Evaluating the correlation of blood pressure and pulse rates of firefighters with their sociodemographic characteristics during a fire and rescue training

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ABSTRACT

Introduction: Cardiac strain has become a prevalent cause of firefighters' death. Standards and regulations set forth a framework to monitor the cardiovascular fitness of firefighters, encourage fitness and create a pathway to diagnosis or detection of disorders. The effectiveness of these standards relies on continuous evaluation of firefighters' health and updating the protocols.

Methods: This study intended to assess the physiological response of 172 firefighters in the middle east for the first time and considered the effect of body mass index, age, gender, and seasonal ambient temperature on their responses before and after a fire and rescue training. The end results should compile the behavioral patterns of firefighters from the region and help authorities to update current health monitoring standards for firefighters accordingly. Blood pressure, heart and respiratory rates were sampled for participants after one minute after when training finished. Non-Parametric statistical analysis was conducted using Nonparametric Spearman rank correlation coefficients and Kruskal-Wallis H-test to evaluate the correlation of age, gender, BMI, and seasonal temperature with participant's physiological response.

Results: This study found obesity in 20% of the sampled population with more cases among male participants. Also, in this study, the hypertension prevalence ratio found as 19.8% at baseline and 26.7% in post-training measurements.

Conclusion: This study could confirm that body mass index and seasonal ambient temperature affect blood pressure, heart and ventilation rates. Heart rate significantly changes with ambient temperature. Also, the results found the gender of participants affects all physiological responses, especially heart rate.

Keywords: Blood pressure, firefighters, hypertension, heart rate, training

Introduction

Cardiovascular and coronary artery risks are the prevalent cause of firefighters' deaths.[1] Previous reports noted that hypertension and cardiovascular-induced deaths are estimated as 45 % of firefighter mortality in the US,[2] and more or less the same ratios found in other parts of the world.[3] Therefore, like many other dangerous occupations, fitness for duty is an imperative factor for firefighters to safely fulfill their job. Firefighters are regularly screened through medical examinations for risks of developing cardiovascular disorders, or other indicators of physiological response disorders that can increase the risk of cardiac attack during their career.

Previous research could confirm that the physiological responses of firefighters are influenced by a long list of factors such as physical characteristics,[4,5,6] working conditions of firefighters,[7,8] working environment temperature,[9] daytime,[10] and assignment cycles, and frequencies.[11] Other factors including gender,[12,13] age,[14] body and surrounding temperature[15,16] noted as sources of discrepancy in physiological responses and consequently cardiovascular risks. Detailed reviews on factors affecting physiological response among firefighters are provided here.[17]

Requirements for firefighter fitness have been adopted in various protocols and standards and are to be used as the basis of assessing firefighters' fitness for the job, though, their implementation is regulated differently across the world.[18] For example, National Fire Protection Association (NFPA) specifies systolic pressure of less than 180 mmHg and diastolic pressure of 100 mmHg as an appropriate fitness of firefighters to safely perform their duties,[19] though, some found those blood pressure recommendations insufficient and demanded more specific guidelines.[20] Investigations on a different population of firefighters across the world show that a great portion of firefighters already suffers from hypertension, despite existing medical and fitness protocols.[8,21,22,23,24] Hence, more studies on firefighters' cardiovascular responses help in updating these guidelines and better protocol implementation.

To our knowledge, data on the physiological responses of firefighters originating mostly from certain parts of the world and more information from underrepresented regions such as the middle east helps broaden the database to be utilized for future preventive measures. With this regard, the current paper aims to assess the physiological responses of middle eastern firefighters during fire and rescue training for the first time. Data from both male and female participants were collected and a correlation between the physiological responses of firefighters with respect to their Body Mass Index (BMI), age, gender and environment temperature was sought in this study.

Methods

This paper presents data collected from individuals before and after fire and rescue training in the International Institute of Fire and Safety located in Muscat, Oman. The institute offers various vocational firefighting training programs and collaborates with different government organizations, industries, and sectors across the middle east region. Data from 172 individuals who participated in fire and rescue training for 12 months were collected and used in this study. The age of trainees ranged between 18-54 years with an average of 23 years old. Of all the participants, 25 participants were females, comprising 14% of the entire sample. To be part of the study, participants had to fit the following criteria: 1) No cardiovascular disease history; 2) Not using any cholesterol or blood pressure medication; 3) Non-smoker; 4) No prior cardiovascular incident or heart diseases; and 5) No physical disabilities.

