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Original Article

Association Between Leisure Time Physical Activity, Cardiopulmonary Fitness, Cardiovascular Risk Factors, and Cardiovascular Workload at Work in Firefighters

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ABSTRACT

Background: Overweight, obesity, and cardiovascular disease risk factors are prevalent among firefighters in some developed countries. It is unclear whether physical activity and cardiopulmonary fitness reduce cardiovascular disease risk and the cardiovascular workload at work in firefighters. The present study investigated the relationship between leisure-time physical activity, cardiopulmonary fitness, cardiovascular disease risk factors, and cardiovascular workload at work in firefighters in Hong Kong.
Methods: Male firefighters ($n = 387$) were randomly selected from serving firefighters in Hong Kong ($n = 5,370$) for the assessment of cardiovascular disease risk factors (obesity, hypertension, diabetes mellitus, dyslipidemia, smoking, known cardiovascular diseases). One-third (Target Group) were randomly selected for the assessment of off-duty leisure-time physical activity using the short version of the International Physical Activity Questionnaire. Maximal oxygen uptake was assessed, as well as cardiovascular workload using heart rate monitoring for each firefighter for four "normal" 24-hour working shifts and during real-situation simulated scenarios.
Results: Overall, 33.9% of the firefighters had at least two cardiovascular disease risk factors. In the Target Group, firefighters who had higher leisure-time physical activity had a lower resting heart rate and a lower average working heart rate, and spent a smaller proportion of time working at a moderate-intensity cardiovascular workload. Firefighters who had moderate aerobic fitness and high leisure-time physical activity had a lower peak working heart rate during the mountain rescue scenario compared with firefighters who had low leisure-time physical activities.
Conclusion: Leisure-time physical activity conferred significant benefits during job tasks of moderate cardiovascular workload in firefighters in Hong Kong.

1. Introduction

Firefighters encounter many hazardous occupational conditions and must work at high levels of exertion during strenuous rescue activities [1–3]. Firefighters are therefore expected to have good physical fitness [4]. As the prevalence of obesity and other chronic diseases continues to increase in many developed countries, the risk profile of firefighters has worsened. A high prevalence of overweight and obesity has been reported among firefighters in the United States and the United Kingdom [2,5]. Many firefighters were also noted to have one or more modifiable risk factors for cardiovascular disease and only modest aerobic capacity [2,6–8]. In a

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recent report on the leading causes of line-of-duty death among US firefighters, a sudden cardiac event accounts for almost half of all fatalities, with 90% of these caused by coronary heart disease [2,9]. Low physical activity and cardiopulmonary fitness have been shown to be associated with unfavorable cardiovascular disease risk profiles in firefighters in the United States [10,11]. The assessment of physical activity in these studies was based on a questionnaire with total weekly aerobic exercise being recorded, without differentiating between the occupational and leisure-time physical activities of the firefighters. The cardiovascular workload at work of the firefighters in these studies remains unclear.

Hong Kong, one of the most urbanized cities in Asia, has experienced a very rapid economic transition from pre- to post-industrial living conditions over the past few decades [12]. An easily accessible Western diet and sedentary living have caused a significant adverse impact on the health status of the population, illustrated by between one-quarter and one-third of the population being obese [13]. It is not clear whether obesity and cardiovascular disease risk factors are prevalent among firefighters in Hong Kong, or whether physical activity and cardiopulmonary fitness play a protective role from cardiovascular disease risk and cardiovascular workload at work. This study was designed to investigate the relationship between leisure-time physical activity, cardiorespiratory fitness, cardiovascular disease risk factors, and cardiovascular workload at work in firefighters in Hong Kong. We hypothesized that those firefighters who are more active during leisure time would have a higher cardiopulmonary fitness, a better cardiovascular health profile, and a lower cardiovascular workload when performing their work.

2. Materials and methods

2.1. Study design and participants

This study is part of a larger occupational survey and health screening program conducted in 2008 in the Fire Services Department of Hong Kong. A total of 450 male firefighters aged 18–54 years were randomly selected (Health Screening Group) from the list of 5,370 serving firefighters in Hong Kong and were invited for the assessment of cardiovascular disease risk factors. A briefing session of the program was given to all participants, and they were informed that one-third of them would be randomly selected (Target Group) to join additional assessments, including physical activity, aerobic fitness, and cardiovascular workload at work. To fully capture the workload of firefighters, real-situation simulated scenarios requiring higher-intensity efforts were conducted as an addition to the monitoring of the "normal" work shifts of the firefighters. Overall, 387 out of 450 (86%) male firefighters consented to participate in this study.

