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RESEARCH ARTICLE

Predicting coronary artery disease risk in firefighters – a cross-sectional study [version 1; peer review: awaiting peer review]

Jaron Ras [ID], Lloyd Leach

Department of Sport, Recreation and Exercise Science, University of The Western Cape, Cape Town, Western Cape, South Africa

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Abstract

Background: Firefighters are placed under severe cardiovascular load in performing active duty and, when carrying various coronary artery disease (CAD) risk factors, firefighters are predisposed to significant morbidity and mortality. Reducing the incidence of these risk factors is paramount. The purpose of this study is to determine the predictors of CAD risk.

Methods: This study used a quantitative, cross-sectional and correlational design. The researchers conveniently sampled 124 full-time firefighters from the City of Cape Town Fire and Rescue Service. A researcher-generated questionnaire was used to collect sociodemographic and CAD risk factors information, such as age, gender, ethnicity, family history of CAD, cigarette smoking and physical activity levels, and all research procedures were conducted according to the American College of Sports Medicine guidelines. Data collection took place between September and November 2019. Linear and logistic regression were used to determine the relationship between the various CAD risk factors and the predictors of CAD risk.

Results: Age was a significant predictor of hypertension (p <0.01), dyslipidemia (p <0.01), diabetes (p <0.01), obesity (p <0.01) and central obesity (p <0.01). Gender was a significant predictor of obesity, central obesity and cigarette smoking (p <0.05). Waist circumference was a significant predictor of hypertension (p <0.01), dyslipidemia (p <0.01) and diabetes (p <0.05).

Conclusion: Age was a significant predictor of various modifiable CAD risk factors, including obesity, in both genders and all ethnicities. Attentive monitoring should be in place as firefighters age, along with behavioural modifications designed to reduce age-related increases in CAD risk factors.

Keywords
cardiovascular, CAD risk factors, age, obesity, firefighters

Corresponding author: Jaron Ras (jaronras@gmail.com)

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Introduction

Firefighting is a hazardous occupation, where firefighters are constantly exposed to harmful chemicals, fumes, and severe temperatures. They routinely function in oxygen-deprived environments, which require the use of breathing apparatus and heavy insulated personal protective equipment (Smith *et al.*, 2013; Smith *et al.*, 2016; Smith *et al.*, 2020). These stressful situations and while wearing their protective equipment place a tremendous load on the cardiovascular system, and, consequently, nearly 50% of firefighter mortalities are related to sudden cardiac death (SCD) (Smith *et al.*, 2013; Smith *et al.*, 2016; Yang *et al.*, 2013). The prevalence of multiple coronary artery disease (CAD) risk factors, particularly obesity, diabetes, hypertension and age, significantly increase the risk of SCD (Smith *et al.*, 2013; von Koenig Soares *et al.*, 2020; Yang *et al.*, 2013). Obesity and age are well-known risk factors of CAD, which augment the development of other modifiable CAD risk factors (Smith *et al.*, 2013; von Koenig Soares *et al.*, 2020).

Healthy dietary practices, behavioural modification and regular exercise have been recommended, by previous researchers, to reduce the incidence of obesity in firefighters, as well as the onset and development of other CAD risk factors (Farioli *et al.*, 2014; Smith *et al.*, 2012a; Smith *et al.*, 2019; Soteriades *et al.*, 2011). However, age is a non-modifiable risk factor and has been associated with the development of obesity, hypertension, dyslipidemia and diabetes. The age-related increases in risk are due to hormonal changes, elasticity of arteries, disrupted cholesterol synthesis and increasing insulin resistance (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Martin *et al.*, 2019; Soteriades *et al.*, 2003; Soteriades *et al.*, 2008). The development and progression of CAD are compounded by the duties related to firefighting, particularly the erratic work schedules, irregular sleep-wake cycles and exposure to hazardous chemicals and fumes (Navarro *et al.*, 2019; Reinberg *et al.*, 2017; Riedel *et al.*, 2019). Furthermore, males and specific ethnic groups have been known to be particularly predisposed to developing certain risk factors, such as hypertension, diabetes and dyslipidemia in firefighters, globally and also in South Africa (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Choi *et al.*, 2016c; Ras & Leach, 2021; van Zyl *et al.*, 2012). Our previous study, conducted on the same population, indicated that increasing CAD risk factor prevalence was significantly related to age, obesity and gender in firefighters (Ras & Leach, 2021). Therefore, this study aimed to predict CAD risk in this population of firefighters, particularly in relation to gender and ethnicity.

