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Research Article
Relationship Between Body Composition and Physical Fitness of Rescue Firefighter Personnel in Selangor, Malaysia

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Abstract

Background and Objective: The complexity of study routine and job nature of firefighters require them to be physically fit and to possess good cardiorespiratory capacity, muscle strength and resistance including a good body composition. This study aimed to identify the relationship between body composition and physical fitness of rescue firefighter personnel in Selangor, Malaysia. **Materials and Methods:** A total of 230 male firefighters aged 20-39 years from 9 randomly selected districts in Selangor participated in this study. Anthropometric measurements, including height, weight, body composition and waist circumference were taken. Individual proficiency performance test was performed using bent knee sit-up, standing broad jump, pull-up, 4×10 m shuttle run and 2.4 km run to assess physical fitness. The VO_2max test was also conducted to evaluate aerobic fitness. **Results:** This study revealed that 42.6% subjects had normal body weight, 46.5% were overweight and 10.3% were obese. The means of bent knee sit-up test, standing broad jump, pull-up test, 4×10 m shuttle run, 2.4 km run and VO_2 max test were 41.52±7.18 count, 222.41±26.03 cm, 6.93±3.79 count, 10.29±0.86 sec, 13.16±2.84 min and 37.66±5.25 mL kg^{-1} min^{-1}, respectively. Body fat was significantly correlated with bent knee sit-up test (r = -0.289, p<0.001), standing broad jump (r = -0.248, p<0.001), pull-up test (r = -0.450, p<0.001), 4×10 km shuttle run (r = 0.347, p<0.001) and 2.4 km run (r = 0.371, p<0.001). Body mass index exhibited a significant correlation with bent knee sit-up test (r = -0.272, p<0.001), standing broad jump (r = -0.234, p<0.001), pull-up test (r = -0.484, p<0.001), 4×10 km shuttle run (r = 0.430, p<0.001) and 2.4 km run (r = 0.399, p<0.001). Body weight also showed a significant correlation with knee sit-up test (r = -0.239, p<0.001), standing broad jump (r = -0.187, p<0.01), pull-up test (r = -0.491, p<0.001), 4×10 km shuttle run (r = 0.396, p<0.001) and 2.4 km run (r = 0.350, p<0.001). **Conclusion:** A specific training programme should be implemented to improve the body composition components and physical fitness among Malaysian firefighters. The body composition components, such as body fat, body mass index and body weight seem to influence physical fitness among Malaysian firefighters excluding aerobic fitness.

Key words: Body composition, body fat, body mass index, body weight, physical fitness, VO_2 max test, rescue firefighters

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

A rescue firefighter (FF) is primarily tasked to save lives whilst maintaining his safety. In various emergencies, rescue FFs wearing personal protective equipment are the first group to arrive and perform physical demanding activities[1]. Their skills, actions and decisions are important during critical situations whilst protecting the victims and the team[2]. Previous studies reported that FFs are exposed to a higher incidence of musculoskeletal injuries, overexertion, substandard physical fitness, cardiovascular incidences[3], muscular sprains and strains as well as tendon, ligament and join tinjuries[4]. Considering all complexities including injuries and job demand, FFs should possess good physical fitness, which includes good cardiorespiratory capacity, muscle strength or resistance and Body Composition (BC)[5,6].

Smith[7] suggested that FFs are required to have high levels of aerobic fitness, anaerobic capacity, muscular strength and endurance. However, the high prevalence of overweight (79.5%) and obesity (33.5%) among United States (US) FFs indicates the above statement as a false assumption[8]. This false assumption has also been proven in other previous studies among US FFs and Brazilian FFs, in which a high prevalence of overweight and obesity is reported[9-12]. Nogueira *et al.*[11] found that obesity is related to lower cardiorespiratory fitness among Brazilian FFs compared with the non-obese group. A similar increased pattern of overweight and obesity prevalence exists among the Malaysian armed forces personnel. The prevalence of overweight and obesity among the Royal Malaysian Navy (RMN)[13] are 29.3 and 7.2%, respectively and that among the Malaysian Army (MA) are 32.8 and 9.3%, respectively[14].

