Research Repository

Physical fitness profile of a large urban fire department: Exploring age and rank dynamics

Title: Physical Fitness Profile of a Large Urban Fire Department: Exploring Age and Rank Dynamics

Authors: Joel R. Martin[1], Robert G. Lockie[2], Marcie Fyock-Martin[1], Nicholas C. Clark[3]

Affiliations:

[1] Sports Medicine Assessment Research & Testing (SMART) Laboratory; George Mason University, Virginia, USA

[2] Department of Kinesiology, California State University, Fullerton, Fullerton, CA, USA.

[3]School of Sport, Rehabilitation, and Exercise Sciences, University of Essex, Colchester, Essex, United Kingdom

Abstract word count: 245 (including headers)

Word count: 5583

Tables: 5

Figures: 1

References: 55

Running Head: Physical Fitness Profile of Fire Department

Corresponding author:

Joel R. Martin, PhD

Associate Professor,

Sports Medicine Assessment, Research & Testing (SMART) Laboratory

School of Kinesiology, George Mason University

10890 George Mason Circle

Katherine Johnson Hall 201E, MSN 4E5

Manassas, VA 20110

Tel: 703-993-9257

Co-Author emails:

Lockie: rlockie@Fullerton.edu

Fyock-Martin: mfyock@gmu.edu

Clark: n.clark@essex.ac.uk

Abstract

BACKGROUND: Firefighter physical fitness (PF) plays a crucial role in mitigating health issues and supporting occupational performance. The influence of rank on firefighter PF remains understudied and previous research is often limited by small sample sizes of firefighters volunteering for research studies, potentially biasing results towards fitter firefighters not representative of entire departments.

OBJECTIVE: To examine the PF profile of firefighters in a large urban fire department and the influence of age and rank on PF.

METHODS: Data, including muscular fitness, estimated aerobic capacity (VO_2max), and body fat percentage (BF%) measures from 1361 firefighters (90% male; age: 37.4±10.1yrs; 60 recruits, 973 firefighters, 290 lieutenants/captains, 38 chiefs) were analyzed. Correlation and ANCOVAs were conducted to examine the impact of rank on PF while controlling for age. Score distributions were scrutinized to profile the PF of the department.

RESULTS: Age was negatively associated with pull-ups (r=-0.39), sit-ups (r=-0.39), and push-ups (r=-0.32), but positively associated with relative VO_2max (r=0.17) and BF% (r=0.39). Rank had a statistically significant, but trivial effect size, on pull-ups (p=0.028, η^2=0.007) and sit-ups (p=0.034, η^2=0.005). Firefighters with lower PF levels were older, had higher BF%, lower fat-free mass, and were a greater proportion of females.

CONCLUSIONS: Firefighters exhibited diverse levels of PF. Age, not rank, appeared to influence firefighters' PF. The findings that firefighters who were older, female, with poorer body composition are more likely to have lower PF levels highlights the need for individualized PF training to enhance occupational performance and health across the fire department.

Key words: firefighter; career; physical fitness; aerobic; muscular; occupational health

1. INTRODUCTION

Maintaining a high level of physical fitness is critical for firefighters to reduce the risk of injury and chronic disease while performing their jobs safely and effectively [1–4]. As a physically demanding occupation, physical tasks include carrying heavy equipment, climbing ladders, dragging hoses, and rescuing individuals from hazards [4, 5]. Such firefighting tasks are more efficiently performed with higher levels of cardiovascular endurance, muscular strength and endurance, and healthy body composition levels [4–7]. Aerobic fitness supports firefighters in sustaining physical exertion for extended periods of time [4, 6], and to reduce the risk of cardiovascular disease [8]. Muscular strength and endurance are necessary for carrying heavy equipment and performing rescue operations [4, 5, 9]. Healthy body composition, characterized by normal levels of body fat percentage (BF%), is imperative because of the negative effects of high BF% on firefighter task performance [7] and the association of obesity with the presence of chronic disease [10].

A shortfall of existing literature is few studies [11, 12] utilize large samples of professional firefighters to represent the physical fitness profile of an entire fire department. For, example several prominent studies reporting physical fitness levels of firefighters have recruited firefighter participants voluntarily [5, 13–15], which can lead to samples not representative of the entire department as ‘fitter’ fighters may be more willing to volunteer [13]. This is problematic as the firefighters with lower levels of physical fitness are a concern because these firefighters may not be able to effectively and efficiently perform firefighting occupational demands [9, 12]. Understanding the diversity of physical fitness levels present within a fire department is important; this is because it facilitates the identification of factors influencing lower fitness levels across the spectrum, thereby informing the development of future strategies for physical fitness screening and targeted interventions.