Methods

The current study used a quantitative, cross-sectional and correlational research design. The researchers approached each fire station individually to inform firefighters of the purpose of the study and then recruit those that were interested, using convenient sampling. In total, 124 full-time firefighters from the City of Cape Town Fire and Rescue Service were recruited to participate in the study. To address the potential bias, 10 fire stations (30 platoons) were randomly selected from the 33 fire stations in the City of Cape Town, which dispersed among

the four major firefighting districts. The researchers were limited to 124 participants, as part of the agreement with the City of Cape Town. Demographic characteristics were collected, which included age, gender and ethnicity. A researcher-generated questionnaire, that included an open-ended question related to a participant information section, a medical information and lifestyle information section, which included both open-ended and closed-ended questions, and the last section included physical measures performed by the researcher. This questionnaire was used to collect subjective CAD risk factor information, such as family history of CAD, cigarette smoking and physical activity levels. The physical activity section of the questionnaire was based on the International Physical Activity Questionnaire (IPAQ) (Bohlmann *et al.*, 2001), which is considered an accurate tool for collecting physical activity data in a South African context. Physical measures were objectively collected by the researcher (TEST DATA section). Data collection took place between September and November 2019. A copy of the questionnaire used can be found here: https://doi.org/10.6084/m9.figshare.14991447

Research procedures

The research procedures in the current study has been repeated from a previous published article (Ras & Leach, 2021). The principle researcher (Jaron Ras) performed all the physical measures and was responsible for administering the data recording sheet (questionnaire). For more information on the testing procedures followed to determine firefighter stature, body mass, blood pressure, blood glucose and cholesterol, please refer to the article that was previously published (Ras & Leach, 2021). The procedures used for all measurements were based on the recommendation by the American College of Sports Medicine (American College of Sports Medicine, 2018). A portable stadiometer was used to measure stature, body mass was measured using a precision electronic scale and blood pressure was measured using a standard blood pressure sphygmomanometer and stethoscope (American College of Sports Medicine, 2018). Total cholesterol and non-fasting blood glucose (NFBG) were measured using an AcuTrend® Plus GC meter. The recommended finger-prick method was used to collect blood samples. The cross-hand technique was used to measure waist circumference (WC) and Hip circumference (HC), using a steel tape measure. Both circumferences were measured at the end of normal expiration and to the nearest 0.1 cm (Geeta *et al.*, 2009). The research instruments used for data collection were calibrated using a criterion, supplied by manufacturers, prior to testing. Calibration involved determining the test-retest reliability of the instruments, using the manufacturer's specifications, and against a calibrated instrument. Only one tester was used in the study to ensure inter-tester reliability and a minimum test-retest reliability coefficient of 0.8 was required prior to the commencement of the study (Geeta *et al.*, 2009).

Statistical analysis

The double-entry method was used to capture data in a Microsoft Office Excel spreadsheet, and then cleaned of errors, which involved removal of extra spaces, case and spell

checking, and error removal. Thereafter, it was exported to the Statistical Package for the Social Sciences (SPSS) version 27 for descriptive and inferential data analysis. Linear and logistic regression statistics were generated to predict CAD risk in firefighters. A p-value of less than 0.05 was used to indicate statistical significance. Coefficient of determination (R^2), Nagelkerke R square value and odds ratios were used to predict CAD risk. All assumptions prior to performing the regression analysis were met. For linear regression, the assumptions met included to following: (1) the data was continuous, (2) the data had a linear relationship, (3) there were no significant outliers, (3) there were independence of observations, (4) there was homoscedasticity and (5) the residuals of the regression line were approximately normally distributed. For binary logistic regression, the following assumptions were met: (1) the dependent variable was dichotomous, (2) the independent variables were continuous, (3) there were independence of observations and (4) there was a linear relationship between the logit transformation of the dependent variable and the continuous variable.

Ethics statement

The study protocol was approved by the Biomedical Research Ethics Committee (BMREC) at the University of the Western Cape (Ethics reference number: BM19/4/3). The study was also approved by the City of Cape Town. The researcher provided firefighters with an information sheet on the day of testing which explained that data would only be disclosed to the principle researcher and supervisor involved (Jaron Ras and Lloyd Leach). All participants gave their written informed consent to participate in the study and for the publication of their data. Participants were given alpha-numeric codes when capturing the data to ensure confidentiality and anonymity.

Results

The mean age, body mass and stature of the firefighters were 37.53±9.05 years, 87.4±17.9 kg and 172.6±7.3 cm, respectively.

Male firefighters represented 79.1% of the participants, and had a mean age of 37.8±9.8 years, a mean body mass of 87.8±18.5 kg and a mean stature of 174.7±6.5 cm. In female firefighters, the mean age was 36.4±5.4 years, the mean body mass was 85.9±16.2 kg and the mean statue was 164.8±4.5 cm. After firefighters were separated into age groups, the 20-29, 30-39, 40-49- and 50-65-years age-groups represented 19.4%, 44.4%, 24.2% and 12.1% of firefighters, respectively. Regarding ethnicity, 56.5% were of mixed ethnicity, 25.8% were of Black ethnicity and 16.9% were of White ethnicity. The prevalence of CAD risk factors in firefighters was diabetes in 8.9%, physical inactivity in 13.7%, a family history of CAD in 20.9%, age in 23.4%, hypertension in 33.1%, obesity in 37.1%, cigarette smoking in 39.5%, and dyslipidemia in 40.3% (Ras & Leach, 2021). In addition, 10.5% of firefighters were on anti-hypertension medication, 6.4% were on diabetes medication, and 4.8% were on lipid-lowering medication. For more information on the CAD risk factor prevalence's or mean values for each risk factor, please refer to the previously published article (Ras & Leach, 2021).