The participants attended an initial session for the assessment of cardiovascular disease risk factors and were then scheduled to undergo a maximal running test in the laboratory. Following the exercise test, the firefighters had their cardiovascular workload monitored for four 24-hour working days and for several real-situation simulated tasks. The leisure-time physical activity, defined as physical activities that occurred during off-duty hours, of the firefighters was recorded within the same study period. Hong Kong firefighters have a 24-hour work, followed by 2 days of off-duty time. Monitoring of the four 24-hour working days and the leisure-time physical activity of each firefighter in this study therefore required a period of 2 weeks to complete. Written informed consent was obtained from all participants prior to their participation in the study. The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster, Hong Kong.

2.2. Development of the real-situation simulated scenarios

In the original occupational survey and health screening program, a self-designed job survey questionnaire that included a list of different rescue activity tasks was distributed to 1,600 firefighters randomly selected from the 5,370 serving firefighters in Hong Kong for the identification of physically very demanding tasks. The job survey questionnaire was designed through focus group meetings with a group of 10 firefighters of different ranks, randomly selected from the Fire Services Department. A list of occupational tasks was provided for the firefighters in the focus group for discussion, and to indicate the frequency and duration with which they needed to perform the particular tasks on the list and how physically demanding each task was. Information obtained from the focus group was used for the development of the job survey questionnaire. Seventy-five percent of the job survey questionnaires were returned. Tasks that were rated at least 15 on the 6–20 Perceived Exertion scale [14] were identified and built into four real-situation simulated scenarios (see below). These were carried out at the West Kowloon Rescue Training Centre of the Hong Kong Fire Services Department, whose training facilities included a simulated tunnel and maze, as well as live-fire simulators to create fire scenes of various situations (Kidde Fire Trainers, http://www.kiddeft.com), and a simulated mountain rescue event conducted at the Pat Sin Leng Country Park in Hong Kong.

2.2.1. Scenario I: water relay

This scenario assumed that a seven-story reinforced concrete building of about 25 m × 30 m was under construction in which a stack of timber and construction materials of about 5 m × 5 m burst into flames on the third floor and the fire had spread to the roof. The fire would be put under control using water jets during the incipient stage in order to prevent it from spreading to nearby domestic structures. During the course of this scenario, a male construction worker was reported missing, and a search of the smoke-logged structure was required. The affected building was located in a remote area with the nearest pedestal hydrant about 260 m away from the structure. Upon arrival, water relay was required to deliver water to the fire scene. A crew of eight firefighters was required to lay hoses from the major pump and convey a booster pump at a distance of about 260 m from the hydrant. Four of the crew members laid 20 hoses from the hydrant to the fire scene, and the other four crew members carried the booster pump to the sixth-floor staircase entrance. Afterward, four crew members with self-contained breathing apparatus (SCBA) laid two hoses (40 mm) from the water dispatcher head to a room with an average room temperature of 54.5 ± 5.7°C and a relative humidity of 42.5 ± 14.8%. They worked in pairs over two different time intervals to tackle the fire. The other four crew members worked in pairs with the SCBA over two different time intervals in another room to carry out the search and rescue at an average temperature of 38.7 ± 3.2°C, and a relative humidity of 98.7 ± 6.6%, and logged with heavy smoke. After locating the casualty, they were required to convey the dummy (68 kg) to a safe place outside the room.

2.2.2. Scenario II: maze searching

This task was created to simulate a Number 4 Alarm operation in an industrial building. Persons were reported missing and searching with SCBA was required. The affected area inside the industrial building was logged with heavy smoke. The building had undergone alterations, unauthorized building works, and there was a large stack of finished products creating an obstruction. A crew of eight firefighters with SCBA was required to commence a search and rescue at the starting point and proceed to the finish point as soon as possible. The maze was designed as a two-level chamber

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logged with heavy smoke with an air temperature of 35.2 ± 0.6°C and a relative humidity of 100 ± 0.0%. Four of the crew members with full firefighting kits and SCBA worked in pairs to perform the search and rescue inside the maze. The other four crew members simultaneously entered the maze through a different entry point.

2.2.3. Scenario III: sewage rescue

This task assumed that two Water Supplies Department maintenance workers were reported missing inside a sewage of about 50 m × 1 m. The sewage entrance was about 50 m from the roadside. Staff of Water Supplies Department confirmed that the section of sewage was isolated and water had been diverted to other sewage drains. A team of four crew members with full firefighting kits and SCBA carried a stretcher, two rescue lines, and ran 50 m to enter the tunnel, which had an air temperature of 42.6 ± 7.9°C and a relative humidity of 90.9 ± 20.8%. After locating the casualty, crew members were required to convey the dummy (45 kg) to the sewage entrance (open air) as soon as possible and then convey the dummy by stretcher to an ambulance parked roadside about 50 m from the sewage entrance.