For fire and rescue training, participants were divided into groups of five individuals and each group was accompanied by an instructor to the fire and rescue facility. The training session for each group lasted for an average of five minutes and sampling was conducted in a resting area that is located near the facility. Figure 1 shows a picture of the facility and the location of the resting area near the facility.

Figure 1: Left - picture of trainee and their instructor ready to start the training session; Right-top view of facility and location of resting area.

Participants entered the fire and rescue facility, where a two-meter diameter of diesel pool fire is burning in the middle of the first floor. Trainees should complete a search inside the first floor and finish the session by finding the exit door on the opposite side of where they entered the facility. Overall, the trainees have a series of activities such as walking on steps, crawling, running, and jumping during the session. The session took an average of 5 minutes and sampling was conducted 2 minutes after the firefighters reached the resting areas where sampling took place.

Three measurements were taken before and after the session; including Heart Rate (HR); Blood pressure (Systolic and Diastolic); and Respiratory Rate (RR). Brachial blood pressure was measured using an aneroid sphygmomanometer and respiratory as well as heart rates were measured using a pulse oximeter. The average of three readings was reported as correct values. Before the training sessions, participants were to undergo a medical examination administered by local hospitals or clinics approved by the Oman Ministry of Health. Staff in the institute's clinic also conducted a medical examination upon the participants' arrival. The height and weight of participants were cross-checked between self-declaration forms and measurements in the clinic and used to calculate Body Mass Index (BMI). The index is defined as the ratio of weight in kilograms to height in meters squared.

Collected data were initially analyzed to obtain descriptive statistics including mean and standard deviation. All mean values are provided here in the format of mean ± standard deviation and all data underwent initial distribution screening for normality using the Shapiro-Wilk test to select appropriate methods for the data analysis. Non-parametric bivariate Spearman rank correlation coefficient was found to be an appropriate method to calculate the magnitude and direction of relations between BMI and the ages of participants. The method is non-parametric, which well handles samples with possible outliers and non-normally distributed data. For gender and seasonal effects, the non-parametric Kruskal – Wallis H test was found to be a proper method for comparing data. Statistical significance for both tests was set as $p<0.05$.

Results

Table 1 listed the mean, maximum, and minimum values of various cardiovascular parameters measured in pre and post-training sessions. It should be noted ventilation rate was calculated using measured respiratory rate, the weight of participants, and assuming an intake of 500 ml of air per breath.

Table 1.: Calculated mean, range, and mode of physiological responses for the entire sample

	Mean		Range		Mode	
Parameters	Pre-Training	Post-Training	Pre-Training	Post-Training	Pre-Training	Post-Training
Weight (kg)	73 ± 19	-	91	-	60	-
Height (cm)	171 ± 8	-	43	-	174	-
Age (Years)	23 ± 6	-	37	-	19	-
BMI	25 ± 6	-	30	-	24	-
Heart Rate (bpm)	87 ± 18	112 ± 21	135	121	78	120
Systolic blood (mmHg)	129 ± 15	133 ± 11	90	112	120	140
Diastolic blood (mmHg)	82 ± 19	83 ± 13	67	77	80	80
Ventilation rate (mL/kg/min	111± 8	156 ± 13	606	334	100	167

Pairwise comparison between body mass index and pre-and post-training values of measurements performed by seeking *r* and *p-values* using Spearman's correlation method. Figure 1 demonstrates a scatter plot of measured parameters versus body mass index and linear correlations along with R^2 values. Pre and post-training ventilation rates show a negative correlation with BMI, where r = -0.691 with *p-value< 0.05* (0.0001) determined for pre-training data and r = -0.720 with *p-value< 0.05* (0.0001). However, the direction of the relation between SBP and DBP changes to positive, though, with lower values. For SBP, the correlation with BMI becomes weaker with pre-training r = 0.436 with *p-value < 0.05 (0.0001)* and post-training *r=0.370* with *p-value < 0.05 (0.0001)*. Further decrease is recorded for DBP with *r=0.381, p-value < 0.05 (0.0001) for pre-training and r= 0.268, p-value < 0.05 (0.001)*. With a slight decline in correlation coefficient, heart rate demonstrates the weakest correlation with BMI calculated as *r=0.044, p-value > 0.05 (0.567)* and *r=0.071, p-value > 0.05 (0.352)* for pre and post-training data, respectively.