In Table 1, age was a significant predictor of body mass index (BMI) ($\beta = 0.25$, F = 23.1, $R^2 = 0.16$, p <0.001), WC ($\beta = 0.79$, F = 42.4, $R^2 = 0.26$, p <0.001), systolic blood pressure (SBP) ($\beta = 0.49$, F = 11.3, $R^2 = 0.17$, p <0.001) and diastolic blood pressure (DBP) ($\beta = 0.24$, F = 13.2, $R^2 = 0.09$, p <0.001). The model found that 16%, 26%, 17% and 9% of the variation in BMI, WC, SBP and DBP, respectively, could be explained by an increase in age. BMI was a significant predictor of SBP ($\beta = 0.11$, F = 12.1, $R^2 = 0.09$, p = 0.001) and DBP ($\beta = 0.20$, F = 25.9, $R^2 = 0.18$, p <0.001). The model found that 9% and 18% of the variance in SBP and DBP, respectively, could be explained by an increase in BMI. WC was found to be a significant predictor of SBP ($\beta = 0.29$, F = 13.5, $R^2 = 0.10$, p <0.001) and DBP ($\beta = 0.56$, F = 32.1, $R^2 = 0.21$, p <0.001). The model found that 10% and 21% of the variance in SBP and DBP, respectively, could be explained by an increase in WC.

Table 1. Linear regression predicting CAD risk based on age, BMI and waist circumference.

Variable	Age				BMI				WC			
	β	R^2	F	p	β	R^2	F	p	β	R^2	F	p
BMI	0.25	0.16	23.1	**<0.001****								
WC	0.79	0.26	42.4	**<0.001****								
SBP	0.49	0.17	11.3	**<0.001****	0.11	0.09	12.1	**0.001****	0.29	0.10	13.5	**<0.001****
DBP	0.24	0.09	13.2	**<0.001****	0.20	0.18	25.9	**<0.001****	0.56	0.21	32.1	**<0.001****
NFBG	0.66	0.03	3.4	0.068	0.37	0.02	2.8	0.99	1.09	0.03	3.78	0.054
TC	1.16	0.02	1.86	0.175	0.89	0.02	2.9	0.093	2.38	0.026	3.2	0.075

Note: *indicates statistical significance <0.05, **indicates statistical significance <0.01; F – ANOVA; R^2 – coefficient of determination.

CAD, coronary artery disease; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; NFBG, non-fasting blood glucose; TC, total cholesterol.

In male firefighters, age was a significant predictor of BMI ($\beta = 0.228$, F = 22.9, $R^2 = 0.19$, p <0.001), WC ($\beta = 0.364$, F = 37.1, $R^2 = 0.28$, p <0.001), SBP ($\beta = 0.434$, F = 8.0, $R^2 = 0.08$, p = 0.006) and DBP ($\beta = 0.351$, F = 9.5, $R^2 = 0.09$, p = 0.003) (Table 2). The model (age) explained 19%, 28%, 8% and 9% of the variation in BMI, WC, SBP and DBP, respectively. Increasing age resulted in an increase in BMI, WC, SBP and DBP. BMI was a significant predictor of SBP ($\beta = 1.009$, F = 13.4, $R^2 = 0.12$, p <0.001) and DBP ($\beta = 0.899$, F = 20.1, $R^2 = 0.17$, p <0.001), explaining 12% and 17% of the variation in SBP and DBP, respectively. WC was a significant predictor of SBP ($\beta = 0.351$, F = 11.5, $R^2 = 0.11$, p <0.001) and DBP ($\beta = 0.329$, F = 19.2, $R^2 = 0.17$, p <0.001), with the model explaining 11% and 17% of the variation in SBP and DBP, respectively. In female firefighters, age was a significant predictor of BMI ($\beta = 0.2541$ F = 6.3, $R^2 = 0.21$, p = 0.019), WC ($\beta = 1.312$, F = 7.6, $R^2 = 0.21$, p = 0.011), and DBP ($\beta = 0.909$, F = 4.8, $R^2 = 0.17$, p = 0.039). The model explained 21%, 21% and 17% of the variation in BMI, WC, and DBP, respectively. BMI was a significant predictor of DBP ($\beta = 1.239$, F = 18.3, $R^2 = 0.43$, p <0.001), and the model explained 43% of the variation in DBP. WC was a significant predictor of DBP ($\beta = 0.582$, F = 23.1, $R^2 = 0.49$, p <0.001), and explained 43% of the variation in DBP.

