

Examining the Relationship between Firefighters' Performance on Physical Ability Test and Measures of Blood Pressure, Pulse Rate, and Aerobic Capacity



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Abstract:

Introduction: Firefighting involves rapid decision-making and physically demanding tasks, yet firefighters are at an elevated cardiovascular risk. This study examined associations between blood pressure, heart rate, aerobic capacity, and physical ability test (PAT) performance in firefighters. We hypothesized that PAT performance would relate to resting cardiovascular measures and aerobic fitness.

Methods: A secondary analysis was conducted using data from 599 full-time firefighters in the City of Cape Town Fire and Rescue Service. The PAT comprised occupation-specific tasks simulating firefighting duties. Measurements included height, weight, resting blood pressure, resting heart rate (RHR), and aerobic capacity. Post-PAT blood pressure and heart rates (HRs) were also recorded. Analyses included t-tests, ANOVA, and regression models.

Results: Age, height, post-test systolic blood pressure (SBP), and SBP change were significantly associated with PAT times ($p < 0.001$). Older firefighters were less likely to pass ($OR=0.96$), while males were 18 times more likely to pass than females. Greater differences in pre-to-post SBP and RHR were associated with higher pass rates ($p < 0.001$). Aerobic capacity had a positive influence on success ($OR=1.06$). Resting SBP, post-PAT SBP, HR responses, and their differences were significantly related to task-specific performance ($p < 0.05$).

Discussion: The findings align with prior research, which shows that obesity, elevated blood pressure, and higher heart rates negatively impact firefighting ability.

Conclusion: Cardiovascular health, reflected by heart rate and blood pressure responses, strongly predicts PAT outcomes. Interventions such as regular physical activity and dietary strategies (*e.g.*, the DASH diet) should be prioritized to improve cardiovascular health and enhance occupational performance, thereby reducing health risks in firefighters.

Keywords: Blood pressure, Heart rate, Aerobic capacity, Physical ability test, Obesity, Cardiovascular health.

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1. INTRODUCTION

Firefighting is a dangerous profession where firefighters are routinely exposed to hazardous chemicals and fumes, as well as extreme temperatures [1-3]. In addition, firefighters are required to perform additional duties, such

as smoke diving, Extrication, and perform emergency resuscitation, while being required to make expeditious decisions [1, 4, 5]. Due to the demanding nature of the firefighting profession, firefighters are required to maintain a good standard of cardiovascular and physical fitness

[3, 6, 7]. However, hypertension and obesity continue to be a serious concern in firefighters, particularly as they age [8-10].

Firefighters have been shown to experience elevated blood pressure while performing fire suppression, reaching near-maximal heart rates [4, 11]. Furthermore, blood pressures are elevated in firefighters, compared to the general civilian population [12, 13]. Previous research has noted that blood pressure responses are often exaggerated in firefighters, particularly while performing strenuous work-related duties [14-16]. However, a systematic review conducted by McMorrow and Fearheller [16] found that there have not been any previous studies conducted that investigated the blood pressure responses pre- and post-emergencies or pre- and post-simulation performance, leaving a significant gap in the literature. In addition, previous research had only focused on the effect of resting measures of cardiovascular health and physical fitness on work ability [3, 16-19], highlighting the need for the current study. It may be hypothesized that blood pressure and heart rate can be significant factors in a firefighter's cardiovascular fitness and performance on duty. As with blood pressure, heart rates were reported to be elevated in firefighters, particularly as a result of alarm response [14]. Moreover, studies have reported that heart rate, at rest, is significantly associated with occupational performance in firefighters [7, 20-22]. This may be related to lower resting heart rates being directly related to higher levels of cardiorespiratory fitness [23, 24]. A systematic review reported that heart rate recovery can be used to measure training status and the accumulation of fatigue [25]. Similarly, a study conducted by Cornell *et al.* [26] reported that heart rate recovery was significantly associated with physical fitness in firefighters. Heart rate recovery has been considered a reliable measure for assessing firefighters' fitness for duty and return to work after rehabilitative interventions [15, 27]. Complementing this, heart rate recovery was shown to be related to early mortality [28-30]. The ideal timespan was reported to be between 5 and 6 minutes post-exercise to retrieve the highest intra-class correlations. Obesity has been shown to exacerbate these cardiovascular concerns, as it increases firefighters' peripheral resistance. Additionally, heat production while wearing PPE increases, while overall work capacity decreases [7, 20, 31-34].

Blood pressure and heart rate recovery, as well as the difference between each variable, may prove to be invaluable assessment tools in assessing firefighters' baseline cardiovascular health and parasympathetic functioning [16, 26, 35]. However, there have not been studies conducted investigating the association between the relationship of pre- and post-blood pressures and heart rates, blood pressure and heart rate recovery, and physical ability test performance in firefighters. Therefore, this study investigates the association between PAT performance, blood pressure, heart rate and aerobic capacity in firefighters. This study hypothesised that demographic characteristics, resting blood pressure, resting heart rate,

and aerobic capacity would be significantly associated with PAT performance in firefighters.

2. METHODS

2.1. Study Design and Population

In the current study a secondary analysis of data collected by the City of Cape Town Fire and Rescue Service (CoCTFRS) was conducted. The data included the physical ability test (PAT) that was conducted by the Fire Services during their annual wellness and Fitness assessment. The data included demographic information, such as age, sex, height, and weight. In addition, data were collected on firefighters' resting heart rates and blood pressures, and post-PAT heart rates and blood pressures. In total, data were collected on 599 male and female full-time firefighters, with ages ranging between 20 and 65 years, as this is the typical retirement age for firefighters. Approval to analyze the secondary data was provided by the Chief Fire Officer and the head firefighter in charge of the wellness and physical fitness assessment. Additionally, all firefighters provided their consent for the data to be used for research purposes. Ethical clearance was granted by the University of the Western Cape (UWC) Biomedical Research Ethics Committee (BMREC) (ethical clearance number: BM21/10/9). Additionally, the Helsinki Declaration has been adhered to in this study. During data collection, all participating firefighters were informed that their written informed consent was obtained before proceeding. The period of data collection spanned from July to August 2022.