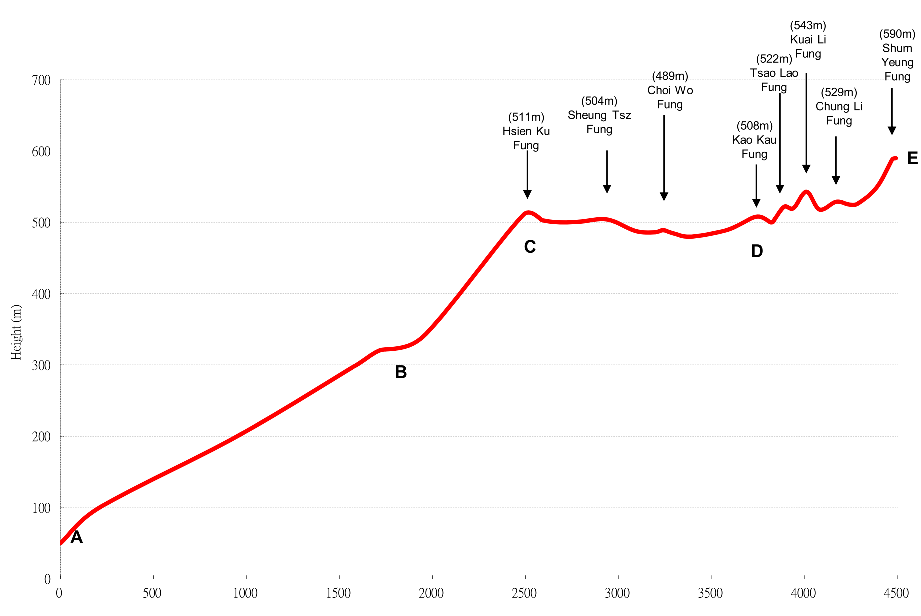
2.2.4. Scenario IV: mountain rescue

A subgroup of firefighters ($n = 29$) from the Target Group were randomly selected to conduct this simulated rescue task. It was assumed that a hiker had accidentally fallen from a slope at location KK143893 (Shun Yeung Fung at a height of 590 m) of Pat Sin Leng (Fig. 1, point E). A crew of 10 firefighters was deployed to conduct this exercise. They were required to proceed to the scene on foot for the mountain rescue operation. They were required to carry the following equipment uphill, perform the rescue, and return to the starting point: descender, four rescue carabiners, one troll tap sling, one short rope (4.5 kg); 150 m line rescue with carrying bag (20.5 kg); 50 m rescue lifeline (9 kg); breakaway (upper part; 11 kg); stretcher, mesh type, breakaway (lower part; 9 kg); and rucksack (5 rescue karabiner, 2 rescue pulley, and 2 anchor strap; 6.5kg). After locating the casualty, the patient was found unconscious, not breathing, and with no detectable pulse rate. One firefighter placed the dummy (68 kg) on the stretcher, and the other firefighter pulled up the dummy from the slope. After cardiopulmonary resuscitation and basic casualty management, the crews had to convey the dummy from KK143893 to KK149892 (Tsao Kau Fung at a height of 508 m) a distance of about 750 m (Fig. 1, point E to point D), pending helicopter winching to a nearby hospital.

2.3. Assessment of cardiovascular disease risk factors

The body weight and percentage body fat of the firefighters was measured using foot-to-foot bioelectrical impedance (TBF-401; Tanita Co., Tokyo, Japan) with participants barefoot and dressed in light T-shirt and shorts. Body weight was measured to the nearest 0.1 kg, and height was measured to the nearest 0.5 cm with a Harpenden statiometer (Holtain, Grymych, UK). Body mass index (BMI) was calculated as weight (kg) divided by height (m^2). The measurement of waist circumference was made at the midpoint between the lower margin of the last palpable rib and the top of the iliac crest [15]. Finger capillary blood samples were collected from participants following a 12-hour fast for the assessment of fasting total cholesterol, low-density lipoprotein cholesterol, and the determination of high-density lipoprotein (HDL) cholesterol levels using a standardized dry-chemistry protocol (Reflotron, Roche Diagnostics, Mannheim, Germany) [16]. Fasting capillary whole-blood glucose levels was also assessed using the Roche Accu-Chek glucometer.

Cardiovascular disease risk factors [17] were defined as follows: general obesity as BMI ≥ 30 kg/m^2 [18] and/or central obesity as waist circumference ≥ 90 cm in men and ≥ 80 cm in women [19]; hypertension as systolic blood pressure (BP) ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg or both, and/or treatment with antihypertensive drugs with regular medical follow-up [20]; diabetes mellitus as fasting (after at least 8 hours of fasting) capillary blood glucose ≥ 6.1 mmol/L and/or random capillary blood glucose ≥ 11.1 mmol/L and/or treatment with known history of diabetes mellitus with or without antidiabetic treatments with



Legend:

	A→B	B→C	C→D→E	E→D
Gradient (deg.)	8.5°	18.5°	2.25°Avg.	- 6.67°Avg.
Distance (km)	1.95	0.55	2	0.75

Total distance:= A→B→C→D→E→D = 5.25 km

Return journey= 9 km

Fig. 1. Cross section of Pat Sin Leng Mountain Range.