In firefighters of mixed-ethnicity, age was a significant predictor of BMI ($\beta = 0.209$, F = 7.7, $R^2 = 0.10$, p = 0.007), WC ($\beta = 0.648$, F = 12.9, $R^2 = 0.16$, p = 0.001), SBP ($\beta = 0.592$ F = 9.5, $R^2 = 0.12$, p = 0.003), DBP ($\beta = 0.362$, F = 5.3, $R^2 = 0.07$, p = 0.024), and NFBG ($\beta = 0.0.057$, F =9.6, $R^2 = 0.12$, p = 0.032) (Table 3). The model explained 10%, 16%, 12%, 7% and 12% of the variation in BMI, WC, SBP, DBP and NFBG, respectively. BMI was a significant predictor of SBP ($\beta = 0.687$, F = 5.1, $R^2 = 0.07$, p = 0.027), DBP ($\beta = 0.058$, F = 14.2, $R^2 = 0.17$, p = <0.005), and NFBG ($\beta = 0.069$, F = 5.8, $R^2 = 0.08$, p = 0.018). The model explained 7%, 17% and 8% of the variation in SBP, DBP and NFBG, respectively. WC was a significant predictor of SBP ($\beta = 0.273$, F = 4.9, $R^2 = 0.07$, p = 0.029), DBP ($\beta = 0.347$, F = 14.3, $R^2 = 0.17$, p <0.001), and NFBG ($\beta = 0.028$, F = 5.9, $R^2 = 0.08$, p = 0.018). The model explained 7%, 17% and 8% of the variation in SBP, DBP and NFBG, respectively.

In Black firefighters, age was a significant predictor of BMI ($\beta = 0.331$, F = 9.9, $R^2 = 0.22$, p = 0.004), WC ($\beta = 1.189$, F = 25.5, $R^2 = 0.46$, p <0.001), SBP ($\beta = 0.824$, F = 5.3, $R^2 = 0.15$, p = 0.028), and DBP ($\beta = 0.854$, F =13.3, $R^2 = 0.31$, p = 0.001). The model explained 22%, 46%, 15% and 31% of the variation in BMI, WC, SBP, and DBP, respectively. BMI was a significant predictor of DBP ($\beta = 1.104$, F = 8.8, $R^2 = 0.20$, p = 0.006), with the model explaining 20% of the variation in DBP. WC was a significant predictor of SBP ($\beta = 0.501$, F = 6.2, $R^2 = 0.14$, p = 0.018), and DBP ($\beta = 0.488$, F = 13.3 $R^2 = 0.28$, p = 0.001), with the model explaining 14% and 28% of the variation in SBP and DBP, respectively.

Table 2. Linear regression predicating CAD risk based on age, BMI and waist circumference in male and female firefighters.

Variable	Gender	Age				BMI				WC			
		β	R²	F	p	β	R²	F	p	β	R²	F	p
BMI	Male	0.238	0.19	22.9	<0.001**								
	Female	0.541	0.21	6.3	0.019*								
WC	Male	0.364	0.28	37.1	<0.001**								
	Female	1.312	0.21	7.6	0.011*								
SBP	Male	0.434	0.08	8.0	0.006**	1.009	0.12	13.4	<0.001**	0.351	0.11	11.5	<0.001**
	Female	0.951	0.14	3.9	0.061	0.817	0.14	4.0	0.057	0.325	0.17	3.2	0.089
DBP	Male	0.351	0.09	9.5	0.003**	0.899	0.17	20.1	<0.001**	0.329	0.17	19.2	<0.001**
	Female	0.909	0.17	4.8	0.039*	1.239	0.43	18.3	<0.001**	0.582	0.49	23.1	<0.001**
NFBG	Male	0.043	0.03	2.9	0.090	0.084	0.03	3.2	0.075	0.034	0.04	3.7	0.054
	Female	0.024	0.03	0.6	0.803	0.006	0.01	0.2	0.637	-0.006	0.00	0.0	0.861
TC	Male	0.013	0.02	1.6	0.204	0.035	0.03	3.3	0.071	0.013	0.03	3.4	0.068
	Female	0.007	-0.00	0.1	0.819	0.012	0.01	0.2	0.626	0.003	0.0	0.1	0.781

Note: * indicates statistical significance <0.05; ** indicates statistical significance <0.01; β – Beta; F – ANOVA; R^2 – coefficient of determination.

CAD, coronary artery disease; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; NFBG, non-fasting blood glucose; TC, total cholesterol.

Table 3. Linear regression predicting CAD risk based on age, BMI, and WC.