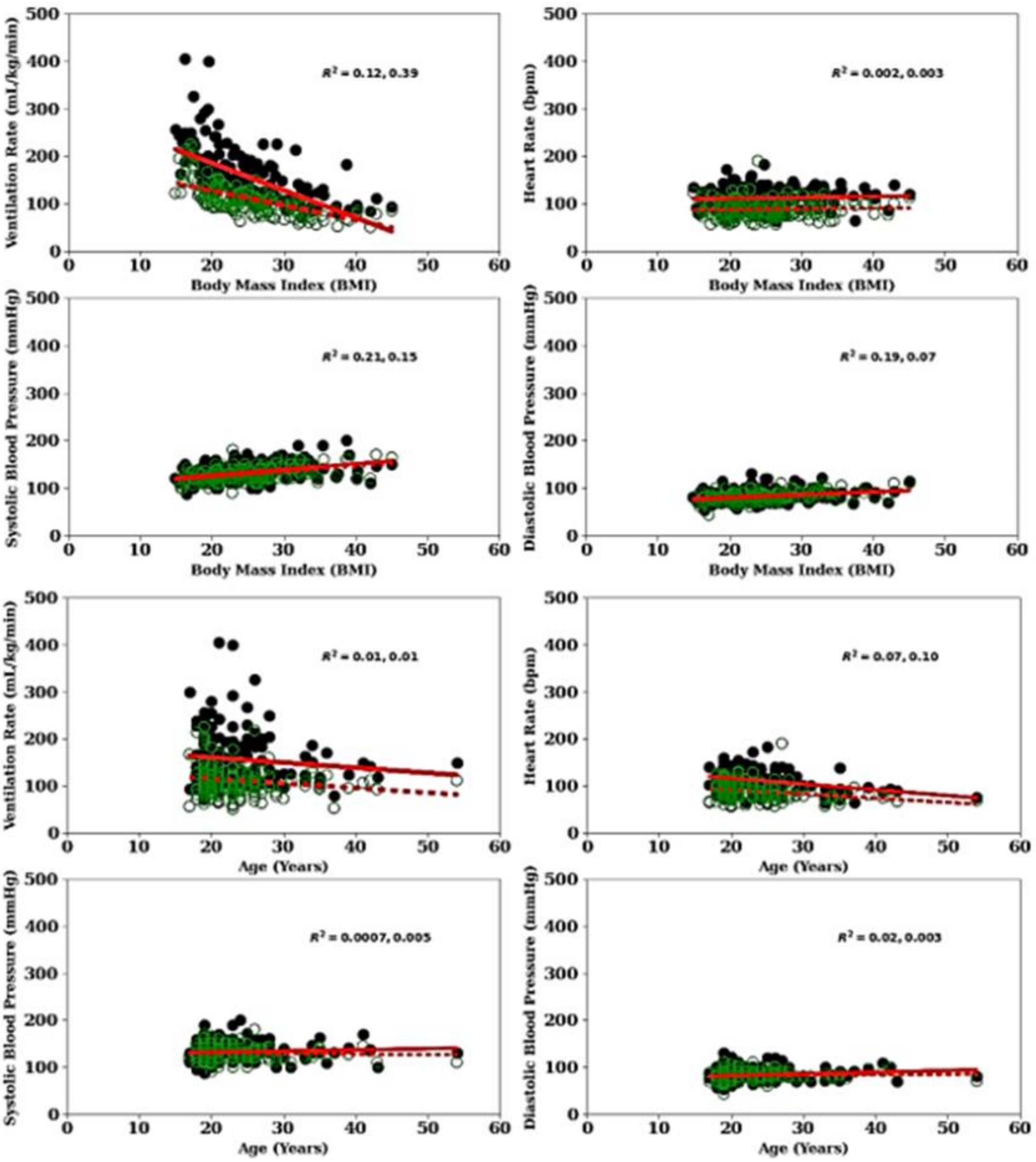

Figure 2: scatter plots of physiological responses versus BMI and age of participants. (Hallow green circles = pre-training values; Black circle = post-training values; dotted line = regression line for pre-training values; bold line = regression line for post-training values. R2= (Pre-training, Post training))

Participant's age and cardiovascular found uncorrelated based on calculated results. As evident in Figure 2, ventilation rates for the age group of less than 30 years old are entirely random and do not follow any pattern. The correlation coefficient calculated for these two variables was determined as r = -0.081, p-value> 0.05 (0.290) for pre-training and r =-0.043 with p-value> 0.05 (0.573). Further, the coefficients recorded for age and pre-training SBP as r=0.060, p-value > 0.05 (0.434), while it slightly changed to r = 0.166 with p-value < 0.05 (0.029) for post-training SBP. However, there is an evident correlation between age and DBP where r coefficients show r = 0.165, p-value < 0.05 (0.030) and r = 0.284, p-value < 0.05 (0.0001) for pre and post-training measurements. Similar to the comparison with BMI, the r value implies no relation between age and heart rate in both pre and post-training trials. In this case, r values were calculated as r = -0.109, p-value > 0.05 (0.156) for pre-training data, and r =0.053, p-value > 0.05 (0.492) in post-training measurements.