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regular medical follow-up [21]; dyslipidemia as raised cholesterol (total cholesterol ≥ 6.2mmol/L or low-density lipoprotein cholesterol of ≥ 4.1 mmol/L) and/or triglyceride > 2.3mmol/L and/or total cholesterol/HDL cholesterol ratio of > 5 [22,23]; smoking as current smokers and ex-smokers irrespective of the daily number of cigarettes smoked [17]; known cardiovascular diseases as a history of documented coronary heart disease, cerebrovascular accident, and/or peripheral artery disease with or without any active treatments.

2.4. Assessment of cardiopulmonary fitness

Maximal oxygen consumption (VO_2max) was obtained from a treadmill running test. The protocol began with a slow jog on the treadmill at 0.45 m/s for 1 minute. The speed increased gradually by 0.22 m/s every minute until it reached 3.8 m/s. Subsequently, the speed remained constant, whereas the gradient was increased by 1% every minute until volitional exhaustion. Gas samples were collected continuously throughout the test via a comfortably fitted facemask (Hans Rudolph, Inc., Kansas, US) and analyzed using the Medgraphics System CPX/DTM metabolic cart (Medical Graphics Corporation, St. Paul, MN, US). Calibration of the metabolic cart was performed prior to each test. Heart rate was recorded throughout the test using a heart rate monitor (Polar E600; Polar Electro Oy, Kempele, Finland). Blood lactate levels were determined at rest and at 1 minute after the test termination from a fingertip capillary blood sample (Lactate Pro Portable Blood Lactate Analyzer, Kyoto, Japan). A maximal effort was accepted if the respiratory exchange ratio was ≥ 1.0, and age-predicted maximal heart rate, and/or a postexercise lactate level of 10.0 mmol/L was attained [24].

2.5. Assessment of physical activity and cardiovascular workload at work

Cardiovascular workload was assessed using ambulatory heart rate monitoring for each firefighter for four “normal” 24-hour working shifts and during real-situation simulated scenarios using a Polar E600 heart rate telemetry system (Polar Electro Oy, Kempele, Finland). This comprised a wrist receiver and an electrode-belt transmitter. Continuous heart rate data were obtained from 15-second averages and expressed per minute. Measured working heart rate ≥ 50% (50%HRmax) and 70% (70%HRmax) of each individual’s maximal heart rate, obtained from the cardiopulmonary fitness test, were used as individualized cutoffs for moderate and vigorous-intensity cardiovascular workload, respectively [25].

2.6. Assessment of leisure-time physical activity

Leisure-time physical activity of the previous 7 off-duty days of each firefighter was assessed using the short version of the International Physical Activity Questionnaire (IPAQ) [26]. The IPAQ has been translated into Chinese with adequate reliability and validity [27]. The IPAQ data were converted into metabolic equivalent scores (MET/min/wk) for each type of activity. The MET score weights each type of activity by its energy expenditure, using 1 MET for sitting, 3.3 METs for walking, 4 METs for moderate activity, and 8 METs for vigorous activity (www.ipad.ki.se). The sum of minutes in walking, moderate, and vigorous MET scores per week gives a combined total physical activity score, which classifies leisure-time physical activity into three (low, moderate, high) categories.

2.7. Data analysis

Continuous data are shown as mean ± standard deviation and median (interquartile range) for normally distributed and nonnormally distributed data, respectively. For normally distributed data, Student *t* test or one-way analysis of variance were used for group comparisons. Analysis of covariance was used to adjust for age, BMI, and smoking status. Linear contrast tests were used to examine the linear trends across different leisure-time physical activity categories. For nonnormally distributed data, Mann–Whitney *U* tests or Kruskal–Wallis tests were used for group comparisons. For categorical data, Chi-square tests were used for comparisons between groups. Pearson and Spearman correlation coefficients were used to test for the correlation between normally distributed and nonnormally distributed data, respectively. All analyses were performed using the statistical software package SPSS (version 13.0 for Windows; SPSS Inc., Chicago, IL, USA).

3. Results

In the Health Screening Group, 142 (36.7%) and eight (2.1%) of the firefighters were identified as overweight and obese, respectively. The prevalence of having at least two, three, four, or five cardiovascular disease risk factors was 33.9%, 12.4%, 3.4%, and 0.3%, respectively. Among the 130 firefighters selected to join the Target Group, 24 were excluded because of musculoskeletal medical problems or poor family histories that prevented a maximal cardiopulmonary fitness test. Physical characteristics and cardiovascular disease risk factors were comparable in firefighters between the Health Screening Group and the Target Group (Tables 1 and 2).