Variable	Gender	Age				BMI				WC			
		β	R²	F	p	β	R²	F	p	β	R²	F	p
BMI	Mixed-ethnicity	0.209	0.10	7.7	0.007**								
	Black	0.331	0.22	9.9	0.004**								
	White	0.244	0.18	5.4	0.032**								
WC	Mixed-ethnicity	0.648	0.16	12.9	0.001**								
	Black	1.189	0.46	25.5	<0.001**								
	White	0.698	0.34	9.9	0.005**								
SBP	Mixed-ethnicity	0.592	0.12	9.5	0.003**	0.687	0.07	5.1	0.027*	0.273	0.07	4.9	0.029*
	Black	0.824	0.15	5.3	0.028**	0.781	0.03	1.9	0.176	0.501	0.14	6.2	0.018*
	White	-0.022	-0.05	0.0	0.938	1.158	0.20	6.1	0.023*	0.317	0.09	2.0	0.171
DBP	Mixed-ethnicity	0.362	0.07	5.3	0.024**	0.058	0.17	14.2	<0.001**	0.347	0.17	14.3	<0.001**
	Black	0.854	0.31	13.3	0.001**	1.104	0.20	8.8	0.006**	0.488	0.28	13.3	0.001**
	White	0.091	0.01	0.3	0.611	0.630	0.14	4.2	0.055	0.214	0.11	2.3	0.145
NFBG	Mixed-ethnicity	0.057	0.12	9.6	0.032**	0.069	0.08	5.8	0.018*	0.028	0.08	5.9	0.018**
	Black	-0.001	0.00	0.0	0.991	-0.038	-0.02	0.278	0.602	0.003	-0.033	0.014	0.906
	White	0.038	-0.04	0.2	0.653	0.135	-0.013	0.7	0.399	0.063	0.04	0.9	0.366
TC	Mixed-ethnicity	0.014	0.02	1.3	0.265	0.018	0.01	0.9	0.356	0.010	0.02	1.5	0.227
	Black	0.007	0.01	0.1	0.713	0.043	2.3	0.04	0.144	0.008	-0.015	0.549	0.464
	White	0.010	0.01	0.2	0.659	0.026	0.02	0.4	0.559	0.011	0.02	0.4	0.553

Note: * indicates statistical significance <0.05; ** indicates statistical significance <0.01; *B* – Beta; F- ANOVA; R² – coefficient of determination.

CAD, coronary artery disease; BMI, body mass index; WC, waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure; NFBG, non-fasting blood glucose; TC, total cholesterol.

In White firefighters, age was a significant predictor of BMI (β = 0.176, F = 6.2, R² = 0.14, p = 0.018), and WC (β = 0.698, F = 9.9, R² = 0.34, p = 0.005), where the model explained 14% and 34% of the variation in BMI and WC, respectively. BMI was a significant predictor of SBP (β = 1.158, F = 6.1, R² = 0.20, p = 0.023), with the model explaining 20% of the variation in SBP.

In Table 4, gender was a significant predictor of obesity [β = 0.878, χ² = 23.1, R² = 0.04, p = 0.050, OR (95% CI): 2.4 (0.9, 5.8)], central obesity [β = 1.503, χ² = 10.9, R² = 0.12, p = 0.001, OR (95% CI): 4.5 (1.8, 11.2)], and cigarette smoking [β = 1.230, χ² = 6.1, R² = 0.07, p = 0.022, OR (95% CI): 3.4 (1.2, 9.8)]. The model explained 4%, 12% and 7% of the variation in obesity, central obesity and cigarette smoking, respectively. Furthermore, females were 2.4 times more likely to be obese, and 4.5 times more likely to have central obesity, whereas males were 3.4 time more likely to be cigarette smokers. Physical inactivity was a significant predictor of central obesity [β = 0.035, χ² = 8.3, R² = 0.06, p = 0.046, OR (95% CI): 2.4 (0.9, 5.8)]. The model explained 6% of the variation in central obesity. Age was a significant predictor of a family history of CAD [β = 0.052, χ² = 9.1, R² = 0.06, p = 0.035, OR (95% CI): 1.1 (1.0, 1.1)]. The model explained 6% of the variation in family history of CAD, and aged firefighters were 1.1 times more likely to have a family history of CAD. Age was a significant predictor of hypertension [β = 0.093, χ² = 4.3, R² = 0.18, p <0.001, OR (95% CI): 1.1 (1.0, 1.2)], dyslipidemia [β = 0.058, χ² = 10.3, R² = 0.08, p = 0.007, OR (95% CI): 1.1 (1.0, 1.1)], diabetes [β = 0.138, χ² = 8.5, R² = 0.24, p = 0.001, OR (95% CI): 1.1 (1.1, 1.2)], obesity [β = 0.066, χ² = 12.3, R² = 0.10, p = 0.003, OR (95% CI): 1.1 (1.0, 1.1)], and central obesity [β = 0.079, χ2 = 8.5, R² = 0.14, p = 0.001, OR (95% CI): 1.1 (1.0, 1.1)]. The model explained 18%, 8%, 24%, 10% and 14% of the variation in hypertension, dyslipidemia, diabetes, obesity and central obesity, respectively. Aging increased the likelihood of firefighters having hypertension, dyslipidemia, diabetes, obesity, and central obesity by 1.1 times. BMI was a significant predictor of hypertension [β = 0.091, χ² = 6.2, R² = 0.08, p = 0.010, OR (95% CI): 1.1 (1.0, 1.2)], and

Table 4. Logistic regression in predicting CAD risk based on gender, physical inactivity, age, BMI and WC.