Baur *et al.*[15] and Durand *et al.*[16] reported that high physical fitness of FFs is significantly associated with lower Body Fat (BF) and Body Mass Index (BMI). In addition, Michaelides *et al.*[17] found an association between increased BMI, BF, Waist Circumference (WC), age and declining of fitness performance in US FF. According to Poplin *et al.*[18], comprehensive fitness can be evaluated based on cardiorespiratory fitness, muscular strength, endurance, flexibility and BC to predict the risk of injury. Individuals with lower comprehensive fitness status have been reported to have a higher risk of injury compared with fit individuals[18].

A positive FF job performance is associated with an improvement of the physical fitness level[17,5]. Previous studies indicated that physiological factors are related to the performance of occupational task and can be measured. Health and skill-related fitness components are mainly used to measure physical fitness performance[19]. The health-related component includes muscular strength, muscular endurance, flexibility and cardiorespiratory. The skill-related component is divided into agility, balance, coordination, speed, power and reaction. Each of the physical fitness elements has an important function that influences performance effectiveness and prevents injuries among FF personnel[1].

To date, several tests have been used by fire departments in many countries to screen for minimal physical capabilities, occupational qualification, requirements and performance in potential FF candidates[17,20]. For example, the candidate physical ability test, ability test and Individual Physical Proficiency Test (IPPT) are used as basic fitness parameters among North American FFs, Italian FFs and Malaysian FFs (MFFs), respectively. According to Atikah *et al.*[1], these physical tests are important to help health practitioners and employers to identify health-related problems to develop and implement wellness programmes. Since, physical fitness, healthy lifestyle and prevention against injuries during on-job performance are important to MFF, this study was conducted to assess BC and physical and aerobic fitness among FF personnel in Selangor, Malaysia and to determine the correlation between the variables studied.

MATERIALS AND METHODS

Ethical approval and authorisation letter: This study followed all the guidelines and procedures approved by the research ethics committee of Universiti Kebangsaan Malaysia (reference No. UKM 1.5.3.5/244/FST-2015-007). A written authorisation letter was obtained from the Fire and Rescue Department of Selangor, Malaysia [reference No. JBPM/SL/OPS:100-2/7/14 Jld 1 (56)] to visit and conduct the study among the FFs.

Sampling and study location: This cross-sectional study was carried out between August and November, 2015 at 9 randomly selected fire and rescue departments in Selangor, Malaysia. The fire and rescue stations selected are located in Serdang, Bangi, Kajang, Shah Alam, Kuala Lumpur International Airport, Cyberjaya, Petaling Jaya and Puchong. A total of 230 subjects completed all parameters in this study. The participants were rescue male FFs aged between 20-39 years. The FFs who had previous history of musculoskeletal injuries were excluded from the study. Subjects were briefed on the study procedures and consent forms were obtained prior to participation.

Anthropometric and BC measurements: The height of the participants was measured to the nearest 0.1 cm without shoes using the SECA body meter (Model 208, Seca, Germany). Body weight was directly measured to the nearest 0.1 kg using the weighing function of the Tanita TBF-300A body fat analyzer (Tanita Corp., Japan). The weight of the uniform was deducted during the measurement. The BC was measured simultaneously with body weight using the body fat analyzer. Based on the bioelectrical impedance analysis (Tanita TBF-300A), the ideal cut-off point for BF is 14-23%. Prior to measurements, the subjects were instructed to fast for 4-5 h, avoid heavy physical activity for 12 h, ensure normal state of hydration and avoid consumption of any alcoholic and caffeinated drinks for 24 h.

The BMI was calculated as:

$$\text{BMI} = \frac{\text{Weight (kg)}}{\text{Height (m}^2\text{)}}$$

The WC was measured to the nearest 0.1 cm using a flexible, non-stretchable plastic measuring tape at the mid-point between the inferior margin of the last rib and the iliac crest.