2.2. Sampling and Participant Recruitment

Data collection took place at a single fire station located in the South District in the Cape Town Metropolitan area. Furthermore, to ensure consistency in terrain, environmental conditions and testing surface, data was collected on dry days with cool temperatures. All physical measurements and PAT tasks were gathered and recorded by qualified firefighters and researchers who were familiar with all testing equipment and research protocols to ensure the consistency and reliability of the test results. All full-time firefighters, regardless of age, who had passed the initial health assessment were tested and included in the data set. Firefighters on sick leave, in administrative duty, with seasonal or part-time employment, or who did not participate in the PAT were excluded from the study. Firefighters who failed to pass the pre-PAT assessment, such as those with elevated blood pressures (systolic blood pressures above 180 mmHg and diastolic blood pressure above 105 mmHg), those with underlying cardiovascular disease (CVD), or those with signs and symptoms of CVD (angina, chest pressure, dyspnea, dizziness or fainting) were excluded from participation.

2.3. Physical Ability Test

The Fire and Rescue Service in the City of Cape Town utilized occupational-specific tasks to evaluate operational performance, following the testing protocol outlined in the wellness manual. The PAT is a standardized work ability

assessment that all firefighters are required to pass when becoming firefighters. This is then used to test the firefighters' occupational readiness annually. Collaborating with industry professionals, the CoCTFRS incorporated these tasks into their fitness and wellness program to mimic the challenges firefighters encounter. These tasks aimed to replicate the physical demands and strains faced by firefighters during their duties. Participants were required to complete a simulation protocol within 9 minutes (540 seconds), with 20 seconds allotted for recovery between tasks, while wearing full PPE and breathing apparatus. The simulation comprised six tasks designed to simulate various stressors encountered by firefighters: step-up (SU), charged hose drag and pull (CHDP), forcible entry (FE), equipment carry (EC), ladder raise and extension (LRE), and rescue drag (RD). Each task had specific completion time requirements, and failure to meet them resulted in a "not yet competent" grade on the Physical Ability Test (PAT). The SU task mandated 30 repetitions on a standardized 200 mm platform within 90 seconds. For the CHDP, firefighters had to drag a tire 27 meters and then pull it an additional 15 meters within 180 seconds. The FE task involved driving a 6-kg sledgehammer to move a tire 600 mm in under 60 seconds. In the EC task, firefighters had to remove two 25 kg foam drums from a 1.2-meter platform, carry them 25 meters, return 25 meters, and place the drums back within 90 seconds. For the LRE, firefighters had to position a ladder against a building, hoist a 35 kg drum using a hauling line, and lower it within 90 seconds before returning the ladder to its original position. Lastly, the RD required firefighters to drag an 80 kg tire 11 meters, execute a 180-degree turn, and continue for another 11 meters within 60 seconds. The protocol used was used previously in a study conducted by Ras *et al.* [17]

2.4. Height, Weight, Blood Pressure, Heart rate and Aerobic Capacity Measurements

Height was measured using a standardized portable stadiometer (Seca portable stadiometer), with firefighters standing barefoot and their heads positioned in the Frankfort plane [36]. The weight of the firefighters was measured with firefighters wearing minimum clothing (shorts for males and shorts and a t-shirt for females) using a calibrated precision weight scale [36]. Body mass index (BMI) was calculated using the formula: $(\text{kg})/(\text{height (m)})^2$. Blood pressure was measured using a blood pressure cuff and a Sphygmomanometer, the standard auscultatory technique employed by trained paramedics. When taking blood pressure, firefighters were instructed to remain seated for five minutes prior to testing. Blood pressure was taken, in a seated position, twice and if blood pressure varied more than 2 mm Hg, blood pressure was taken for a third time. Heart rate was taken using a pulse oximeter (SantaMedical Finger Pulse Oximeter). Additionally, heart rate was measured for 60 seconds to ensure the accuracy of the readings. Aerobic capacity was estimated using the heart rate ratio formula: $\text{VO}_2 \text{ max} = 15.3 \times (\text{HRmax} \div \text{HRrest})$ [37]. Heart rate max was estimated using Tanaka's formula, *i.e.*, $\text{HRmax} = 208 -$

$0.7 \times \text{age}$ [38]. Once the firefighters had completed the PAT, they performed the PAT, where they were asked to remove their breathing apparatus and jacket and then remain seated for five minutes before their blood pressure was taken. Blood pressure and heart rate differences were calculated by subtracting post-PAT measures from pre-PAT measures.

2.5. Statistical Analysis

The data were cleaned and coded using a Microsoft Excel spreadsheet. Thereafter, the data were imported into a statistical software package, namely SPSS® software, version 29 (Chicago, Illinois, USA), and analysed. Descriptive statistical analyses, such as the mean and standard deviation. Thereafter, group comparisons were performed using the independent samples t-test and the one-way analysis of variance (ANOVA). Univariable and multivariable linear regressions were conducted to determine the sociodemographic characteristics and cardiovascular health measures (blood pressure and heart rate) that were significantly associated with performance on the PAT. In addition, logistic regression was used to assess the association between demographic characteristics, blood pressure, heart rate, and overall pass rates for the PAT and pass rates for each PAT task, *i.e.*, SU, CHDP, FE, EC, LRE, and RD. Three models were used to assess the effect of confounding factors on occupational performance. For the linear and logistic regression models, Model 2 was adjusted for age and sex and Model 3 was adjusted for age, sex and aerobic capacity. For all models, the PAT completion times, PAT pass rates, and pass rates for each PAT task were considered as the dependent variables. The independent variables included measures such as height, weight, BMI, SBP, DBP and pulse rate. To ensure that significant collinearity and multicollinearity were not present, which could impact the statistical outcomes, the variance inflation factor (VIF) and Durbin-Watson statistics were used. In addition, a test statistic of between 1.5 and 2.5 for the Durbin-Watson indicated the absence of autocorrelation, while a VIF <5 was used to demonstrate the absence of significant collinearity. For this dataset, the data was normalized using the fractional ranking and inverse DF, IDF.NORMAL transformation [39]. A *p*-value of <0.05 was used to indicate statistical significance.