The weight of female trainees ranged from 35-107 kg, their height recorded in the range of 150-170 cm and all of them aged 18-21 years old. Table 2 lists R-values and p-values calculated for both females' and males' physiological responses. For female participants, a robust correlation between ventilation rates, and blood pressures with their BMIs are evident. However, the ventilation rate shows a stronger correlation with females participants' BMIs than male trainees, and more importantly, the direction of correlation in post-training measurement for female participants is totally opposite to the one calculated for male participants. Correlation for heart rates is not detected for both female and male samples.

Table 2.: list of R-coefficient and p-values calculated for male and female participants using the Spearman correlation method

	Male			
	Pre-training		**Post-training**	
Parameters	R-value	*p-value*	R-value	*p-value*
Heart Rate (bpm)	0.094	>0.05	0.048	>0.05
Ventilation Rate (mL/kg/min)	-0.211	<0.05	-0.529	<0.05
Systolic Pressure (mmHg)	0.464	<0.05	0.337	<0.05
Diastolic Pressure (mmHg)	0.342	<0.05	0.242	<0.05
	Female			
Heart Rate (bpm)	0.085	0.690	0.239	0.260
Ventilation Rate (mL/kg/min)	-0.771	<0.001	0.906	<0.001
Systolic Pressure (mmHg)	0.509	0.011	0.466	0.021
Diastolic Pressure (mmHg)	0.557	0.004	0.481	0.017

Table 3.: list of R-coefficient and p-values calculated for male and female participants using Spearman correlation method

	Pre-training		**Post-training**	
Parameters	H-value	*p-value*	H-value	*p-value*
Heart Rate (bpm)	26.50	<0.05	4.92	<0.05
Ventilation Rate (mL/kg/min)	12.51	<0.05	10.38	<0.05
Systolic Pressure (mmHg)	2.58	>0.05	17.26	<0.05
Diastolic Pressure (mmHg)	2.49	>0.05	14.54	<0.05

Table 3 lists H-values and p-values calculated through non-parametric analysis of the similarity between the distribution of female and male participants using Kruskal-Wallis H tests. In all post-training responses, there is a significant difference between the distribution of male and female participants in terms of heart rates, ventilation rates and blood pressure. However, the test is unable to reject the null hypothesis of similarity for systolic and diastolic pressure in pre-training samples for both groups. On the contrary, heart rate and ventilation rates, similar to post-training samples, show a significant difference in responses.

Seasons categories were arranged in a way to classify all training sessions in June and July as the summer season; those performed in September and October as the fall season; and the sessions completed in January until the beginning of March as winter seasons. The average ambient temperature was calculated as 42 ̊C for summer, 36 ̊C for fall, and 25 ̊c for winter.

Figure 3 provides boxplots of all parameters depicted versus seasons. Heart and ventilation rates differ for various seasons in pre and post-training samples. Also, the distributions show skewness of various shapes for different seasons in these two parameters. In contrast, there is a similarity between medians and distribution shapes of heart rates for different seasons. In most cases, the skewness of data is limited, and distribution behaves as normal. For samples collected in pre-training sessions during the summer, the median has the same value as the lower quantile which corresponds to a wide skewness to the right side of the distribution. In terms of diastolic blood pressure, the similarity of medians is evident with a significant difference in distribution shape