An occupational factor still relatively unexamined in the literature that may affect firefighter physical fitness is rank. As firefighters advance in rank (*e.g.,* firefighter, to lieutenant, to captain) their job responsibilities and, consequently, daily physical occupational demands change [17, 18]. In lower-ranking positions, firefighters may be tasked with more physically demanding work, whereas those in supervisory or administrative positions experience longer periods of sedentary activities [18]. However, all firefighters, regardless of rank, may need to perform strenuous tasks (e.g., sprinting, moving heavy objects, etc.) in emergency situations. Further, the capacity a firefighter possesses across different physical fitness components critical for safe and effective occupational performance should be independent of both rank and age [19, 20] as many firefighting tasks (e.g., lifting and moving equipment) are absolute in nature [9].

Recently, Hare and colleagues conducted a study examining the impact of rank on firefighter physical fitness and occupational performance in a sample of 160 firefighters (12 female) from a single fire department [21]. Interestingly, when age was controlled for, significant effects of rank were observed on several physical fitness metrics, including body mass index (BMI), BF%, and aerobic fitness. Specifically, recruits exhibited lower BMI and BF%, along with greater VO_2max compared to incumbents, but not in contrast to officers, and no disparities were identified between incumbents and officers [21]. The Hare et al. study [21] was limited by the absence of muscular fitness measures, including strength or endurance. A review by Fyock-Martin et al. concluded current evidence supports that muscular fitness is a crucial determinant of firefighting task performance [4]. Moreover, the classification of "officers" encompassing lieutenants, captains, and chiefs, although necessitated by sample size limitations, may have obscured significant differences in physical fitness among these distinct positions within the fire service.

There were three purposes for the present study. The first purpose was to describe the physical fitness profile of the entire department and to examine demographic (e.g., age, sex) and anthropometric (e.g., height, mass, body composition) differences in firefighters who had lower levels of performance on the physical fitness tests. It was hypothesized that firefighters with lower performances muscular and aerobic fitness assessments would be older, consist of a greater proportion of females, and have worse body composition measures. The second purpose was to examine the relationship between age and the physical fitness levels measured for muscular fitness, aerobic capacity, and BF%. The association of age with physical fitness was done first to understand the influence of age on physical fitness in the sample of an entire fire department and to determine whether age should be controlled for in subsequent analyses. It was hypothesized that age would be negatively associated with muscular endurance and aerobic capacity while positively associated with BF%. The third purpose was to examine physical fitness components of muscular endurance, aerobic capacity, and BF% across different firefighter ranks. It was hypothesized that higher-rank firefighters would have lower scores for muscular endurance and aerobic capacity, and higher BF% measures.

2. METHODS

2.1 Experimental Approach to the Problem

A cross-sectional study was conducted using retrospective physical fitness data collected in 2022 from a large urban fire department of professional firefighters in the mid-Atlantic region of the United States. Firefighters were required to perform an annual mandatory physical fitness assessment, in a single testing session, that included the following battery of tests: body composition, maximum pull-up repetitions, number of sit-up repetitions in 60 seconds, number of push-up repetitions in 60 seconds, and a 3-minute step test. All uniformed personnel were required to participate in the physical fitness assessment each year. Employees who declined to participate were referred to the public safety occupational health center for further medical evaluation. Unsatisfactory performance, determined by a total fitness score adjusted for age and sex [22], would result in the firefighter being required to perform a stress test, and consult with a public safety occupational health center doctor and behavioral health consult. Performance on the treadmill test would determine placement into an in-station fitness improvement plan (≥10 metabolic equivalents) or being placed on light duty (<10 metabolic equivalents).

2.2 Participants

Physical fitness records from 1361 firefighters were included (male, 1225; female, 136; age: 37.4±10.1 yrs; years of service: 10.3±8.8 yrs; height 173.0±13.1 cm; body mass 90.8±14.8 kg; BMI 30.6±5.7 kg/m^2). Ethical approval was obtained from the XXX University institutional review board (IRB#: 1871116-1). The review board approved the study as a retrospective analysis of deidentified data provided directly from the fire department to researchers at George Mason University for the purposes of informing local community fire service operations (IRB#: 1871116). Accordingly, informed consent was not obtained.

2.3 Procedures

All testing took place at a single facility supervised by trained staff who were supervised by a National Strength and Conditioning Association certified strength and conditioning specialist.