	Gender					
Model:	***B***	**χ²**	***df***	**p**	**R²**	**OR (95% CI)**
Obesity (BMI)	0.878	3.8	1	0.050*	0.04	2.4 (0.9 – 5.8)
Central obesity	1.503	10.9	1	0.001**	0.12	4.5 (1.8 – 11.2)
Cigarette smoker	1.230	6.1	1	0.022*	0.07	3.4 (1.2 – 9.8)
	Physical inactivity					
Model:	***B***	**χ²**	**df**	**p**	**R2**	**OR (95% CI)**
Central obesity	0.035	8.3	1	0.046*	0.06	1.0 (1.0 – 1.1)
	Family history					
Model	**B**	**χ²**	**df**	**p**	**R2**	**OR (95% CI)**
Age	0.052	9.1	1	0.035*	0.06	1.1 (1.0 – 1.1)
	Age					
Model:	**B**	**χ²**	**df**	**p**	**R2**	**OR (95% CI)**
Hypertension	0.093	4.3	1	<0.001**	0.18	1.1 (1.0 – 1.2)
Dyslipidemia	0.058	10.3	1	0.007**	0.08	1.1 (1.0 – 1.1)
Diabetes	0.138	6.7	1	0.001**	0.24	1.1 (1.1 – 1.2)
Obesity (BMI)	0.066	12.3	1	0.003**	0.10	1.1 (1.0 – 1.1)
Central obesity	0.079	8.5	1	0.001**	0.14	1.1 (1.0 – 1.1)
	BMI					
Model:	**B**	**χ²**	**df**	**p**	**R2**	**OR (95% CI)**
Hypertension	0.091	6.2	1	0.010**	0.08	1.1 (1.0, 1.2)
Dyslipidemia	0.077	10.9	1	0.025*	0.06	1.1 (1.0, 1.2)
	Waist circumference					
Model:	**B**	**χ²**	**df**	**p**	**R2**	**OR (95% CI)**
Hypertension	0.052	12.1	1	0.001**	0.15	1.1 (1.0, 1.1)
Dyslipidemia	0.039	18.9	1	0.006**	0.09	1.0 (1.0, 1.1)
Diabetes	0.035	8.9	1	0.026*	0.06	1.0 (1.0, 1.1)

Note: * indicates statistical significance <0.05; ** indicates statistical significance <0.01; *B* – Beta; X2 - Chi-square; *df* - degree of freedom; OR (95% CI) = odds ratio (95% confidence interval; R2 - Nagelkerke R square value.

CAD, coronary artery disease; BMI, body mass index; WC, waist circumference.

dyslipidemia [β = 0.077, χ² = 10.9, R² = 0.06, p = 0.025, OR (95% CI): 1.1 (1.0, 1.1)] in firefighters. The model explained 8% and 6% of the variation in hypertension and dyslipidemia, respectively, where increasing BMI increased the likelihood of hypertension and dyslipdemia by 1.1 times. WC was a significant predictor of hypertension [β = 0.052, χ² = 12.1, R² = 0.15, p = 0.001, OR (95% CI): 1.1 (1.0, 1.1)], dyslipidemia [β = 0.039, χ² = 18.9, R² = 0.09, p = 0.006, OR (95% CI): 1.1 (1.0, 1.1)], and diabetes [β = 0.046, χ² = 8.9, R² = 0.06, p = 0.026, OR (95% CI): 1.1 (1.0, 1.1)]. The model explained 15%, 9% and 6% of the variation in hypertension, dyslipidemia and diabetes, respectively. Additionally, when WC increased, the firefighters were 1.1 times more likely to have hypertension, dyslipidemia and diabetes.

Discussion

Age was a significant predictor of an increase in BMI and WC. Furthermore, age, BMI and WC were significant predictors of SBP and DBP. This is consistent with previous literature which indicated that age, BMI and WC were significant catalysts for the development of major CAD risk factors, particularly hypertension (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Damacena *et al.*, 2020; Jang *et al.*, 2020; Soteriades *et al.*, 1997; Soteriades *et al.*, 2003). Interestingly, age was the highest predictor of CAD risk in the current study, followed by WC and BMI. This is supported by previous literature, which consistently reported that increasing age was the most important determinant in the development of CAD, followed by BMI and WC (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Choi *et al.*, 2016c; Damacena *et al.*, 2020; Lee & Kim, 2017; Smith *et al.*, 2013; Soteriades *et al.*, 2003). Dyslipidemia was the most prevalent CAD risk factor in firefighters, yet, was not predicted by age, BMI or WC. Firefighters' diets appear to be the most significant cause of dyslipidemia (de Ridder *et al.*, 2017; Liska *et al.*, 2016; Sanders *et al.*, 2016).