Heart rate data were recorded during the four “normal” 24-hour working shifts in 95 firefighters of the Target Group. The remaining 10% reported no data because the participants forgot to turn on the recording mode of the heart rate monitor, or because of telemetric interference.

Smoking status and BMI were found to be significantly associated with the study outcomes. Fifteen out of 95 participants were smokers/ex-smokers. Smoker/ex-smokers were significantly taller (176 ± 4 vs. 173 ± 4, $p = 0.026$) and heavier (78.5 ± 6.2 vs. 72.5 ± 6.9, $p = 0.002$) with a greater waist circumference

Table 1
Physical characteristics and cardiovascular disease risk factors in firefighters

	Health Screening Group ($n = 387$)	Target Group ($n = 95$)	p
Age (y)			0.353
18–29	86 (22.2)	24 (25.3)	
30–39	142 (36.7)	41 (43.2)	
40–49	130 (33.6)	26 (27.4)	
≥ 50	29 (7.5)	4 (4.2)	
Height (cm)	174 ± 4	174 ± 5	0.893
Weight (kg)	74.1 ± 7.6	73.5 ± 7.1	0.501
BMI (kg/m^2)			0.762
< 25	237 (61.2)	57 (60.0)	
25–29.9	142 (36.7)	37 (38.9)	
≥ 30	8 (2.1)	1 (1.1)	
Body fat (%)	13.3 ± 2.9	12.6 ± 2.6	0.038
Waist circumference (cm)	81.8 ± 6.9	80.6 ± 6.8	0.119
Hypertension status*			0.647
Normal	125 (32.3)	35 (36.8)	
Prehypertension	216 (55.8)	51 (53.7)	
Hypertension I	42 (10.9)	9 (9.5)	
Hypertension II	4 (1.0%)	0	
TC (mmol/L)	4.3 ± 1.2	4.2 ± 1.1	0.864
LDL-C (mmol/L)	2.7 ± 1.0	2.7 ± 0.9	0.724
HDL-C (mmol/L)	1.2 ± 0.3	1.2 ± 0.3	0.384
TG (mmol/L)	1.0 ± 0.8	0.9 ± 0.8	0.391
Glucose (mmol/L)	5.6 ± 0.9	5.6 ± 0.7	0.400

Data are presented as n (%) or mean ± SD. *See Table 2.
BMI, body mass index; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; TC, total cholesterol; TG, triglycerides.

Table 2
Definition of blood pressure (BP) classification

BP classification	Systolic BP (mmHg)		Diastolic BP (mmHg)
Normal	< 120	And	< 80
Prehypertension	120–139	Or	80–89
Stage 1 hypertension	140–159	Or	90–99
Stage 2 hypertension	≥ 160	Or	≥ 100

Note. From "The seventh report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure," by A.V. Chobanian, G.L. Bakris, H.R. Black, W.C. Cushman, L.A. Green, J.L. Izzo JL, D.W. Jones, B.J. Materson, S. Oparil, J.T. Wright Jr, E.J. Roccella; National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee, 2003, *JAMA*, *289*, p. 2560–7. Copyright 2003, American Medical Association. Reprinted with permission.

(84.7 ± 6.4 vs. 79.8 ± 6.6, $p = 0.010$). Smokers/ex-smokers had a significantly lower maximal heart rate during the maximal running test (184 ± 12 vs. 192 ± 11, $p = 0.019$) and a significantly higher average heart rate during the Sewage Rescue scenario when compared to nonsmokers (168 ± 4 vs. 160 ± 13, $p = 0.002$). No significant differences in cardiovascular disease risk factors, cardiopulmonary fitness, and the other study outcomes could be found. BMI was positively associated with age ($r = 0.388$, $p < 0.001$), systolic BP ($r = 0.234$, $p = 0.022$), triglycerides ($r = 0.358$, $p < 0.001$), and the proportion of working heart rate above 70%HRmax in the Maze Searching scenario ($\rho = 0.377$, $p = 0.003$). BMI was negatively associated with HDL cholesterol ($r = -0.250$, $p = 0.019$) and cardiopulmonary fitness level per kilogram of body mass ($r = -0.409$, $p < 0.001$).

Firefighters who had higher leisure-time physical activity had lower resting heart rate. They also tended to be heavier (p for trend = 0.019) but had similar percentage fat than firefighters who had moderate or low leisure-time physical activity (Table 3). There was no statistical difference in waist circumference, resting BP, blood cholesterols, glucose, or maximal oxygen consumption in firefighters in different leisure-time physical activity categories.

During the four 24-hour working shifts, firefighters who had higher levels of leisure-time physical activity time showed a lower average working heart rate and a smaller proportion of their working heart rate exceeding 50%HRmax (Table 4).