To ensure firefighters could participate in physical fitness testing, they first underwent a physical examination conducted by a physician. Physical fitness tests were chosen by the fire department staff based on their reliability [23] and reported relationship to firefighter representative job tasks [4, 7]. The procedures, namely order and rest periods, were determined based on pilot testing and logistical constraints (e.g., time, personnel, and equipment) to test all uniformed personnel annually.

Body composition: Body composition was assessed using bioelectric impedance analysis (BIA) with a commercially available device (InBody 270, InBody USA, Cerritos, CA, USA). The total body mass, BMI, percentage of body mass that was fat mass (BF%), fat mass, and fat-free mass were primary measures of interest in the present study. BMI was computed from height and mass data. Reliability has been reported for this BF% assessment device (ICC = 0.93) [24] with the InBody 270 to have acceptable levels of agreement with dual-energy X-ray absorptiometry [25].

Pull-ups: Firefighters grasped an overhead bar with a pronated grip at shoulder width while keeping their elbows fully extended and feet off the ground. For a repetition to be successful, firefighters had to pull themselves up in a linear path, bringing their chin above the level of the bar, and then descend in a controlled manner back to the starting position. Repetitions were not counted if firefighters used momentum, twisted, or swung during the exercise, or if their chin did not reach the top of the bar. To ensure consistent effort, no rest was allowed in between repetitions. Firefighters performed as many pull-up repetitions as possible with no time limit and the assessment ended when firefighters released their grip from the bar. Reliability has been reported for maximum pull-up procedures (intraclass correlation coefficient [ICC] = 0.95) [23].

Sit-ups: Following the maximum pull-up repetition assessment firefighters had 2 minutes of rest. The sit-up assessment began with firefighters seated and their toes positioned under 80lb dumbbells, while their arms remained crossed at chest level and each hand contacting the opposite shoulder. A buzzer was placed behind the participant in line with the upper thoracic spine. Firefighters completed a repetition by flexing at the hip to raise the torso from the ground, contacting their elbows to their knees, then lowering their torso back to the starting position in a controlled manner until triggering the buzzer (AssessPro Rep-Addition Push-up Tester, Gopher Sports, Owatonna, MN, USA). A repetition was considered successful if there was an audible beep of the buzzer in the down position. Instructions were to complete as many repetitions as possible in 60 seconds. Reliability has been reported for timed sit-up procedures (ICC = 0.93) [26].

Push-ups: Following the maximum sit-up repetition assessment firefighters had 2 minutes of rest before beginning the push-up assessment. Firefighters placed their hands shoulder-width apart, extended their elbows, and rested on the ball of their feet with a flat back. A 3-inch buzzer was positioned directly under the firefighters' sternum. To perform a successful repetition, firefighters had to lower themselves in a controlled manner, until they reached the depth of the buzzer, triggering an audible beep, before fully extending their elbows to return to the starting position. Repetitions were not counted if the buzzer was not triggered, or the tester visually determined that the firefighter did not maintain a straight line from the ankle, knee, hip, and shoulder joint. Firefighters were instructed to perform as many repetitions as possible within 60 seconds. Reliability has been reported for 60-second push-up procedures (ICC = 0.98) [27].

Aerobic capacity: Following the maximum push-up repetition assessment firefighters had 3 minutes of rest before beginning the 3-minute step test. The 3-minute step test was used to evaluate the firefighters' aerobic capacity (e.g., VO_2max). During the test, firefighters stepped up and down a 41.3 cm box to a tempo of 88 and 96 beats per minute for females and males, respectively. All steps must have been in cadence, and if a participant could not maintain it after a warning, the test was terminated. Immediately after the test and 15 seconds after the heart rate was recorded and used to determine the firefighters' aerobic capacity based on the Queen step test formula [28]: Men: $VO_2max = 111.33 – (0.42- \text{Heart Rate})$; Women: $VO_2max = 65.81 – (0.1847 – \text{Heart Rate})$. The equations provide VO_2max in relative terms to body mass in which the units are mL/kg/min. Absolute VO_2max, with units of L/min, was computed by multiplying the relative VO_2max by each firefighter's body mass and converting from mL to L (i.e., dividing by 1000) [28]. Test-retest reliability has been reported for this aerobic capacity test ($r = 0.92$) [28].