In male firefighters, age was a significant predictor of BMI and WC, and age, BMI and WC were significant predictors of SBP and DBP. In female firefighters, age was a significant predictor of BMI and WC, and age, BMI and WC were significant predictors of DBP. Philippe Gendron *et al.* (2018a) reported that, in male firefighters, BMI was significantly different between the group that presented with no CAD risk factors compared to the group with one or more risk factors. Choi *et al.* (2016c) reported that in both male and female firefighters, age was significantly correlated with BMI and WC in firefighters. Li *et al.* (2017) reported that, among male and female firefighters, age and obesity were significantly associated with metabolic syndrome. Smith *et al.* (2020) reported a similar result, where BMI significantly increased as firefighters aged.

In firefighters of mixed ethnicity, age, BMI and WC were significant predictors of SBP, DBP and NFBG, and age and WC were significant predictors of SBP in Black firefighters. In White firefighters, BMI was a significant predictor of SBP. In all ethnic groups, age was a significant predictor of BMI and WC. Previous literature indicated that all ethnicities were prone to developing CAD with increasing age, BMI and WC. Age was significantly related to obesity across all ethnic groups of firefighters (Choi *et al.*, 2016a; Choi *et al.*, 2016c; Damacena *et al.*, 2020; Poston *et al.*, 2015), which corresponds to the results in the present study.

The logistic regression model indicated that females were 2.4 and 4.5 times more likely to be obese and have central obesity, compared to males. However, males were significantly more likely (3.4 times) to be cigarette smokers. This is contrary to previous studies, which indicated that male firefighters were more likely to be obese than female firefighters (Crespo-Ruiz *et al.*, 2020; Gendron *et al.*, 2018b; Gendron *et al.*, 2018a; Jahnke *et al.*, 2012a; Jahnke *et al.*, 2012b;

Li *et al.*, 2017). In addition, previous studies indicated that female firefighters were more likely to be cigarette smokers compared to males (Gendron *et al.*, 2018b; Gendron *et al.*, 2018a; Jitnarin *et al.*, 2013; Jitnarin *et al.*, 2019; Li *et al.*, 2017). Central obesity was a significant predictor of physical inactivity, which was similar to Damacena *et al.* (2020) who indicated that central obesity was a significant predictor of physical inactivity, where firefighters who had central obesity were 3.43 times more likely to be physically inactive.

Age was a significant predictor for hypertension, dyslipidemia, diabetes, obesity and central obesity. Damacena *et al.* (2020) reported that central obesity was significantly associated with increased age in firefighters, with the 40-49 years age-group being 4.9 times more likely to have central obesity, and the 50-59 years age-group being 5.41 times more likely to have central obesity. This is consistent with previous literature which indicated a linear relationship between increased age and the incidence of hypertension, dyslipidemia, diabetes and obesity (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Choi *et al.*, 2016c; Damacena *et al.*, 2020; Smith *et al.*, 2012b; Smith *et al.*, 2020; Soteriades *et al.*, 1997; Soteriades *et al.*, 2002). Eastlake *et al.* (2015) reported that age in firefighters had a significant association with high blood cholesterol and high blood pressure, with aged firefighters being 1.08 times and 1.06 times more likely to have elevated blood cholesterol and high blood pressure, respectively. Burgess *et al.* (2012) reported that age was significantly associated with dyslipidemia, and that aged firefighters were 3.3 times more likely to be dyslipidemic. The role of age in the development and progression of major CAD risk factors may be attributed to the cascade of age-related alterations in normal homeostatic functioning (Costantino *et al.*, 2016; Ferrucci & Fabbri, 2018; Morgan *et al.*, 2016). Aging was reported to reduce the growth hormones essential for angiogenesis and vascular maintenance, contributing to the increase in blood pressure (Costantino *et al.*, 2016; Lakatta, 2002). The increased inflammatory response due to aging, the increased catabolic metabolism due to a decrease in anabolic hormones, specifically, testosterone, oestrogen, and growth hormone, and the reduced insulin sensitivity and cholesterol regulation, all collectively result in an increase in adipose tissue accumulation, particularly around the abdomen (Gadde *et al.*, 2018; Pandey *et al.*, 2018). All these age-related changes were associated with the increased incidence of CAD risk in firefighters, specifically obesity, hypertension and dyslipidemia (Costantino *et al.*, 2016; de Schutter *et al.*, 2014; Ferrucci & Fabbri, 2018; Gadde *et al.*, 2018). However, the stressful nature of firefighting, the constant inhalation of toxic chemicals and fumes, irregular sleep-wake cycles, and poor dietary practices, further compounded the negative effects of aging in this population, and augment the CAD risk (Adetona *et al.*, 2016; Bonnell *et al.*, 2017; Costantino *et al.*, 2016; Ferrucci & Fabbri, 2018; Lakatta, 2002; Navarro *et al.*, 2019; Reinberg *et al.*, 2017; Riedel *et al.*, 2019; Sanders *et al.*, 2016; Yang *et al.*, 2013). The longer firefighters are in service, the more this effect is compounded (Adetona *et al.*, 2016;

Bonnell *et al.*, 2017; Costantino *et al.*, 2016; Ferrucci & Fabbri, 2018; Lakatta, 2002; Navarro *et al.*, 2019; Reinberg *et al.*, 2017; Riedel *et al.*, 2019; Sanders *et al.*, 2016; Yang *et al.*, 2013).