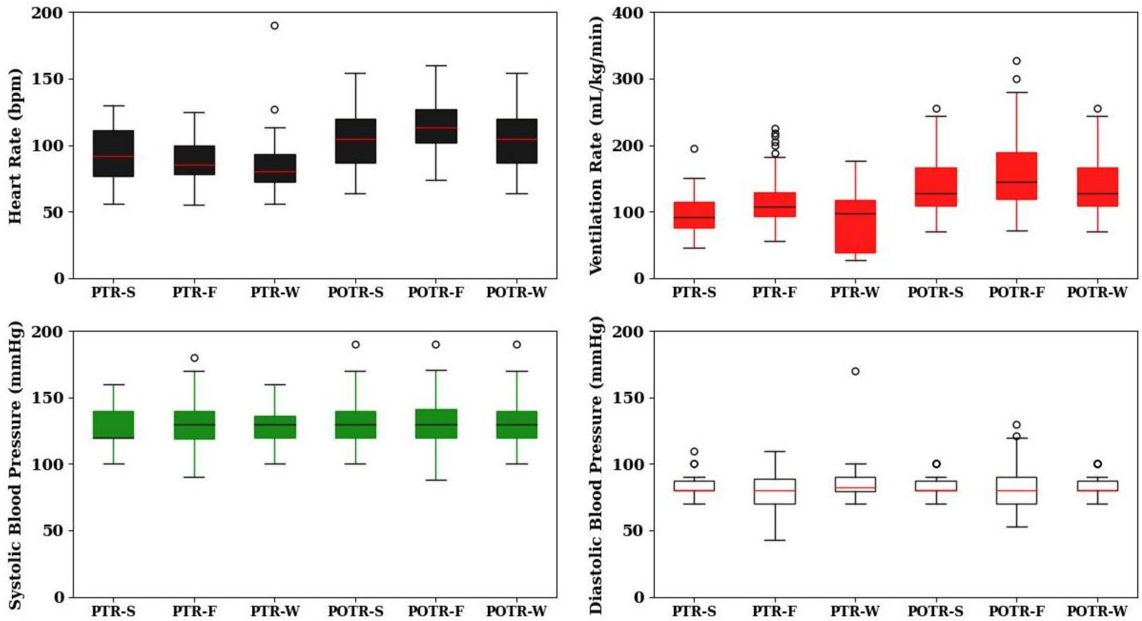

Figure 3: boxplot of physiological responses sampled pre and post-training in different seasons. (PTR= Pre-Training; POTR= Post-Training; S=Summer; F=Fall; W=Winter)

Heart and ventilation rates differ for various seasons in pre and post-training samples. Also, the distributions show skewness of various shapes for different seasons in these two parameters. In contrast, there is a similarity between medians and distribution shapes of heart rates for different seasons. In most cases, the skewness of data is limited, and the distribution behaves as normal. For samples collected in pre-training sessions during the summer, the median has the same value as the lower quantile which corresponds to a wide skewness to the right side of the distribution. In terms of diastolic blood pressure, the similarity of medians is evident with a significant difference in distribution shape.

The effect of different ambient temperatures was further examined by running Kruskal-Wallis H-test. In terms of ventilation rates for both pre and post-training, the samples have a significant difference in median and distribution which corresponds an agreement with the observation in Figure 3. The test failed to reject the null hypothesis for heart rate.

For systolic and diastolic pressure, the differences in distribution median and samples are not detected by the H-score and p-value given in Table 4. In both cases of pre and post-training samples, the null hypothesis of similar distribution remained valid based on the analysis which was commensurate with the observation of the boxplot provided in Figure 3.

Table 4.: List of H-scores and p-values versus physiological parameters obtained from Kruskal – Wallis test with cut-off $\chi 2 = 5.99$ and two-degrees freedom.

	Pre-training		Post-training	
Parameters	H-value	*p-value*	H-value	*p-value*
Heart Rate (bpm)	26.50	<0.05	4.92	<0.05
Ventilation Rate (mL/kg/min)	12.51	<0.05	10.38	<0.05
Systolic Pressure (mmHg)	2.58	>0.05	17.26	<0.05
Diastolic Pressure (mmHg)	2.49	>0.05	14.54	<0.05

Discussion

Physiological responses of firefighters from a training center in the middle east were sampled for the first time which led to several findings. Mean systolic and diastolic pressure calculated in this study was recorded in the range of 129-133 mm Hg and 82-83 mmHg, respectively for both pre and post-training samples. The range is in agreement with previous studies where firefighter systolic and diastolic pressure before and after firefighting activity were in the range of 135-137 mmHg, and 84 mmHg, respectively.[5,25] This is also in line with the study on Croatian firefighters, whose maximum changes in both diastolic and systolic pressure did not exceed more than 3% before and after flashover training.[22] This study found that correlation between systolic and diastolic pressures with BMI to be positive and stronger in females than male participants. A similar correlation was found in another study where firefighter BMI and blood pressure showed a positive relation in pre and post-training samples.[22] The result could support that firefighters' blood pressure and indeed risk of cardiovascular diseases increases with a higher body mass index.