2.4 Statistical Analysis

Because all available active-duty firefighters' data was provided by the fire department, an *a priori* power analysis was not conducted. The deidentified data were provided in a spreadsheet. The normality of variables was assessed using Kolmogorov-Smirnov tests and Q-Q density plots. None of the physical fitness variables exhibited normal distribution, and common transformations such as exponential, log, and power failed to alter their distributions; therefore, large sample theory was employed, enabling the use of parametric inferential tests in subsequent analyses [29]. Rank was categorized into four groups based on position classifications provided in the retrospective data set: 1) recruits, 2) firefighters (firefighter, fire technician, firefighter/medic), 3) Lieutenants/Captains, and 4) Battalion and Deputy Fire Chiefs. Descriptive statistics were computed for demographic and physical fitness variables, along with the proportion (%) of all firefighters that were classed as firefighters (% = [number of firefighters ÷ all firefighters] × 100).

For the first purpose, which was to profile the physical fitness of the entire department, we evaluated the distribution of scores using skewness and kurtosis metrics. Additionally, percentile and quartile scores for each physical fitness measure were computed. Firefighters who scored zero on any of the muscular fitness assessments were classified as low performers for muscular fitness. Similarly, the bottom 20% based on estimated relative VO_2max values were classified as low performers for aerobic fitness. To assess differences between firefighters with lower levels of muscular and aerobic fitness, independent sample t-tests for continuous variables and chi-square tests of independence for categorical variables were conducted. Finally, firefighters were classified as having low muscular and aerobic fitness (e.g., zero score on a muscular fitness assessment and bottom 20% in terms of VO_2max) were compared to those classified as having higher levels of muscular and aerobic fitness (e.g., no zero scores on a muscular fitness assessment and a VO_2max greater than the 20th percentile).

The second purpose, which was to examine the relationship between age and muscular endurance, aerobic capacity, and body composition, was assessed with Pearson correlations. The strength of correlations were interpreted as weak, $r \geq 0.10$-0.39; moderate, $r \geq 0.40$-0.69; strong, $r \geq 0.70$ [30]. The proportion (%) of variance shared between measures was assessed with the coefficient of determination (r^2) [31]. An $r^2 \geq 0.60$ was employed as a threshold for defining a considerable proportion of shared variance between measures [31].

For the third purpose, and based on the results from the correlation analysis, an analysis of covariance (ANCOVA) was used to compare the means of the physical fitness measures by rank while controlling for age as a covariate, similar to the approach by Hare and colleagues [21]. Prior to each ANCOVA assumption of linearity, homogeneity of regression slopes, normality of residuals, and homogeneity of variances were checked. Partial eta-square effect sizes were categorized as small (η^2=0.01), medium (η^2=0.06), and large (η^2=0.14) [30]. For significant main effects, Tukey contrasts were performed with single-step adjusted p-value [32]. There were a large number of firefighters who with zero scores on one or more of the muscular endurance assessments from the data set (n=239). As a follow-up to the main ANCOVA analysis, a sensitivity analysis was conducted to determine whether removing these firefighters would alter our interpretation of the ANCOVA tests. Sensitivity analyses were performed by removing firefighters with zero scores in one or more of the muscular endurance assessments from the data set (n=239). This was done in a stepwise fashion per muscular physical fitness assessment and rechecking the ANCOVA results at each step following the process described above. Comparisons were then conducted to examine differences in demographic and anthropometric variables between those removed and the rest of the sample. Parametric tests were used due to the large sample group sizes [29]. All analyses were performed using R (Version 4.2.1, R Core Team, Vienna, Austria). For all analyses alpha was set *a priori* at 0.05.

3. RESULTS

3.1 Overall fire department physical fitness

Descriptive statistics of the demographics and physical fitness profile of the fire department are provided in Tables 1 and 2, respectively. Pullups, VO_2max, BF%, and fat mass were positively skewed while sit-ups, push-ups, and fat-free mass were negatively skewed. Notably, none of the skewness values exceeded, 1 or -1, which would have indicated moderate to strong skewness. Kurtosis values indicated that most of the variables were had mesokurtic, or normal distributions. The kurtosis of sit-ups was 2.11, characteristic of a distribution with a higher peak. The range of variables highlighted the diversity of physical fitness levels of firefighters within the fire department.