3. RESULTS

3.1. Differences between Demographic Characteristics and PAT Performance

Table 1 presents the demographic characteristics of the participants, categorized by sex and age groups. The mean age of the firefighters was 39.4 ± 10.0 years, with a mean weight of 85.4 ± 16.9 kg, height of 1.7 ± 0.1 m, and BMI of 27.9 ± 6.7 kg·m⁻². Males were significantly heavier ($p = 0.009$), taller ($p < 0.001$), and had higher SBP compared to females ($p < 0.001$). Male firefighters were found to complete the PAT significantly faster than female firefighters ($p < 0.001$). In addition, the resting heart rate was higher in females than in males ($p = 0.003$). There was a significant difference in BMI according to sex and age groups ($p < 0.001$). Based on age groups, the oldest age

group of firefighters (50 and older) had the highest BMIs ($p < 0.001$), DBPs ($p < 0.001$), resting heart rates ($p = 0.003$), post-PAT heart rates ($p = 0.041$), SBP (post) ($p < 0.001$), and the lowest aerobic capacity ($p = 0.008$) and slowest PAT completion times ($p < 0.001$).

3.2. Linear Associations between Demographic Characteristics, Blood Pressure, Heart Rate, Aerobic Capacity and PAT Performance in Firefighters

Table 2 presents the results of univariable and multi-variable analyses in relation to the Physical Ability Test. In the univariable models, age demonstrated a significant positive association ($\beta = 3.750$, $p < 0.001$) with physical

ability, while weight, diastolic blood pressure, and heart rate post-test showed no significant relationship. The results showed that height, BMI, heart rate, and SBP, both pre-and-post-test, exhibited significant associations with physical ability ($p < 0.001$, $p = 0.003$, $p < 0.001$, $p < 0.001$, $p < 0.001$, respectively). In model 2, after adjustment for age and sex, height ($p < 0.001$), heart rate ($p = 0.015$), and SBP both pre-and-post-test ($p < 0.001$) retained their significant associations with the PAT. In model 3, age, height, SBP (post) and SBP diff. remained significantly associated with PAT completion times (all $p < 0.001$). The results confirm the hypothesis that PAT performance is significantly related to demographic characteristics and measures of cardiovascular health.

Table 1. Demographic characteristics of firefighters based on sex and age categories.

-	Total Firefighters		Sex				p	Age Category								-
			Males		Females			20-29		30-39		40-49		50+		
	N	$\bar{x}\pm SD$	N	$\bar{x}\pm SD$	N	$\bar{x}\pm SD$		N	$\bar{x}\pm SD$	N	$\bar{x}\pm SD$	N	$\bar{x}\pm SD$	N	$\bar{x}\pm SD$	
Age (years)	599	39.4±10.0	531	39.6±10.3	68	37.8±6.9	0.162	116	26.3±2.3	216	34.5±2.9	158	44.9±	109	54.6±3.6	<0.001
Weight (kg)	599	85.4±16.9	531	86.2±16.7	68	79.1±17.3	0.009	116	75.1±13.2	216	83.0±15.3	158	87.7±17.9	109	85.4±16.9	<0.001
Height (m)	599	1.7±0.1	531	1.7±0.1	68	1.6±0.1	<0.001	116	1.7±0.1	216	1.7±0.1	158	1.7±0.1	109	1.8±0.1	0.074
Body Mass Index (kg•m-2)	599	27.9±6.7	531	27.8±6.7	68	29.4±7.1	0.193	116	24.9±4.8	216	27.6±6.1	158	28.5±7.1	109	30.5±7.5	<0.001
Systolic blood pressure (mm Hg)	599	137.3±43.2	531	138.4±45.4	68	128.9±16.6	<0.001	116	133.1±12.8	216	137.7±68.6	158	136.4±17.5	109	142.2±17.7	0.464
Diastolic blood pressure (mm Hg)	599	86.1±10.5	531	86.2±10.5	68	85.1±10.5	0.416	116	81.5±9.4	216	84.9±9.3	158	89.7±10.2	109	89.7±11.7	<0.001
Pulse rate (bpm)	599	83.6±14.9	531	82.9±14.5	68	88.6±16.8	0.003	116	79.9±14.1	216	84.7±16.2	158	85.9±13.9	109	81,6±13.5	0.003
Systolic blood pressure (post) (mm Hg)	599	163.1±24.9	531	164.0±24.8	68	156.0±25.4	0.013	116	159.7±23.4	216	161.1±22.2	158	165.3±26.8	109	167.6±29.3	0.041
Diastolic blood pressure (post) (mm Hg)	599	91.4±33.9	531	91.7±35.4	68	89.7±20.1	0.647	116	85.9±19.2	216	93.9±50.1	158	92.9±19.5	109	90.4±19.1	0.206
Pulse rate post (bpm)	599	147.8±19.9	531	147.5±19.8	68	150.3±20.0	0.276	116	149.6±21.7	216	150.9±18.3	158	148.3±18.7	109	139.4±20.4	<0.001
Systolic blood pressure diff. (mm Hg)	599	28.6±29.0	531	28.5±28.6	68	29.0±32.3	0.885	116	26.4±24.2	216	29.3±27.5	158	30.5±31.1	109	26.7±33.3	<0.001
Diastolic blood pressure diff. (mm Hg)	599	6.3±35.6	531	6.3±36.8	68	5.8±24.5	0.903	116	4.3±20.1	216	10.6±52.2	158	5.1±21.8	109	1.5±20.9	0.581
Pulse rate diff. (bpm)	599	65.6±24.1	531	65.9±24.0	68	63.0±24.6	0.343	116	71.8±28.9	216	67.5±21.2	158	62.4±21.9	109	59.9±25.9	0.131
Physical ability test (s)	599	410.9±180.3	531	377.1±133.1	68	675.7±264.8	<0.001	116	350.4±101.6	216	405.9±202.7	158	435.9±181.8	109	449.9±181.8	<0.001

Note: * indicates statistically significance <0.05; ** indicates statistical significance <0.01; † - indicates statistical significance <0.001. Kg - kilogram; m - meter; kg•m⁻² - kilogram per meter squared; mm Hg - millimetres of mercury; bpm - beats per minute.

Table 2. Linear regression describing the linear association between demographic characteristics, resting and recovery blood pressure, and heart rate in firefighters.