In the present study, BMI was a significant predictor of hypertension and dyslipidemia. Eastlake *et al.* (2015) reported that BMI was a significant predictor of high cholesterol, where firefighters were 1.09 times more likely to have high cholesterol as BMI increased. Previous research indicated a linear relationship between increased BMI and the incidence of hypertension and dsylipidemia (Choi *et al.*, 2016a; Choi *et al.*, 2016b; Choi *et al.*, 2016c; Soteriades *et al.*, 1997; Soteriades *et al.*, 2002; Soteriades *et al.*, 2003; Soteriades *et al.*, 2008). The strong predictive value of BMI, particularly to blood pressure and dyslipidaemia, can be explained by the increase in peripheral vascular resistance associated with an increase in total body mass related to adipose tissue accumulation, and the resultant cholesterol synthesis dysregulation associated with increased adiposity (Alpert *et al.*, 2014; Ariyanti & Besral, 2019; de Schutter *et al.*, 2014; Shulman, 2014).

In the present study, WC was a significant predictor of hypertension, dyslipidemia and diabetes. This is similar to the results reported by Damacena *et al.* (2020), where increased WC was a significant predictor of total cholesterol, blood glucose and blood pressure, with firefighters being 1.71 and 2.94 more likely to have elevated total cholesterol and blood glucose concentrations, respectively. In the literature, WC has a linear relationship with blood pressure, blood cholesterol and glucose concentration (Choi *et al.*, 2016c; Soteriades *et al.*, 1997; Soteriades *et al.*, 2002). The strong predictive value of WC related to CAD risk can be attributed to a similar mechanism implicated in increased BMI, in which an increase in adiposity also increases peripheral vascular resistance, resulting in hypertension and cholesterol synthesis dysregulation (Alpert *et al.*, 2014; Ariyanti & Besral, 2019; de Schutter *et al.*, 2014; Shulman, 2014). Abdominal fat, especially when central obesity is present, is associated with an increased risk of diabetes and, presumably, due to abdominal adipose tissue being more insulin resistant (Emdin *et al.*, 2017; Shulman, 2014).

Strengths and limitations
This was the first study in South Africa to predict CAD risk in firefighters according to age, gender and ethnicity. This study provides valuable information for the City of Cape Town to consider how to increase the longevity of firefighter careers.

A limitation was that the study used convenient sampling that negatively impacted the external validity as selection bias may have occurred, due to firefighters opting not to participate that have known CAD risk factors. Also, the relatively small sample size of 124 firefighters negatively impacted the power of the study, which could be seen where variables trended towards significance, but required a larger sample size to

be realized. The study was also under-represented by female participants.

Recommendations
It is recommended that future studies use random sampling and a larger sample, which is sufficiently powered in order to ensure external validity. In addition, a more representative sample of female firefighters is recommended, as females are notably underrepresented, both in the present study and in global firefighter research.

Conclusion
In conclusion, age was a significant predictor of CAD risk, including obesity, and this was consistent across both genders and all ethnicities. WC was a significant predictor of blood pressure and cardiometabolic abnormalities, particularly in relation to firefighters of mixed ethnicity. The City of Cape Town Fire and Rescue service should emphasise behavioural modification, such as a healthier diet and an exercise routine designed for firefighters, to reduce the likelihood of obesity and, in particular, central obesity. As firefighters age, attentive monitoring, such as annual or biannual medical, cardiovascular and fitness screenings should be in place to reduce age-related obesity, and the subsequent development of lifestyle-related CAD risk factors, specifically hypertension, dyslipidemia and diabetes.

Data availability
Underlying data
The captured data contains confidential information on firefighters that cannot be made publicly available as part of the agreement with the City of Cape Town Fire and Rescue Service. Only the researchers directly involved in the study, i.e., Jaron Ras and Lloyd Leach, have access to this data. If researchers require the data, requests should be submitted to the corresponding author (Jaron Ras: jaronras@gmail.com), where permission will then be requested from the City of Cape Town Fire and Rescue Service and upon signing a data access agreement in compliance with the City of Cape Town data regulations.

Extended data
Figshare: Prevalence of Coronary Artery Disease Risk Factors in the City of Cape Town Fire and Rescue Service. CC0 License (https://doi.org/10.6084/m9.figshare.14991447) and (https://doi.org/10.6084/m9.figshare.14991576)

This project contains the following extended data:
- Data recording sheet (Questionnaire)
- Study protocol

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