-----Table 1 here----

-----Table 2 here----

Muscular fitness low performers: Of the 1361 firefighters, 17.6% (n=239) demonstrated a zero score on one or more of the muscular endurance assessments. Those with non-zero scores for physical fitness measures (n=1122), were found to be younger (36.2±9.9 vs. 43.1±9.0 years; t(1359)=-9.860, p<0.001, d=0.70), with fewer years of service (9.3±8.6 vs. 15.1±8.4 years; t(1359)=-9.625, p<0.001, d=0.69) and fewer females (6.1% vs. 10.0% Female; X^2(1, 1361)=109.06, p<0.001). Additionally, those with zero-scores had greater body mass (98.8±17.0 vs. 89.1±13.7 kg; t(1359)=-9.423, p<0.001, d=0.67); BMI (32.9±5.4 vs. 30.1±5.7 kg/m^2; t(1359)=-6.834, p<0.001, d=0.49), BF% (31.4±6.1 vs. 21.2±6.5%; t(1359)=-22.224, p<0.001, d=1.59), fat mass (31.1±8.6 vs. 19.3±7.5 kg; t(1359)=-21.473, p<0.001, d=1.46) and less fat-free mass (67.6±12.6 vs. 69.9±9.9 kg; t(1359)=3.067, p=0.002, d=0.20) and estimated relative VO_2max (43.0±6.7 vs 46.0±6.4 mL/kg/min; t(1359)=6.458, p<0.001, d=0.45).

Aerobic fitness lower performers: There were 270 (111 female; age: 35.8±9.5 years; years of service: 8.5±8.0 years) firefighters in the lower 20th percentile of relative VO_2max.

Those with lower VO_2max scores were found to be younger (35.8±9.5 vs. 37.8±10.2 years; t(1359)=-2.854, p=0.004, d=0.20), fewer years of service (8.5±8.0 vs. 10.8±8.9 years; t(1359)=-3.765, p<0.001, d=0.26), shorter in stature (171.0±11.4 vs. 173.5±13.4 cm; t(1359)=-2.762, p=0.006, d=0.20), lower body mass (87.2±17.4 vs. 91.7±14.0 kg; t(1359)=-4.513, p<0.001, d=0.29), lower BMI (29.9±5.9 vs. 30.8±5.7 kg/m^2; t(1359)=-2.38, p<0.001, d=0.16), greater BF% (26.6±8.2 vs. 22.1±7.0%; t(1359)=9.255, p<0.001, d=0.60), lower fat-free mass (63.5±12.6 vs. 71.0±9.3 kg; t(1359)=-10.91, p<0.001, d=0.60), and greater fat mass (23.7±9.9 vs. 20.7±8.6 kg; t(1359)=4.877, p<0.001, d=0.32). In terms of the muscular physical fitness outcomes, those with lower relative VO_2max performed fewer repetitions of pull-ups (4.2±4.9 vs. 6.7±4.9 repetitions; t(1359)=-7.630, p<0.001, d=1.56), sit-ups (42.9±7.8 vs. 44.3±8.1 repetitions; t(1359)=-2.585, p<0.001, d=0.18) and push-ups (32.2±13.4 vs. 40.0±12.1 repetitions; t(1359)=-9.312, p<0.001, d=0.61).

Overall low versus high performers: There were 89 firefighters (61 female; age: 41.6±8.9 years; years of service: 13.4±7.7 years) firefighters with a zero score on a muscular fitness assessment and in the lower 20th percentile of relative VO_2max. Those with lower overall physical fitness were older (41.6±8.9 vs. 36.8±10.0 years; t(1030)=-4.353, p<0.001, d=0.51), more years of service (13.4±7.7 vs. 9.9±8.7 years; t(1030)=-3.627, p=0.003, d=0.42), shorter in stature (169.9±10.8 vs. 173.1±13.5 cm; t(1030)=-2.192, p=0.029, d=0.26), greater BF% (33.4±6.8 vs. 20.8±6.4%; t(1030)=-17.741, p<0.001, d=1.91), lower fat-free mass (59.9±12.6 vs. 70.8±9.2 kg; t(1030)=-10.307, p<0.001, d=0.99), and greater fat mass (30.6±10.0 vs. 19.1±7.4 kg; t(1030)=13.519, p<0.001, d=1.31).

3.1 Association of Age with Physical Fitness Outcomes

The Pearson's correlations between physical fitness outcomes and age are provided in Table 3. Age was negatively associated with pull-ups (r=-0.39, r^2=0.15, $p<0.001$), sit-ups (r=-0.39, r^2=0.15, $p<0.001$) and push-ups (r=-0.32, r^2=0.10, $p<0.001$), but positively associated with estimated relative VO_2max (r=0.17, r^2=0.03, $p<0.001$), absolute VO_2max (r=0.23, r^2=0.05, $p<0.001$) and BF% (r=0.39, r^2=0.15, $p<0.001$). Magnitudes of the coefficients of determination indicated that the influence of age on physical fitness measures was statistically significant, but weak in magnitude. The associations among the muscular physical fitness assessments were all moderate to strong (Table 3). BF% and fat mass had a moderate association with the muscular physical fitness assessments. Fat-free mass had a strong association with estimated absolute VO_2max (r=0.71, r^2=0.51, $p<0.001$).