Variable	Model 1a				Model 2b				Model 3c			
	B	SE	R2	p-value	B	SE	R2	p-value	B	SE	R2	p-value
Model: Physical Ability Test	-	-	-	-	-	-	-	-	-	-	-	-
Age (years)	3.750	0.720	0.043	<0.001†	4.305	0.603	0.333	<0.001†	4.202	0.601	0.342	<0.001†
Weight (kg)	-0.260	0.538	0.001	0.629	-0.541	0.476	0.334	0.256	-	-	-	-
Height (m)	-828.010	96.655	0.174	<0.001†	-467.826	90.563	0.428	<0.001†	-458.04	90.43	0.434	<0.001†
Body Mass Index (kg•m-2)	4.182	1.382	0.025	0.003**	1.666	1.132	0.388	0.142	-	-	-	-
Systolic blood pressure (mm Hg)	-0.001	0.001	0.002	0.230	0.001	0.001	0.334	0.307	-	-	-	-
Diastolic blood pressure (mm Hg)	0.573	0.714	0.001	0.422	-0.359	0.612	0.334	0.558	-	-	-	-
Heart rate (bpm)	1.917	0.497	0.025	<0.001†	1.010	0.414	0.339	0.015*	-0.166	1.175	0.341	0.888
Systolic blood pressure (post) (mm Hg)	-1.491	0.290	0.042	<0.001†	-1.347	0.240	0.367	<0.001†	-1.329	0.239	0.374	<0.001†
Diastolic blood pressure (post) (mm Hg)	-0.167	0.218	0.001	0.443	-0.156	0.178	0.334	0.381	-	-	-	-
Heart rate post (bpm)	0.235	0.372	0.001	0.528	0.409	0.309	0.335	0.187	-	-	-	-
Systolic blood pressure diff. (mm Hg)	0.894	0.252	0.021	<0.001†	-0.933	0.204	0.356	<0.001†	-1.138	0.231	0.367	<0.001†
Diastolic blood pressure diff. (mm Hg)	-0.165	0.207	0.001	0.425	-0.092	0.169	0.334	0.586	-	-	-	-
Heart rate diff. (bpm)	-0.565	0.306	0.006	0.065	-0.093	0.255	0.334	0.716	-	-	-	-
Aerobic capacity	-3.951	1.108	0.021	<0.001†	-2.491	0.917	0.342	0.007**	-	-	-	-

Note: * indicates statistical significance <0.05; ** indicates statistical significance <0.01; † - indicates statistical significance <0.001.

a - univariable models; b - multivariable models adjusted for age and sex; c - multivariable models adjusted for age, sex and aerobic capacity.

Kg - kilogram; m - meter; kg•m-2 - kilogram per meter squared; mm Hg - millimetres mercury; bpm - beats per minute; B - unstandardized beta coefficient; SE - standard error; R2 - R-squared.

3.3. Associations between Demographic Characteristics, Blood Pressure, Heart Rate, Aerobic Capacity and PAT Performance in Firefighters

Table 3 presents the odds ratios of firefighters passing the physical ability test, based on demographic characteristics, resting and recovery blood pressure, and heart rate. Age was found to be significantly associated with the PAT pass rate (OR = 0.96, $p < 0.001$). Similarly, males were eighteen times more likely to pass the PAT compared

to females (OR = 18.41, $p < 0.001$). Firefighters with higher BMIs and higher heart rates were less likely to pass the PAT ($p < 0.001$). In addition, firefighters with higher SBP differences and higher heart rate differences, pre-and-post-test, were more likely to pass the PAT (both $p < 0.001$). An increase in aerobic capacity was associated with an increase in the odds of passing the PAT (OR = 1.06, $p = 0.003$). These results confirm our hypothesis that a linear relationship exists between demographic characteristics and cardiovascular measures in firefighters.

Table 3. Logistic regression describing the odds ratios of firefighters passing the physical ability test based on demographics characteristics, resting and recovery blood pressure, and heart rate in firefighters.

	Model 1			Models 2			Model 3		
	OR (95% CI)	SE	p-value	OR (95% CI)	SE	p-value	OR (95% CI)	SE	p-value
Model: PAT pass rate	-	-	-	-	-	-	-	-	-
Age (years)	0.96 (0.93, 0.98)	0.011	<0.001†	0.92 (0.89, 0.95)	0.01	<0.001†	0.92 (0.89, 0.95)	0.01	<0.001
Sex	18.41 (10.32, 32.87)	0.296	<0.001†	28.99 (15.06, 55.82)	0.33	<0.001†	28.56 (14.69, 55.52)	0.34	<0.001
Weight (kg)	0.99 (0.98, 1.01)	0.01	0.626	0.99 (0.98, 1.02)	0.01	0.673	-	-	-
Height (m)	4801.41 (127.59, 180687.32)	1.85	<0.001†	96.85 (1.04, 9035.51)	2.31	0.048*	68.87 (0.78, 6262.83)	2.30	0.066
Body Mass Index (kg•m-2)	0.92 (0.88, 0.97)	0.024	<0.001†	0.94 (0.89, 0.99)	0.03	0.039*	0.95 (0.89, 1.00)	0.030	0.061
Systolic blood pressure (mm Hg)	1.00 (1.00, 1.00)	0.00	0.803	1.00 (0.99, 1.02)	0.01	0.622	-	-	-
Diastolic blood pressure (mm Hg)	0.99 (0.97, 1.01)	0.01	0.291	0.99 (0.97, 1.02)	0.01	0.867	-	-	-
Hypertension	0.79 (0.51, 1.23)	0.23	0.290	0.71 (0.41, 1.23)	0.29	0.226	-	-	-
Heart rate (bpm)	0.97 (0.95, 0.98)	0.01	<0.001†	0.97 (0.95, 0.99)	0.01	<0.001†	0.91 (0.86, 0.95)	0.02	<0.001
Systolic blood pressure (post) (mm Hg)	1.02 (1.01, 1.03)	0.01	<0.001†	1.02 (1.01, 1.03)	0.01	0.002**	1.02 (1.01, 1.03)	0.01	0.003**

(Table 3) contd.....