Physical fitness test: The IPPT was conducted to evaluate whether the physical fitness level of MFF personnel is compatible with their assignment requirements[21]. There are two components of fitness divided into 5 types of tests. The first component is the study of muscular strength, power and endurance involving bent knee sit-up test, standing broad jump, pull-up test and 4×10 m shuttle run test. One minute sit-up was performed to measure muscular endurance. The subject's feet were held by a colleague whilst lying on the back with knees bent and heels flat on the floor. The hands were interlocked behind his head and the buttocks were touching the floor. The elbows had to be in contact with the knees in coming up position and the shoulder had to reach to the ground in going down position. The number of sit-up repetitions over 1 min was counted. Standing broad jump was measured to test muscle stretching from standing on both feet before and after the subject jumped passed the required ground line. Results were recorded in centimetres. Longer distance indicated higher score with good performance. The pull-up test was used for 30 sec to measure muscle strength and power. The subject held himself upright along the bar and pulled-up until the chin's position on top of the bar line was in a straight body position. The number of pull-up repetition was counted. About 4×10 m shuttle run was performed on a flat surface. The subject ran back and forth to measure the efficiency of his anaerobic system and leg power. Results of this test were recorded in seconds. Shorter time taken to complete this study indicated a higher score. Cardiovascular test was the second component and it involved a 2.4 km run. A flat surface area with a 2.4 km distance was used for this test. Time in minutes and seconds were recorded when the subject reached the finish line. This study was carried out to measure the ability of the cardiovascular system, stamina and lower body part muscle endurance of the subjects.

Aerobic fitness test: A maximal multistage 20 m shuttle run was used to determine the maximal aerobic power of subjects[22]. This test was performed to estimate the VO_2 max. The test was carried out with a cassette that produced beep sounds according to the fitness level described by Brewer *et al.*[23]. Prior to the start of the study, all subjects were required to perform warm-up exercises and trial runs for several sub levels for adaptation. The subjects were required to run continuously between two lines, which were 20 m apart, in proportion to the beep sound and time intervals. In this study, the subjects ran on a flat and non-slippery surface. At the first beep sound, the subjects began their run from the first to the second line and were advised to start at slow speed because the running velocity increased by 0.5 km h^{-1} at each level[22]. If the subjects reached the line before the next beep sound, they had to wait before continuing. The running continued until the subjects failed to reach the line before the beep sound after two warnings. Subjects were evaluated based on the highest level achieved. The estimated value of VO_2 max according to the level and sublevel in which the subject stops was determined[24] based on the VO_2 max.

Data analysis: All data were analysed using the Statistical Package for the Social Sciences for Windows (SPSS 23.0, SPSS Inc., Chicago, IL). The results were expressed as percentages, mean and standard deviation. Pearson test was performed to determine the relationship between BF, BMI and body weight and each actual physical component test score of IPPT and VO_2 max. Results were considered to be significant at $p<0.05$.

RESULTS AND DISCUSSION

Anthropometric characteristics and BC: Physical characteristic and body composition of the subjects are shown in Table 1. The mean of BF among the subjects in this study was 25.77%, thus, the subjects were classified as high BF category. A previous study among RMN trainee personnel showed lower means of body weight (62.3 kg), BF (12.3%) and BMI (22.0 kg m^{-2})[25] compared with the present study. Meanwhile, mean WC was reported to be lower than the

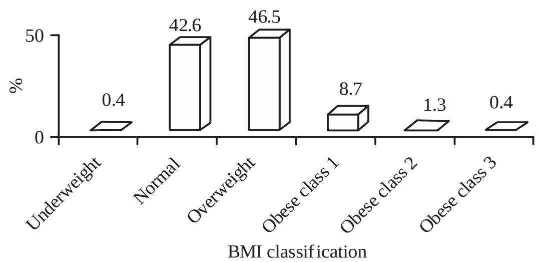

Fig. 1: Distribution of subjects according to BMI classification

Table 1: Physical characteristic and body composition of the subjects (n = 230)