-----Table 3 here----

3.2 Effect of Rank on Physical Fitness Outcomes

The majority (71.5%) of the sample was ranked as firefighters (Table 1). Significant effects of rank on age ($F(3,1357)=129.3$, $p<0.001$, $\eta^2=0.22$), years of service ($F(3,1357)=220.2$, $p<0.001$, $\eta^2=0.33$), body mass ($F(3,1357)=4.962$, $p=0.002$, $\eta^2=0.01$) and body mass index ($F(3,1357)=4.962$, $p=0.001$, $\eta^2=0.01$) were found. Post-hoc testing indicated that firefighters at the higher ranks were older and had more years of service and lieutenants/captains had greater mass and BMI than firefighters ($p<0.001$).

The ANCOVAs revealed that rank had a small but significant effect on pull-ups ($F(3,1356)=3.053$, $p=0.028$, $\eta^2= 0.007$) and sit-ups ($F(3,1356)=2.863$, $p=0.034$, $\eta^2=0.005$) (Table 4). Post-hoc tests revealed recruits performed better on sit-ups than chiefs ($p=0.045$). Rank was not found to have a significant main effect on push-ups, VO_2max, BF%, fat-free mas, or fat mass; however, the covariate of age was significant ($p<0.001$) in all ANCOVA tests (Table 4). Distribution plots of physical fitness outcomes by rank are provided in Figure 1A-H. Notably bimodal distributions were evident in several cases, supporting the prior results that sub-groups of 'fit' and 'less fit' firefighters within each rank existed within the department.

-----Table 4 here----

-----Figure 1 here----

As previously mentioned the sensitivity analysis was performed in a stepwise fashion by removing those with zero curl-ups (n=1; male, age: 49 years; years of service: 21 years; height 162.6 cm; mass 82.5 kg; BMI 31.2 kg/m^2) first, followed by push-ups (n=7; 3 male, 4 female; age: 42.6±12.8 years; years of service: 14.7±9.2 years; height 173.4±11.9 cm; mass 99.6±25.2 kg; BMI 33.2±8.2 kg/m^2), and then pull-ups (n=237; 169 male, 68 female; age: 43.1±10.2 years; years of service: 15.1±9.6 years; height 173.6±14.3 cm; mass 98.8±19.4 kg; BMI 32.9±6.1 kg/m^2). There was no change from prior results with the removal of the single participant with zero sit-ups. Removing those with zero push-ups (n=7) yielded a significant main effect of rank for push-up performance ($F(3,1348)=2.62$, $p=0.049$, $\eta^2= 0.006$) and post-hoc testing indicated significant pairwise difference between firefighters and recruits ($p=0.049$). Results from the last step of the sensitivity analysis, when those with zero pull-ups (n=237) were removed, are presented in Table 5. As compared to the full-data set rank no longer had a significant main effect for sit-ups ($F(3,1348)=1.56$, $p=0.197$, $\eta^2= 0.004$) but rank became significant for push-ups ($F(3,1348)=3.32$, $p=0.019$, $\eta^2= 0.009$) and fat-free mass ($F(3,1348)=3.32$, $p=0.041$, $\eta^2= 0.009$).

-----Table 5 here----

4. DISCUSSION

The present study aimed to address 3 primary purposes which were to 1) describe the physical fitness profile of a large, urban fire department, 2) explore the association between age and physical fitness measures, and 3) to assess physical fitness across different firefighter ranks. The findings of the study largely supported the hypotheses formulated. The first hypothesis was supported as firefighters with lower performance in muscular and aerobic fitness assessments were indeed found to be older, comprised a higher proportion of females, and exhibited poorer body composition measures. The second hypothesis, that older firefighters would have lower performance on selected physical fitness assessments, was supported for muscular fitness and BF%, but not aerobic capacity. However, the magnitude of these associations were relatively weak. The third hypothesis, that higher-ranking firefighters would have lower performance on selected physical fitness assessments was not entirely supported by the results. Despite reaching statistical significance in several measures of physical fitness, the effect sizes of rank were minimal or small for all physical fitness measures.