-	Model 1			Models 2			Model 3		
	OR (95% CI)	SE	p-value	OR (95% CI)	SE	p-value	OR (95% CI)	SE	p-value
Diastolic blood pressure (post) (mm Hg)	1.01 (0.99, 1.02)	0.01	0.312	1.01 (0.99, 1.02)	0.01	0.203	-	-	-
Heart rate post (bpm)	1.01 (0.99, 1.02)	0.01	0.235	1.01 (0.99, 1.02)	0.01	0.469	-	-	-
Systolic blood pressure diff. (mm Hg)	1.01 (1.00, 1.02)	0.00	0.025*	1.02 (1.01, 1.03)	0.01	0.001†	1.01 (1.00, 1.02)	0.01	0.033*
Diastolic blood pressure diff. (mm Hg)	1.01 (0.99, 1.02)	0.01	0.161	1.01 (1.00, 1.02)	0.01	0.014*	1.01 (0.99, 1.02)	0.01	0.220
Heart rate diff. (bpm)	1.02 (1.01, 1.03)	0.01	<0.001†	1.01 (0.99, 1.02)	0.01	0.182	-	-	-
Aerobic capacity	1.06 (1.02, 1.09)	0.02	0.003**	1.05 (1.01, 1.09)	0.021	0.023*	-	-	-

Note: * indicates statistical significance <0.05; ** indicates statistical significance <0.01; † - indicates statistical significance <0.001.

a - univariable models; b - multivariable models adjusted for age and sex; c - multivariable models adjusted for age, sex and aerobic capacity.

Kg - kilogram; m - meter; kg•m⁻² - kilogram per meter squared; mm Hg - millimeters mercury; bpm - beats per minute; OR - odds ratio; CI - confidence interval; SE -standard error.

3.4. Multivariable Analysis

In model 2 of the multivariable analysis, after adjusting for age and sex, an increase in BMI and heart rate remained associated with lower PAT pass rates in firefighters ($p = 0.039$, $p < 0.001$). In addition, a larger difference between SBP and DBP pre-and-post-test was associated with a higher likelihood of passing the PAT ($p < 0.001$, $p = 0.014$). After adjustment, an increase in aerobic capacity remained significantly associated with an increase in odds of passing the PAT (OR = 1.05, $p = 0.023$). In model 3, age (OR = 0.92), sex (OR = 28.56), heart rate (OR = 0.91), systolic blood pressure (post) (OR = 1.02), and SBP difference (OR = 1.10) remained significantly associated with PAT pass rates. The hypothesis remained true after adjustment for age, sex and aerobic capacity.

3.5. Associations between Demographic Characteristics, Blood Pressure, Heart Rate, Aerobic Capacity and Individual Task Performance in Firefighters

Table 4 presents the association and odds ratios for passing the individual PAT tasks, based on demographic characteristics, resting and recovery blood pressure, and heart rate, as well as aerobic capacity, in firefighters. Univariable analysis showed that age decreased the odds of passing the SU (OR = 0.91), EC (OR = 0.94), LRE (OR = 0.95), and RD tasks (OR = 0.94). An increase in heart rate decreased the odds of passing the CHDP (OR = 0.95), FE (OR = 0.96), EC (OR = 0.96), LRE (OR = 0.96), and the RD (OR = 0.95) tasks. An increase in heart rate post-PAT was significantly associated with the SU (OR = 1.04), FE (OR = 1.03), EC (OR = 1.03), LRE (OR = 1.03) and RD (OR = 1.03) tasks. An increase in the heart rate difference was significantly associated with the CHDP (OR = 1.04), FE (OR = 1.04), EC (OR = 1.05), LRE (OR = 1.04) and RD (OR = 1.04) tasks. The results of the logistic regression confirmed the hypothesis, showing that resting and post-PAT heart rates and blood pressures were significantly associated with performance on each individual PAT task.

3.6. Multivariable Analysis

In the multivariable analysis, after adjusting for age and sex, an increase in age remained significantly associated with a decrease in the odds of passing the SU (OR = 0.85), EC (OR = 0.93), LRE (OR = 0.94), and RD (OR = 0.94) tasks. After adjustment for covariates, an increase in resting heart rate remained significantly associated with a decrease in odds of firefighters passing the CHDP (OR = 0.96), FE (OR = 0.96), EC (OR = 0.96), LRE (OR = 0.97) and RD (OR = 0.97) tasks. In addition, an increase in heart rate post-PAT was significantly associated with an increased odds of firefighters passing the SU (OR = 1.03), FE (OR = 1.02), EC (OR = 1.03), LRE (OR = 1.03), and RD (OR = 1.03) tasks. In addition, an increase in heart rate difference was associated with increased odds of passing the CHDP (OR = 1.04), FE (OR = 1.04), EC (OR = 1.05), LRE (OR = 1.04), RD (OR = 1.04). The hypothesis remained true after adjusting for covariates, such as age and sex, indicating that resting measures of heart rate and blood pressure as well as post-PAT were significantly associated with PAT task performance.

4. DISCUSSION

The results of the present study indicated that increased pre-and-post blood pressure, heart rates, and BMI, particularly above 30 kg•m⁻² and age, were related to worse performance on the PAT. In addition, higher post-PAT heart rates and blood pressures, as well as a larger difference between pre-and-post blood pressures and heart rate pressures were significantly associated with better performance on the PAT and had higher odds of passing the PAT and each task. The findings of this study are corroborated by previous study studies, where it has been reported that obesity is significantly and negatively associated with PAT performance and were less likely to pass the PAT [3, 17, 40]. In addition, resting blood pressures and heart rates were shown to be negatively related to ability test performance in firefighters [7, 20, 22].

Table 4. Logistic regression describing the odds ratios of firefighters passing each physical ability test task based on demographic characteristics, resting and recovery blood pressure, and heart rate in firefighters.