Parameters	Mean±SD	Range
Weight (kg)	73.56±11.55	51.30-118.30
Height (cm)	169.38±5.33	157.20-186.60
BMI (kg m^{-2})	25.59±3.62	16.50-41.60
Body fat (%)	25.77±6.19	12.40-53.00
Fat mass (kg)	19.37±7.26	1.10-48.50
MFF (kg)	54.07±6.24	19.00-82.60
Body water (%)	54.65±4.62	40.10-76.00
Waist circumference	85.99±9.58	65.50-125.50

MFF: Malaysian firefighters

cut-off point for Asian male (<90 cm) based on WHO/IASO/IOTF[26]. This finding is higher compared with that obtained by Sedek *et al.*[13], who reported a mean WC of 82.2 cm. The mean BMI of the subjects was slightly overweight. However, it is lower compared with that of the US FF study (26.27 kg m^2)[2]. According to Soteriades *et al.*[27], BMI classification is crucial among FFs because every 1 U increase in BMI is associated with 5% increased risk of job disability. The distribution of BMI classification[28] on the overall subjects is shown in Fig. 1. The prevalence of subjects classified as overweight is higher (46.5%) compared with normal (42.6%), followed by obese (10.4%) and underweight (0.4%).

Physical and aerobic fitness: Table 2 presents descriptive data on physical (IPPT) and aerobic fitness assessments among subjects. The mean actual IPPT scores for bent knee sit-up test, standing broad jump, pull-up test, 4×10 m shuttle run and 2.4 km run were 41.52±7.18 count, 222.41±26.03 cm, 6.93±3.79 count, 10.29±0.86 sec and 13.16±2.84 min:sec, respectively. The overall mean for the actual score of physical fitness demonstrated was 16.00±5.49, with a minimum classification score of 2 and a maximum classification score of 25. The IPPT showed that 172 subjects passed the test, whereas 58 subjects failed to achieve the required minimum score. The mean VO_2 max was 37.66±5.25 mL kg^{-1} min^{-1}, which ranged from 30.20-48.70 mL kg^{-1} min^{-1}.

This study indicated that the means of sit-up and pull-up counts were lower compared with those of RMN trainee personnel (42.27 sit-up counts and 8.11 pull-up counts)[25]. The

Table 2: Physical fitness and aerobic fitness score of the subjects

Parameters	No.	Mean±SD (range)
Actual fitness score		
Bent knee sit-up (count)	230	41.52±7.18 (20.00-69.00)
Standing broad jump (cm)	230	222.41±26.03 (20.00-300.00)
Pull-up (count)	230	6.93±3.79 (1.00-20.00)
4×10 m shuttle run (sec)	230	10.29±0.86 (8.20-15.84)
2.4 km run (min:sec)	230	13.16±2.84 (8.40-30.00)
Classification fitness score		
Bent knee sit-up	230	4.58±0.95 (0-5)
Standing broad jump	230	3.01±1.48 (0-5)
Pull-up	230	2.75±1.66 (0-8)
4×10 m shuttle run	230	3.78±1.72 (0-5)
2.4 km run	230	1.89±1.81 (0-5)
Overall score	230	16.00±5.49 (2-25)
Score (passed/failed)	230	172/58
Aerobic fitness test scores		
VO_2 max (mL kg^{-1} min^{-1})	130	37.66±5.25 (30.20-48.70)

mean of sit-up count was also a lower compared with that of US FFs (46.93 sit-up count) in a study by Poplin *et al.*[18]. Nevertheless, the mean of sit-up count (41.52 counts) was higher in this study compared with that in a study by Michaelides *et al.*[17] among US FFs (38 counts). The mean distance of standing broad jump of FFs in this study was shorter compared with that of Swiss soldiers (226 cm)[29] and RMN trainees (224 cm)[25]. In the present study, shorter distance achieved indicated lower muscle power. Thus, the Malaysian FF subjects exhibited lower muscle power compared with the Swiss soldiers and RMN trainees.