4.1 Fitness Profile of the Fire Department

The findings regarding the overall fitness profile of the fire department highlight the diversity in physical fitness levels among firefighters. The substantial proportion of firefighters registering zero scores for the pull-up muscular fitness assessment is notable. The results indicated that those were zero scores was likely attributable to some extent body composition (e.g., greater BF%, greater fat mass, and less fat-free mass) of these firefighters, which is not unexpected based on previous research [33, 34]. As previously detailed, the occupational tasks undertaken by firefighters have been consistently linked to elevated requirements in aerobic fitness, muscular fitness, and potential benefits from having lower body fat [4–7]. An influential study by Gledhill and Jamnik [9] quantified the weights of objects common to the firefighter occupation and the associated forces to move the objects. The necessary force production exceeded 45.4 kg in most instances, concluding that high levels of muscular strength and endurance in the upper and lower body are necessary (18). A substantial body of literature has reported that higher levels of physical fitness are associated with a lower risk of injury [35–38]. Specific to firefighters, there is evidence indicating a reduction in musculoskeletal injury risk secondary to overall physical fitness [12, 39]. However, Ras and colleagues [40] suggested that the physical fitness-injury risk relationship is confounded when considering that greater levels of physical fitness, which are associated with the ability to perform firefighter occupational tasks, may lead to a greater workload burden for fitter firefighters [39]. Physical fitness, including aerobic fitness, muscular fitness, and body composition, are well documented to be associated with risk factors of cardiovascular diseases and musculoskeletal health [41–43]. Specifically in firefighters, a negative association has been reported between push-up capacity and baseline with cardiovascular disease events over a 10-year follow-up period [44]. Considering that push-ups and pull-up ability are strongly correlated [34], combined with the substantial number of firefighters unable to perform pull-ups, this presents a concern for long-term health of firefighters.

4.2 Age and rank dynamics with firefighter physical fitness

The age and rank of firefighters are intrinsically linked, as progression through the ranks requires accumulating time spent in each position to qualify for promotion. Consequently, it is anticipated that firefighters occupying higher rank positions are typically older than those in lower ranks. The finding that, when age is factored in as a controlling variable, rank exhibited no to negligible impact on physical fitness metrics adds to the limited body of research addressing the influence of firefighter rank on physical fitness [21, 45]. As individuals age, a consistent decline in muscular and aerobic fitness is observed, with a general decrease occurring about every decade following the age of 30 years for most adults [46, 47]. Nonetheless, the unique occupational demands of firefighting, which necessitate greater levels of physical fitness [4], would challenge the assumption that the typical age-related physical fitness changes observed in the general population are universally applicable to firefighters.

Previous studies reported differing findings regarding age with muscular fitness [14, 15] aerobic fitness [11], and body composition [14, 15]. Findley and colleagues [14] conducted a study involving 159 male firefighters, ranging in age from 20 to 49 years, who underwent a 2-minute maximum sit-up and push-up assessment until reaching volitional fatigue. While their investigation revealed no significant alterations in push-up performance across age groups, Findley and colleagues [14] did report a notable age-related decline in sit-up performance. Conversely, Kirlin et al. [15] reported no discernible age-associated differences in push-up and sit-up assessments when examining female firefighters aged between 20 and 54 years. Notably, our study encompassed a substantial cohort of firefighters aged 50 and older, a demographic group traditionally underrepresented in prior research [14, 15]. This inclusion allowed for a more comprehensive examination of age-related variations in physical fitness spanning a firefighter's career trajectory.

In a study conducted by Cameron and colleagues [11], a decline in aerobic fitness emerged across 10-year age groups (20-29, 30-39, 40-49, 50+ years), with the most substantial reduction occurring between the 30-39 and 40-49 age groups. Consistent with these findings, Kirlin and associates [15] also reported declines in aerobic fitness related to age. Conversely, and similar to our present investigation, Findley and colleagues failed to uncover a statistically significant difference in aerobic fitness attributable to age [14]. Notably, the firefighters included in the study by Findley and colleagues [14] exhibited considerably lower VO_2max values (20-29 years: 33.0±8.0 mL/kg/min; 30-39: 32.0±8.6 mL/kg/min; 40-49: 28.5±7.3 mL/kg/min) in comparison to the firefighters in the current study (20-29 years: 44.3±6.0 mL/kg/min; 30-39: 44.8±6.5 mL/kg/min; 40-49: 46.3±6.7 mL/kg/min). It should be noted that VO_2max was estimated using different methods in the Findley study (e.g., submaximal cycle ergometry) compared to our study (e.g., submaximal step test), which could contribute to differences [48]. Additionally, the fire department in the present study had the policy in place which would result in punitive actions for poor performance on the overall physical fitness testing. Incentives, whether punitive or compensatory, would serve as motivation to firefighters to perform better on a mandatory physical fitness test [18]. Future research should explore the impact of incentives on firefighter physical fitness in more depth.