-	Step-up		Charged Hose Drag and Pull		Forcible Entry		Equipment Carry		Ladder Raise and Extension		Rescue Drag	
	Univariable (a)	Multivariable (b)	Univariable (a)	Multivariable (b)	Univariable (a)	Multivariable (b)	Univariable (a)	Multivariable (b)	Univariable (a)	Multivariable (b)	Univariable (a)	Multivariable (b)
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Model: Step-up	-	-	-	-	-	-	-	-	-	-	-	-
Age (years)	0.91 (0.84, 0.98) *	0.85 (0.76, 0.95)**	0.97 (0.92, 1.02)	-	0.96 (0.91, 1.01)	-	0.94 (0.91, 0.99) **	0.93 (0.89, 0.98)**	0.95 (0.91, 0.99)**	0.94 (0.89, 0.98)**	0.95 (0.91, 0.98)**	0.94 (0.89, 0.98)**
Sex	8.25 (2.01, 33.79)**	25.24 (3.89, 163.44)†	8.48 (2.66, 27.11)	-	8.73 (3.16, 24.12) †	11.49 (2.85, 34.29)†	3.12 (1.18, 9.27) *	4.09 (1.47, 11.41)**	3.81 (1.59, 9.13)	-	2.48 (0.96, 6.40)	-
Weight (kg)	0.94 (0.89, 0.99)*	0.94 (0.88, 0.99)*	1.00 (0.96, 1.04)	-	1.02 (0.97, 1.04)	-	1.00 (0.97, 1.04)	-	1.02 (0.99, 1.06)	-	1.03 (0.99, 1.07)	-
Height (m)	0.00 (0.00, 1.05)	-	50.81 (0.00, 940824.97)	-	50.81 (0.00, 940824.97)	-	52.52 (0.02, 169825.71)	-	24.51 (0.02, 33789.27)	-	85.10 (0.16, 45259.19)	-
BMI (kg•m-2)	0.87 (0.75, 1.01)	-	0.92 (0.81, 1.04)	-	0.92 (0.81, 1.04)	-	0.96 (0.85, 1.08)	-	1.02 (0.93, 1.13)	-	1.04 (0.95, 1.23)	-
SBP (mm Hg)	1.00 (0.99, 1.00)	-	1.02 (0.98, 1.06)	-	0.99 (0.99, 1.01)	-	1.00 (0.99, 1.02)	-	1.01 (0.99, 1.04)	-	1.01 (0.98, 1.04)	-
DBP (mm Hg)	1.02 (0.95, 1.09)	-	1.02 (0.96, 1.08)	-	0.99 (0.95, 1.04)	-	1.01 (0.97, 1.05)	-	1.00 (0.99, 1.04)	-	0.99 (0.96, 1.03)	-
Hypertension	0.39 (0.08, 1.97)	-	0.59 (0.18, 1.99)	-	0.39 (0.12, 1.23)	-	0.68 (0.28, 1.64)	-	0.74 (0.33, 1.66)	-	0.52 (0.22, 11.21)	-
Heart rate (bpm)	0.98 (0.94, 1.03)	-	0.95 (0.92, 0.99)*	0.96 (0.92, 0.99)*	0.96 (0.92, 0.99)**	0.96 (0.93, 0.99)*	0.96 (0.93, 0.99) **	0.96 (0.93, 0.99)**	0.96 (0.94, 0.99)**	0.97 (0.94, 0.99)*	0.95 90.93, 0.98) †	0.97 (0.94, 0.99)*
SBP (post) (mm Hg)	1.01 (0.98, 1.04)	-	1.02 (0.99, 1.05)	-	1.02 (0.99, 1.04)	-	1.02 (1.00, 1.04)*	1.02 (1.00, 1.04)*	1.01 (0.99, 1.03)	-	1.01 (0.99, 1.03)	-
DBP (post) (mm Hg)	0.99 (0.98, 1.01)	-	0.99 (0.99, 1.01)	-	1.00 (0.98, 1.02)	-	1.01 (0.98, 1.03)	-	0.99 (0.99, 1.01)	-	0.99 (0.99, 1.01)	-
Heart rate post (bpm)	1.04 (1.01, 1.07)**	1.03 (1.00, 1.07)*	1.02 (0.99, 1.05)	-	1.03 (1.00, 1.05)*	1.02 (1.00, 1.05)*	1.03 (1.01, 1.05) †	1.03 (1.01, 1.05)**	1.03 (1.01, 1.05)**	1.03 (1.01, 1.05)**	1.03 (1.01, 1.04)**	1.03 (1.01, 1.05)**
SBP diff. (mm Hg)	1.04 (1.02, 1.07)**	1.01 (0.99, 1.03)	1.02 (0.99, 1.04)	-	1.02 (1.00, 1.04)	-	1.02 (1.00, 1.03)*	1.01 (0.99, 1.03)	1.01 (0.99, 1.02)	-	1.01 (0.99, 1.02)	-
DBP diff. (mm Hg)	1.01 (0.98, 1.04)	-	0.99 (0.99, 1.01)	-	1.01 (0.98, 1.03)	-	1.01 (0.98, 1.03)	-	0.99 (0.99, 1.01)	-	1.00 (0.99, 1.01)	-
Heart rate diff. (bpm)	0.99 (0.99, 1.01)	-	1.04 (1.02, 1.06) ***	1.04 (1.01, 1.06)**	1.04 (1.02, 1.06)†	1.04 (1.02, 1.06)†	1.05 (1.03, 1.06) †	1.05 (1.03, 1.06) †	1.04 (1.02, 1.06)***	1.04 (1.02, 1.06) †	1.04 (1.03, 1.06) †	1.04 (1.02, 1.06)***
Aerobic capacity	0.995 (0.89, 1.10)	0.98 (0.88, 1.10)	1.06 (0.96, 1.17) **	1.04 (0.94, 1.15)**	1.06 (0.98, 1.16)**	1.05 (0.96, 1.14)**	1.04 (0.97, 1.12)**	1.03 (0.96, 1.11)*	1.02 (0.96, 1.08)	1.01 (0.95, 1.08)	1.05 (0.99, 1.13)**	1.05 (0.98, 1.12)**

Note: * indicates statistically significance <0.05; ** indicates statistical significance <0.01; † - indicates statistical significance <0.001.

a - univariable models; b - multivariable models adjusted for age and sex.

Kg - kilogram; m - meter; kg•m-2 - kilogram per meter squared; mm Hg - millimeters mercury; bpm - beats per minute.

4.1. Associations between Demographic Characteristics and PAT Performance

In the results of the current study, as firefighters aged, their performance on the PAT decreased significantly. Similarly, Michalides *et al.* [7] reported that age was negatively correlated with ability test performance in firefighters. Similarly, Williford *et al.* [22] reported that as firefighters aged, their performance of occupational tasks significantly decreased. This was further corroborated by Ras *et al.* [17] where the study found that in firefighters from Cape Town, age was negatively correlated with occupational performance. Previous studies have found that aging is associated with a decrease in cardio-respiratory fitness and musculoskeletal health among firefighters [41-43]. In addition, as firefighters age, their likelihood of developing cardiovascular disease increases significantly [6, 44, 45]. The combination of reduced cardiorespiratory fitness and musculoskeletal health, as well as a reduction in cardiovascular health, may explain the poorer performance on the PAT. In addition, males were significantly more likely to pass the PAT compared to females, with female completion times nearly double those of males (675.7 seconds vs 377.1 seconds). This is supported in previous studies, where it has been well established that female firefighters' tended to fare worse on the occupational performance assessments, compared to male firefighters [3, 17, 46]. Males have been shown to have a higher muscle mass, and bone mineral density and are able to produce higher force compared to females [46-48], providing a possible explanation for the difference in results. In addition, males were found to be taller and heavier than females, which is significantly correlated with task performance in firefighters [17, 18, 22]. Furthermore, a meta-analysis conducted by Nuzzo [49] indicated that men tended to have much greater cross-sectional area and greater distribution of Type II fibres compared to females, which accounts for much of the strength disparities between males and females. This may provide an additional reason for the sex disparities, as the PAT is very strength and anaerobic power dominant [17, 50].