Firefighters within all leisure-time physical activity categories spent nearly 100% of the time in the real-situation simulated scenarios with a working heart rate above 50%HRmax, and with a working heart rate above 70%HRmax in the Water Relay scenario. Interestingly, firefighters with low level of leisure-time physical activity tended to have a lower proportion of working heart rate exceeding 70%HRmax in the Maze Searching scenario ($p = 0.080$; Table 5). Firefighters who had higher leisure-time physical activity had a lower peak working heart rate during the mountain rescue scenario (p for trend = 0.036).

4. Discussion

The findings from this study provide some support for the hypothesis that firefighters who are more physically active in their leisure-time will use lower cardiovascular workload to perform the firefighting tasks. We did not find that firefighters who are more active during their leisure-time have higher cardiopulmonary fitness and a better cardiovascular health profile.

Despite numerous studies that have demonstrated that regular physical activity accounts for a better cardiovascular health profile and better cardiopulmonary fitness [10,28–34], our study did not find these beneficial associations. In the current study, we used the internationally accepted BMI categorization for overweight (BMI = 25–29.9 kg/m^2) and obese (BMI ≥ 30 kg/m^2) to allow comparisons with studies from other countries. According to a population-based study conducted in 1995 in Hong Kong, the prevalence of obesity (defined as BMI ≥ 25 kg/m^2 for the Asian population [16]) was 38% in men. The prevalence of overweight (BMI = 25–29.9 kg/m^2) in our participants was similar to the prevalence of "obesity" (BMI ≥ 25 kg/m^2 cutoff for the Asian population [19]) of the local Hong Kong population [13]. Considering

Table 3
Physical characteristics and cardiovascular disease risk factors in firefighters from different leisure-time physical activity categories

	Level of leisure-time physical activity			p	Adjusted p*	p (linear trend)
	Low (n = 19)	Moderate (n = 30)	High (n = 46)			
Age (y)	33.3 ± 6.2	35.7 ± 8.1	37.5 ± 7.7	0.131	–	0.045
Height (cm)	174 ± 5	173 ± 5	174 ± 4	0.306	–	0.359
Weight (kg)	70.2 ± 6.0	73.4 ± 6.5	74.8 ± 7.5	0.054	–	0.019
BMI (kg/m^2)	23.3 ± 1.5	24.6 ± 2.2	24.6 ± 2.4	0.053	–	0.046
BMI ≥ 25 kg/m^2	3 (15.8)	14 (46.7)	20 (43.5)	0.066	–	0.081
Body fat (%)	11.9 ± 2.1	12.5 ± 2.1	13.0 ± 2.9	0.264	–	0.104
Waist circumference (cm)	78.1 ± 5.1	81.3 ± 6.0	81.2 ± 7.7	0.209	–	0.149
Systolic BP (mmHg)	124 ± 10	122 ± 12	123 ± 11	0.790	0.239	0.877
Diastolic BP (mmHg)	75 ± 6	74 ± 8	74 ± 8	0.857	0.247	0.671
TC (mmol/L)	3.9 ± 1.5	4.5 ± 1.0	4.2 ± 0.8	0.172	0.213	0.408
TG (mmol/L)	0.8 ± 0.4	1.1 ± 0.8	0.9 ± 1.0	0.512	0.441	0.817
HDL-C (mmol/L)	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.3	0.980	0.891	0.859
LDL-C (mmol/L)	2.9 ± 1.0	2.8 ± 1.0	2.5 ± 0.9	0.438	0.163	0.224
Glucose (mmol/L)	5.7 ± 0.6	5.5 ± 0.8	5.5 ± 0.6	0.723	0.709	0.495
VO_2max (mL/min)	3311 ± 333	3371 ± 450	3498 ± 398	0.176	0.081	0.068
VO_2max (mL/min/kg)	47.2 ± 3.5	46.1 ± 6.3	47.0 ± 5.3	0.727	0.307	0.970
HRrest (beats/min)	71 ± 12	68 ± 10	64 ± 8	0.017	0.016	0.005
RER at maximal	1.15 ± 0.07	1.15 ± 0.07	1.13 ± 0.07	0.304	0.220	0.172
Lactate at maximal (mmol/L)	14.0 ± 2.2	13.6 ± 1.9	13.0 ± 1.5	0.115	0.163	0.039

Data are presented as n (%) or mean ± SD.
*p values were adjusted for age, BMI, and smoking status.
BMI, body mass index; BP, blood pressure; HDL-C, HDL cholesterol; LDL-C, LDL cholesterol; RER, respiratory exchange ratio; TC, total cholesterol; TG, triglycerides; VO_2max, maximal oxygen consumption.