The shuttle run test was carried out to measure flexibility, muscle strength and power[25]. In this study, the mean time taken to complete the shuttle run test was lower (10.29 sec) compared with that of RMN trainees (11.05 sec)[25]. To examine the ability of the cardiovascular system, stamina and lower muscle endurance of FFs, the 2.4 km run test was carried out. This study found that the mean time of the 2.4 km run test was higher (13.16 min) in FFs compared with that in RMN trainees (11.93 min)[25] and 18 years old male cadet officers (11.13 min)[30]. According to the IPPT manual, the recommended period for the 2.4 km run test was between 10.21 and 14 min (Fire and Rescue Department, Malaysia, 2014). Thus, the finding of this study is considered to be satisfactory.

Cardiorespiratory fitness, which can be examined through aerobic fitness is an important component and known to be associated with chronic disease prevention[31]. Brown and Stickford[32] found that the required regular stimulating job task among FFs is within 60-95% of one's maximal capacity to ensure optimal readiness. The aerobic capacity needed to perform the activities regularly on fire ground was suggested[33-35] to be at 33.5, 45 and 49 mL kg^{-1} min^{-1}. According to Blair *et al.*[36], the VO_2 max value of 35 mL kg^{-1} min^{-1} for male is adequate for the purpose of

Table 3: Correlation between body fat percentage with physical and aerobic fitness test

Test	No.	Body fat (r)	p-value
Actual fitness score			
Bent knee sit-up (count)	230	-0.289	<0.001**
Standing broad jump (cm)	230	-0.248	<0.001**
Pull-up (count)	230	-0.450	<0.001**
4×10 m shuttle run (sec)	230	0.347	<0.001**
2.4 km run (min:sec)	230	0.371	<0.001**
Aerobic fitness test scores			
VO_2 max (mL kg^{-1} min^{-1})	130	-0.049	0.582

**Significantly correlated at p<0.001

Table 4: Correlation between BMI with physical and aerobic fitness test

Test	No.	BMI (R)	p-value
Actual fitness score			
Bent knee sit-up (count)	230	-0.272	<0.001**
Standing broad jump (cm)	230	-0.234	<0.001**
Pull-up (count)	230	-0.484	<0.001**
4×10 m shuttle run (sec)	230	0.430	<0.001**
2.4 km run (min:sec)	230	0.399	<0.001**
Aerobic fitness test scores			
VO_2 max (mL kg^{-1} min^{-1})	130	0.026	0.766

**Significant correlated at p<0.001

promoting health. In the present study, the mean VO_2 max value of 37.66 mL kg^{-1} min^{-1} was found to be adequate to promote good health. This finding is almost similar to that obtained by Sedek *et al.*[25] among RMN trainees with VO_2 max value of 37.33 mL kg^{-1} min^{-1} and by another study among South African FFs with VO_2 max value[2] of 37.56 mL kg^{-1} min^{-1}. The VO_2 max value in the present study is lower than the results reported among the Canadian FFs (38.5 mL kg^{-1} min^{-1})[20], Italian FFs (39.6 mL kg^{-1} min^{-1})[37] and US FFs (40.9 mL kg^{-1} min^{-1}) in a study by Sheaff *et al.*[38]. According to Copper[24], the VO_2 max value among FFs in this study was average based on the achieved VO_2 max value.

Relationship between BC and physical and aerobic fitness: Correlation test was performed to determine the relationship between physical fitness and BC. Results showed that BF had a low significant inverse correlation with bent knee sit-up test (r = -0.289, p<0.001), standing broad jump (r = -0.248, p<0.001) and moderate significant inverse correlation with pull-up test (r = -0.450, p<0.001) (Table 3). Meanwhile, a significant low positive correlation was observed between BF and 4×10 m shuttle run (r = 0.347, p<0.001) and 2.4 km run (r = 0.371, p<0.001). Significant inverse correlation was also found between BMI and bent knee sit-up test (r = -0.272, p<0.001), standing broad jump (r = -0.234, p<0.001) and pull-up test (r = -0.484, p<0.001) (Table 4). Similar to BF, BMI was positively correlated with 4×10 m shuttle run (r = 0.430, p<0.001) and 2.4 km run (r = 0.399, p<0.001). Body weight was significantly inverse correlated with bent knee sit-up test (r = -0.239, p<0.001), standing broad jump (r = -0.187, p<0.01) and pull-up test (r = -0.491, p<0.001) (Table 5). Positive correlation was observed between body weight and 4×10 m shuttle run (r = 0.396, p<0.001) and 2.4 km run (r = 0.350, p<0.001).