Height was a significant factor in firefighters passing the PAT, where significant inverse associations were present between height and PAT completion times, which remained significant after adjustment for age, sex and aerobic capacity in firefighters. Phillips *et al.* [40] reported similar results, where the authors found that taller and heavier firefighters tended to perform better on simulated firefighting tasks compared to shorter firefighters and those who weighed less. In addition, the results of the current study showed that heavier firefighters were less likely to pass the step-up task, which is similar to the results reported by Phillips *et al.* Phillips *et al.* [40] noted that heavier firefighters had an advantage over tasks that required heavy lifting and force production but performed worse on tasks that required them to support their body weight while carrying additional loads. These results were supported by previous studies that height may be advantageous in performing many tasks, particularly those

that require firefighters to lift objects and apply high amounts of force, such as a ladder raise and extension and rescue drag [7, 22, 51]. The current study reported that BMI was significantly associated with decreased PAT performance. Previous literature supports these results, as it has been consistently shown that firefighters with higher BMIs, particularly those over 30 kg•m⁻² performed significantly worse on firefighter ability tests [7, 18, 20, 52].

4.2. Associations between Heart Rate and PAT Performance

The current results showed that heart rate, heart rate post-PAT, and pre-and-post-PAT differences were significantly related to PAT performance. Similarly, studies by Michaelides *et al.* [7, 20] reported that heart rate was inversely associated with ability test performance in firefighters. This was supported by Williams *et al.* [53] Those who did not finish the candidate physical ability test reported a higher heart rate than those who completed it. Similarly, Davis *et al.* [54] found that maximal heart rate was significantly associated with performance on simulated firefighting tasks. Firefighters with a lower resting heart rate, theoretically, would have a higher heart rate reserve and be able to achieve a higher increase in heart rate while performing the PAT [23, 25, 55]. Adaptations to exercise, as one increases their aerobic capacity, is a decrease in resting heart rates [56, 57]. If firefighters perform the PAT at their maximum capacity, their heart rates would increase exponentially, particularly if they attempt to complete the PAT as quickly as possible [7, 18, 20]. In addition, in those firefighters with higher resting blood pressures and heart rates, there would be a concomitant increase in heart rates during the PAT, which may remain elevated well after completion of the PAT [31, 58-60]. This would result in a lower cardiac output and higher heart rates during the PAT [61, 62], resulting in firefighters reaching exertional fatigue earlier [17, 58, 61-63], leading to poorer performance. Moreover, this poses a significant risk to firefighters, potentially leading to sudden cardiac events.¹ This could provide a possible explanation for the linear association between PAT completion times and a larger heart rate difference.

4.3. Associations between Blood Pressure and PAT Performance

Systolic blood pressure, pre-and-post-PAT, and the difference between pre-and-post-PAT blood pressure readings were significantly associated with PAT completion times and pass rates. A study by Rynne *et al.* [64] reported that firefighters who had hypertension had higher blood pressure responses than firefighters who were normotensive. In the current study, the mean blood pressure post-PAT was 163.1 mm Hg, compared to Rynne *et al.* [64], where blood pressures ranged between 135.9 and 141.9 mm Hg. The exaggerated difference between the two studies may be explained by the firefighters in the current study having higher resting blood pressures, which may explain the exaggerated post-PAT blood pressures. Blood pressures have been shown to increase

linearly with heart rate and exercise intensities [65, 66]. Less fit firefighters, or those with higher resting blood pressures, may cause them to reach a point where their mean arterial pressure starts to reduce cardiac output [16, 58, 67]. Moreover, the association between the difference between pre-and-post-PAT blood pressures and PAT performance may be explained by the blood pressure "reserve" in normotensive firefighters before the afterload starts to reduce cardiorespiratory functioning [67-69]. Previous studies have shown that the stress related to firefighters and the constant exposure to toxic chemicals and fumes may be important factors accounting for arterial dysfunction, which ultimately leads to an increase in blood pressure and dysfunctional blood pressure regulation [16, 64, 70]. The exaggerated blood pressure responses may result in, not only reduced work capacity, but also lead to adverse cardiovascular events [10]. The results indicated that blood pressure, pre-and-post-PAT remained significantly associated with PAT performance after adjustment for aerobic capacity. This suggests that, regardless of the firefighters' cardiorespiratory fitness and muscles' ability to utilize oxygen, the increased blood pressure as a result of physical exertion, may independently reduce cardiac output and work capacity [16, 67]. Stress has been linked to increased blood pressure [71, 72]. Firefighting is a strenuous occupation that often leads firefighters to develop blood pressure abnormalities [5, 72-74]. Stress and blood pressure may need to be monitored as this may negatively impact work capacity, regardless of overall physical fitness levels.

4.4. Associations between Aerobic Capacity and PAT Performance

In the present study, aerobic capacity was significantly associated with PAT completion times and overall PAT pass rates in firefighters. Similarly, studies conducted by Skinner *et al.* [52] and Sheaff *et al.* [75] reported that VO₂max was significantly and inversely associated with ability test/work performance tests in completion times. Fitter firefighters may be able to sustain a higher level of intensity for longer during the PAT, explaining the association present in the current study. Fitter firefighters would likely have lower resting and exercise blood pressure levels, suggesting that firefighters with lower blood pressures may be fitter. Interestingly, in the present study, aerobic capacity was not associated with pass rates for individual tasks. Previous studies have suggested that overall muscular strength and endurance may play a larger role in completing specific tasks, rather than aerobic capacity. [17, 18, 22, 51] Firefighters who have a higher aerobic capacity may have a lower body mass, which has been shown to disadvantage firefighters when completing individual tasks [40, 76]. The current study used a calculation that estimated VO₂max, which may be less accurate for older adults [37, 57]. This may have influenced the results slightly, and should be kept in mind when interpreting the findings.