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Table 4
Ambulatory heart rate monitoring in firefighters from different leisure-time physical activity categories during the four 24-hour work shifts

	Level of leisure-time physical activity			p	Adjusted p*	p (linear trend)
	Low ($n = 19$)	Moderate ($n = 30$)	High ($n = 46$)			
50%HRmax (beats/min)	97 ± 6	97 ± 5	94 ± 6	0.013	0.082	0.013
70%HRmax (beats/min)	136 ± 9	136 ± 7	131 ± 8	0.013	0.082	0.013
4Day: average HR (beats/min)	81 ± 8	78 ± 8	75 ± 7	0.014	0.011	0.004
4Day: peak HR (beats/min)	173 ± 19	170 ± 23	165 ± 20	0.432	0.571	0.198
4Day: %HR > 50%HRmax (%)	16.8 (12.9–27.8)	12.6 (10.0–16.6)	10.7 (7.6–17.9)	0.025		
4Day: %HR > 70%HRmax (%)	2.0 (0.7–3.7)	1.1 (0.5–3.1)	1.2 (0.5–2.7)	0.541		

Data are presented as mean ± SD or median (IQR).
*p values were adjusted for age, BMI, and smoking status.
4Day, 4 days of 24-hour work shifts ambulatory heart rate monitoring; %HR >50%HRmax and %HR > 70%HRmax, measured working heart rate at or greater than 50% and 70% of each individual's maximal heart rate, respectively; BMI, body mass index; HRmax, maximal heart rate; IQR, interquartile range.

the results of a recent study on the assessment of body composition by dual-energy X-ray absorptiometry showing that percent body fat ranged from approximately 18% to 26% in Chinese men [35], it is reasonable to believe that some firefighters who are muscular may have been misclassified into the overweight category. A slightly better cardiovascular disease risk profile in firefighters was found in comparison to the local Hong Kong population [13]. Obesity is closely linked with cardiovascular fitness level and increased risk of cardiovascular mortality [36], and it is reasonable to assume that the firefighters in the current study were better "conditioned" than the general population. The requirement of physical activity levels in terms of exercise frequency, duration, and intensity in conditioned people have to be higher and be more specific to achieve additional cardiovascular health benefits [29,33].

In this study, all firefighters spent > 80% of their working day with heart rate values less than the 50%HRmax cutoff during the 24-hour working shifts, indicating that firefighters spent a large proportion of their working day being sedentary or engaged in light intensity activities [25]. This finding is consistent with previous studies [37,38]. Importantly, firefighters who had higher physical activity in their leisure time experienced a reduced moderate cardiovascular workload, which suggests that leisure-time physical activity did confer a significant benefit when conducting job tasks of moderate cardiovascular workload in firefighters. Our results also demonstrated that all firefighters performed the simulated scenarios at much more vigorous levels of exertion, as indicated by the percentage of working heart rate above 70%HRmax. However, there was no statistical difference in vigorous cardiovascular workload between firefighters in the different leisure-time physical activity categories. This may be because of limitations in the categorization of leisure-time physical activity using the IPAQ questionnaire. By contrast, cardiopulmonary fitness level was similar among firefighters with different levels of leisure-time physical activity in this study, which may suggest that firefighters who had a low level of leisure-time physical activity did not perform the simulated scenarios as hard as the firefighters who had a high level

Table 5
Ambulatory heart rate monitoring in firefighters from different leisure-time physical activity categories during real-situation simulated scenarios