Table 5: Correlation between body weight with physical and aerobic fitness test

Test	No.	Body weight (R)	p-value
Actual fitness score			
Bent knee sit-up (count)	230	-0.239	<0.001**
Standing broad jump (cm)	230	-0.187	0.005*
Pull-up (count)	230	-0.491	<0.001**
4×10 m shuttle run (sec)	230	0.396	<0.001**
2.4 km run (min:sec)	230	0.350	<0.001**
Aerobic fitness test scores			
VO_2 max (mL kg^{-1} min^{-1})	130	0.022	0.802

*Significantly correlated at p<0.01, **Significantly correlated at p<0.001

Michaelides *et al.*[17] reported that the low performance achieved in the number of sit-up test is significantly positively correlated with BF (r = 0.57, p<0.01). However, Poplin *et al.*[18] demonstrated that increased BF is correlated with reduced repetitions in sit-up among US FFs. The significant inverse correlation between body weight and distance of standing broad jump (r = -0.187, p<0.01) was supported by Calavalle *et al.*[37]. The study showed that FFs with greater body weight have fewer sudden jumps. The present study showed that 4×10 m shuttle run and 2.4 km run were significantly correlated with BF and BMI. In comparison, Razalee *et al.*[25] showed significant correlations between 2.4 km run and BF (r = 0.321) and BMI (r = 0.373) but no correlation was observed between 4×10 m shuttle run and BF (r = -0.210, p>0.05) and BMI (r = -0.114, p>0.05).

A previous study considered that VO_2 max result designates the job performance for occupational health purpose among FFs[11]. In this study, aerobic fitness was not significantly correlated with BF (r = -0.049, p = 0.582), BMI (r = 0.026, p = 0.766) and body weight (r = 0.022, p = 0.802). This finding may indicate that aerobic fitness test is not affected by BF, BMI and body weight. Nogueira *et al.*[11] reported a strong correlation between aerobic fitness and BMI and BF. On the other hand, a study among Brazilian FFs showed that VO_2 max is inversely associated with BF and body weight[37]. This result was also reported in a study by Nogueira *et al.*[11], who found that Brazilian FFs with BMI <25 kg m^{-2} had a higher VO_2 max value (44.8 mL kg^{-1} min^{-1}) compared with FFs with BMI ≥25 kg m^{-2} (43.5 mL kg^{-1} min^{-1}).

CONCLUSION

This study assessed physical fitness using basic IPPT test, aerobic fitness and BC of FFs. All physical fitness components were significantly correlated with BF, BMI and body weight.

However, aerobic fitness was not significantly correlated with BC, BMI and body weight. The aerobic fitness among Malaysian FFs was adequate for the purpose of promoting health. The results of this study can be used to educate Malaysian FFs the importance of BC components to improve their job performance. The FFs should give extra focus on their BF, BMI and weight status. Thus, health-related programmes should be designed to reduce BF and maintain good BC among Malaysian FFs as they influence their performance.

SIGNIFICANCE STATEMENT

The present study was conducted to determine the prevalence of obesity and the status of physical fitness of Malaysian firefighters (FFs). This study is intended to serve as a reference source for health-related programmes of Malaysian FF personnel and provide useful information to formulate new health policy regarding Body Composition (BC) and physical fitness. Inclusion of measurements of waist circumference and body fat percentage as part of the routine fitness test besides Body Mass Index (BMI) measurements is important to identify individuals at risk of abdominal obesity and high fat levels. The BC and physical fitness play an important role to ensure good health and physical readiness among Malaysian FF personnel in performing their duties.

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