4.5. Factors affecting Individual Task Performance

For the SU task, younger, lighter males with higher post-PAT heart rates and a larger SBP difference were more

likely to pass the step-up task. This is a similar result found by Phillips *et al.* [40], who reported that tasks incorporating moving their own body weight and additional load, such as the stair climb or SU task, their performance decreased. In addition, older firefighters may have sustained lower limb injuries or musculoskeletal discomfort which may influence their performance on this task [17, 77]. Moreover, the SU task, due to its anaerobic nature [78], would cause significant increases in blood pressure. Firefighters with lower blood pressure may tolerate a larger increase in blood pressure before significant fatigue sets in. 16,58 A similar result was shown in the CHDP task, where firefighters who had lower resting heart rates, larger heart rate differences, and higher aerobic capacity were more likely to pass. Similar, studies by Michaelides *et al.* [7, 20] have shown that firefighters with lower resting heart rates were more likely to pass the hose drag task. In addition, a lower resting blood pressure will result in a higher cardiac output as peripheral resistance remains lower [58, 66]. In addition, the CHDP is the most strenuous of the tasks causing the highest physical stressors, which higher blood pressures may accentuate, leading to premature fatigue and lower work rates [17, 50]. It was found that males who had a lower heart rate and larger heart rate difference were more likely to pass the FE task. The FE task is an upper extremity-dominated task, where higher force production would equate to quicker task completion [50, 79]. Research has shown that females tend to have significantly lower upper-body muscular and force production compared to males, possibly explaining the performance bias toward males [46-48]. For the EC, younger males with a lower resting heart rate, higher heart rate difference, and higher aerobic capacity were more likely to pass. In addition, for the LRE and RD tasks, younger firefighters with lower resting heart rates and larger heart rate differences were more likely to pass. Similar to the FE task, the EC required firefighters to carry 25kg drums 50 meters. Insufficient grip strength would lead to poorer performance. Research has indicated that males tended to have higher grip strength compared to female firefighters, explaining males' better performance [17, 50]. In addition, there may have been a fatigue carryover to early onset of cardiovascular and muscular exhaustion in firefighters who had higher blood pressure and heart rates [50, 79, 80], as the 20-second recovery between each task would be insufficient [81, 82]. Possibly, firefighters who had lower resting blood pressures and heart rates had higher cardiorespiratory fitness levels and were less likely to have experienced significant fatigue prematurely during the PAT. The outcome of the study suggests that blood pressure and heart rate play an important role in the workability and efficiency of firefighters beyond the assumption that it may potentially lead to cardiovascular incidents on-duty.

4.6. Strengths and Limitations

A strength of the study was the relatively large sample size, which strengthened the results that were drawn from the dataset. This was the first study conducted on firefighters from the CoCTFRS that investigated the association between physical ability test performance and blood pressure and heart rate pre-and-post-PAT. However,

there were several limitations of the study. The first limitation was that this was a secondary data analysis, which could influence the validity of the results. Secondly, female firefighters made up a very small proportion of participants in the current study, which may limit the generalizability of the results to this population. Thirdly, there were instances of missing data in the datasheet, and these firefighters were excluded from the analysis. A fourth limitation would be that healthier and fitter firefighters may have been more likely to complete the PAT. Lastly, aerobic capacity was estimated using a non-exercise calculation, which may not have been a true reflection of the firefighters' aerobic fitness levels, especially since this calculation takes age into account and may have biased the results in favor of younger firefighters.

CONCLUSION

The study's results highlight several key factors that influence firefighters' performance on the physical ability test. Elevated BMI, blood pressure, and heart rates, along with age-related declines in fitness, pose challenges to PAT completion. Males and taller firefighters performed significantly better than shorter firefighters and those who were female. Cardiovascular health, as indicated by heart rate and blood pressure responses, strongly influences physical ability test outcomes. Aerobic capacity correlates with overall PAT performance but not necessarily with individual task success. These findings highlight the complex interplay of physiological and demographic factors in firefighter readiness, underscoring the importance of tailored interventions to enhance the physical and psychological aspects of cardiovascular health, optimize performance, and mitigate risk in this critical occupation. These may include the DASH diet, the Mediterranean Diet, and the PHLAME intervention, as well as following the recommendations for exercise and physical activity by the National Fire Protection Association (NFPA).

RECOMMENDATIONS FOR FUTURE RESEARCH

In future research, longitudinal studies are warranted to evaluate the potential impact of blood pressure and heart rate on firefighters' occupational performance. In addition, studies should be conducted to investigate the effect that the stressors of firefighting may contribute to blood pressure complications in firefighters, and ultimately, their occupational performance. Finally, a larger, more representative sample of female firefighters is needed to enable the generalizability of results to the female firefighter population, even if female firefighters make up a relatively small proportion of firemen in the CoCTFRS.

AUTHOR'S CONTRIBUTIONS

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

LIST OF ABBREVIATIONS

PAT	= Physical Ability Test
RHR	= Resting Heart Rate
SBP	= Systolic Blood Pressure
CoCTFRS	= City of Cape Town Fire and Rescue Service
CVD	= Cardiovascular Disease
CHDP	= Charged Hose Drag and Pull
FE	= Forcible Entry
SU	= Step-Up
LRE	= Ladder Raise and Extension
BMI	= Body Mass Index

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study was approved by the Biomedical Research Ethics Committee (BMREC) (BM21/10/9) of the University of the Western Cape, South Africa.

HUMAN AND ANIMAL RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of institutional and/or research committee and with the 1975 Declaration of Helsinki, as revised in 2013.

CONSENT FOR PUBLICATION

The Head firefighter in charge of the physical ability test granted permission to conduct the secondary analysis.

STANDARDS OF REPORTING

STROBE guidelines were followed.

AVAILABILITY OF DATA AND MATERIALS

Due to the agreement between the researcher and the City of Cape Town Fire and Rescue Service, the data cannot be made publicly available. However, if researchers are interested in accessing the data, approval will be requested from the City of Cape Town Fire and Rescue Service to be disclosed to the interested researcher(s).

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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