	Level of leisure-time physical activity			p	Adjusted p*	p (linear trend)
	Low ($n = 19$)	Moderate ($n = 30$)	High ($n = 46$)			
WR: average HR (beats/min)	164 ± 18	163 ± 12	161 ± 13	0.803	0.979	0.512
WR: peak HR (beats/min)	186 ± 14	185 ± 14	182 ± 12	0.493	0.812	0.250
WR: %HR > 50%HRmax (%)	100 (100–100)	100 (100–100)	100 (100–100)	1.000		
WR: %HR > 70%HRmax (%)	100 (76.1–100)	100 (87.0–100)	100 (94.9–100)	0.498		
RPE after the WR task	17.0 ± 2.1	16.8 ± 3.1	16.1 ± 2.7	0.460	0.663	0.238
MS: average HR (beats/min)	156 ± 19	160 ± 13	159 ± 16	0.784	0.920	0.770
MS: peak HR (beats/min)	179 ± 17	180 ± 13	177 ± 14	0.786	0.878	0.650
MS: %HR > 50%HRmax (%)	100 (100–100)	100 (100–100)	100 (100–100)	0.555		
MS: %HR > 70%HRmax (%)	90.0 (65.2–100)	100 (90.1–100)	96.8 (94.2–100)	0.080		
RPE after the MS task	15.5 ± 3.5	15.4 ± 2.7	15.6 ± 2.6	0.968	0.997	0.909
SR: average HR (beats/min)	158 ± 15	162 ± 10	162 ± 13	0.470	0.463	0.304
SR: peak HR (beats/min)	183 ± 14	183 ± 11	182 ± 13	0.970	0.975	0.825
SR: %HR > 50%HRmax (%)	100 (100–100)	100 (1001–00)	100 (100–100)	0.200		
SR: %HR > 70%HRmax (%)	93.3 (76.7–100)	88.5 (83.3–100)	100 (93.1–100)	0.186		
RPE after the SR task	17.0 ± 1.2	16.4 ± 2.4	16.8 ± 2.7	0.773	0.677	0.888
	Low ($n = 8$)	Moderate ($n = 6$)	High ($n = 15$)			
MR: average HR (beats/min)	143 ± 11	135 ± 11	135 ± 10	0.229	0.109	0.142
MR: peak HR (beats/min)	191 ± 10	177 ± 11	178 ± 11	0.052	0.099	0.036
MR: %HR > 50%HRmax (%)	100 (100–100)	100 (98–100)	100 (99–100)	0.105		
MR: %HR > 70%HRmax (%)	72.5 (64.2–76.7)	51.8 (39.8–80.7)	62.3 (49.8–75.2)	0.300		
RPE after the MR task	18.9 ± 1.7	16.8 ± 3.4	16.6 ± 3.1	0.199	0.349	0.098

Data are presented as mean ± SD or median (IQR).
*p values were adjusted for age, BMI and smoking status.
%HR >50%HRmax and %HR > 70%HRmax, measured working heart rate at or greater than 50% and 70% of each individual's maximal heart rate, respectively; BMI, body mass index; HRmax, maximal heart rate; IQR, interquartile range; MR, mountain rescue; MS, maze searching; RPE, rate of perceived exertion; SR, sewage rescue; WR, water relay.

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of leisure-time physical activity did. Possible reasons may include less motivation in firefighters with a low level of leisure-time physical activity in performing vigorous activities; or some of the work was covered by their teammates who had a higher level of leisure-time physical activity.

Studies on physiological and metabolic responses in firefighters under simulated firefighting tasks had been widely reported, and it has been suggested that the minimum aerobic capacity, as measured by maximum oxygen consumption, necessary to safely perform firefighting duties ranges from 33.9 mL/kg/min to 45 mL/kg/min [11,39,40]. The National Fire Protection Association has suggested a minimal aerobic capacity of 42 mL/kg/min for firefighters to safely complete firefighting activities [4]. In the current study, 78.3% of the firefighters had a maximal oxygen consumption that exceeds 42 mL/kg/min, suggesting that unlike other studies on firefighters that documented substandard aerobic fitness [6], cardiopulmonary fitness in the majority of the firefighters in this study fulfilled the general requirement for firefighting activities. One of the contributory factors to better physical "conditioning" in firefighters of this study might be related to the annual physical fitness assessment among all firefighters conducted by the Hong Kong Fire Services. Components of the annual physical fitness assessment include aerobic fitness, muscle strength, and muscle endurance. Firefighters who fail this physical fitness assessment are required to join a physical fitness training program prior to resuming their duties. Apart from the annual physical fitness assessment, the Hong Kong Fire Services also arranges regular physical training sessions and fire drills for all firefighters during their on-duty time. The inclusion of physical fitness assessment, physical training sessions, and fire drills regularly across the working life of firefighters might be a useful booster for firefighters to maintain their body weight and physical fitness; however, Hong Kong is a geographically small region, which makes the implementation of the physical fitness assessment and training sessions among firefighters easier compared to other countries [9]. Other recommendations and strategies given by the Hong Kong Fire Services to local firefighters on health and wellness and to promote physical fitness include encouragement of having sufficient nutrient intake with a healthy balanced diet, enhancement of leisure-time physical activities and physical activities during on-duty time, incremental increases in the frequency of fire drill practice in the hot environment, cultivation of a positive mood for exercise training among colleagues, and training facilities in different fire stations.

The limitations of this study include monitoring the firefighters as a team and the assessment of leisure-time physical activity. When working as a team the specific role of each individual in each task is not identical, and it is possible that duties of a heavier workload are assigned to firefighters who are fitter. The evaluation of leisure-time physical activity was performed by using the IPAQ-short questionnaire. The objective assessment of physical activity would have been ideal; however, this was not feasible in our setting.

A strength of the study is that it utilizes ambulatory heart rate monitoring of real-situation firefighters' work. Heart rate monitoring has been commonly used as an objective method of assessing physical activity [41].

In conclusion, leisure-time physical activity confers significant benefit when performing job tasks of moderate cardiovascular workload in firefighters of this study.

Conflicts of interest

The authors declare no conflicts of interest.

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