The age of participants and blood pressure showed a weak correlation in this study, mostly documented in after-training samples. Calculated correlations are less than 0.2 which makes it hard to draw any conclusion on correlation between these two parameters. Previous studies could not determine any correlation between age and blood pressure and current study corroborate those findings.[22] Similar results confirmed the effect of ambient temperature, where systolic and diastolic pressures of firefighters show no sensitivity to seasonal temperature changes.

Blood pressures remained unchanged concerning variation in ambient temperatures. Richardson and Capra conducted studies on the effect of various ambient temperatures on Queensland firefighters in Australia while wearing fully encapsulated chemical protective clothes.[26] They reported an increase in the blood pressure of firefighters with the temperature elevation. This study, in contrast, observed insignificant changes in blood pressure in pre and post-training blood pressure measurement. In the current study, the humidity was not a controlled variable, the temperature was measured as an average of the test day and firefighters wore normal firefighting gear. However further studies need to address the discrepancy found between this study and those measured in.[26]

Heart rates measured in this study show a mean value of 87 ± 18 bpm and 112 ± 21 bpm for pre and post-training measurements, respectively. This monotonic increase of heartbeats found here is consistent with previous studies where the heartbeat measurements grow from the range of 78-89 bpm for pre-activity samples to a range of 110-120 bpm for post-activity samples.[22,9,25] Also, analysis of the correlation between heart rate with BMI and the age of participants confirmed that heart rates are not affected by those two parameters which are commensurate with previous study[22]. However, heart rate sensitivity concerning seasonal temperature changes is evident from the results which are commensurate with the results reported in the previous studies on the relation between heart rate and ambient temperature.[27]

This study could confirm that the percentage of sampled firefighters who are obese (BMI>30) is 20% (20.34%), whereas the obesity among female and male participants is equally as 20%. Moreover, the share of overweight trainees was found to be as high as 23% for those who have 25<BMI<30. For female participants, the percentage of overweight participants was recorded as 16.66%, while this is calculated as 24.50% for male participants. Ras and Leach found over 30% of sampled South African firefighters as obese;[21] similar ratios were found for sampled firefighters in Massachusetts, USA;[28] a ratio of 41% was reported for samples in Texas, USA;[29] and 27% among Croatian firefighters.[22] The comparison suggests that middle eastern firefighters considered in this study have a lower number of obesity cases than their colleagues in other parts of the world.

According to the occupational medical program for fire departments published by NFPA,[30] 19.8% of participants were found to have hypertension in this study under pre-training conditions, while it increased to 26.7% after training. Of these, 3.48% of participants had values corresponding to stage 2 and 15.11% were in thresholds between stage 1 and stage 2 for pre-training measurements. The values considerably increased to 19.76% and 8.13% for stages 1 and 2, respectively in post-training samples.

It was found that sampled firefighters have a lower hypertension prevalence ratio. Soteriades et al (2003) noted a hypertensive prevalence ratio of 23% for firefighters examined in Massachusetts [20] and Choi et al (2016) highlighted a hypertensive prevalence ratio of 11% for firefighters in southern California.[8] However, the ratio dramatically increased for their European counterparts in Croatia where it was reported as 52% for the age group of 18-34 years and 53% for 35-49 years.[22] The ratio for South African firefighters, in the city of Cape Town, is noted as 33% mainly in male participants with ages over 40 years[21] and it decreases to 7% and 18.1% for Iranian and Korean firefighters, respectively.[23,24] Although the results show that sampled firefighters have blood pressures lower than the global average, robust health monitoring programs should be in place to prevent the growth of the hypertensive firefighter population in this region in the future.

It is noteworthy to address the limitation of this study. Foremost, there were inconsistencies between the population of sampled female and male participants. Future studies should address the shortcoming and include data on more female firefighters, though, the inconsistency has previously been addressed worldwide by the research community in other works.

Conclusion

The results corroborated previous findings, where systolic and diastolic pressure as well as ventilation rates strongly correlated with BMI. Changes in ventilation rates among female trainees with respect to their BMI were more significant than male participants. This study found that heart rates significantly change with ambient temperature in both pre and post-training measurements, while it remains unchanged concerning BMI, age, and gender of participants. Obesity and hypertension prevalence ratios were calculated for participants and compared with previous studies. Obesity was found in 20% of participants which is lower than the global average. About 19.8% and 26.7% of participants were determined with hypertension in pre and post-training measurements, respectively.

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