Dobson and colleagues [45] reported that firefighters in higher ranks exhibited increased sedentary behavior and poorer body composition. However, it is noteworthy that the study by Dobson and colleagues [45] did not account for age as a potential confounding factor. Previous investigations have presented divergent results concerning the relationship between age and BF% [11, 14, 15]. For instance, Cameron et al. [11] found a positive association between age and BF%, whereas Findley et al. [14] and Kirlin et al. [15] reported no significant impact of age on

BF%. Thus, our study adds new knowledge of the role of rank and age regarding firefighter body composition. A strength of the approach in the current study, compared to previous research, is the consideration of age as a covariate when exploring the influence of rank on physical fitness levels [45]. Additionally, in contrast to other studies that have analyzed categorical age variables [11, 15], we opted to analyze age as a continuous variable. This choice avoids the common pitfalls associated with unnecessarily categorizing continuous variables [49, 50].

Hare and colleagues [26] did find an effect of rank on firefighter physical fitness measures of BF% and VO_2max when controlling for age. In our study, we observed that while firefighter rank did not seem to exert a significant influence on physical fitness. Differences between the findings could be due to contextual or cultural differences within the fire departments, such as the consequences of the mandatory physical testing of the fire departments, resources, incentives or physical fitness resources provided to firefighters [18].

4.3 Implications

The diversity of physical fitness levels and the impact of factors, such as age and sex, on muscular fitness within our sample carries significant implications for fire departments. It emphasizes the importance of recognizing age-related physical variations among firefighters. Nevertheless, it is essential to acknowledge that, regardless of age, the physical demands of firefighting persist, necessitating a minimum level of physical fitness for safe and effective duty performance. In cases where a firefighter's physical fitness level falls short of a predefined standard, the risk of injury escalates [35, 39], or their co-firefighters may be burdened with additional workload to compensate for their limitations in physical aptitude.

The differing findings reported in this study compared to previous studies [11, 14, 15, 21] has important implications for practitioners. When literature presents conflicting reports on whether a phenomenon occurs or not (e.g., ageing-associated decline in firefighter muscular endurance), it indicates that the occurrence of a phenomenon is possible, but it is not certain or consistent. Consequently, routine physical fitness assessments are essential to determine whether some previously observed and documented phenomena (e.g., ageing-associated decline in firefighter muscular endurance) has or has not actually emerged in a particular sample or for a specific individual. This determination guides the need for interventions targeted to specific individuals' physical fitness profiles. The current body of literature on firefighters' physical fitness determinants underscores the value of regular physical fitness assessments [4, 9, 21]. This ensures operational readiness and helps identify firefighters at higher risk of chronic health conditions. Results from routine physical fitness testing can inform individualized interventions to support firefighters with low levels of physical fitness.

4.4 Strengths and Limitations

Several strengths of the study should be stated. The present study incorporated multiple data analysis techniques to offer a comprehensive understanding of physical fitness among firefighters in a large urban fire department at both group and individual levels. One significant strength of the present study is the nearly complete representation of firefighters within the department. Thus, the common limitations associated with small sample sizes and the 'Healthy Worker Effect' [16] observed in prior studies [5, 13–15] did not bias the findings. Previous studies [36, 37] have reported an association of poor physical fitness with elevated musculoskeletal injury risk and the findings may have broader implications for the fire service to mitigate firefighter injuries. Lastly, the results provide new insights into how rank influences firefighter physical fitness, addressing a gap highlighted in limited studies [21] related to this occupational factor that may influence firefighter physical fitness.

The present study has several limitations that need to be taken into consideration. Firefighters were aware of the criteria for physical fitness assessment in advance, and although deficient performance would lead to punitive actions, there were no incentives to exceed satisfactory performance. As a result, individuals may have been focusing on achieving physical fitness levels necessary to pass the assessment, rather than providing their maximum effort during the actual assessments or preparatory exercise training prior to the assessment [51]. Additionally, the physical fitness assessment protocol used in this study did not include a measure of lower body muscle performance (e.g., maximum strength, muscular power) which is crucial for tactical populations such as firefighters [52]. Given that many firefighting tasks require producing large amounts of muscle force quickly, such as forcible entry, charged hose advances, and dummy drags [9], the battery of physical fitness assessments used in this study failed to capture all muscle performance characteristics essential for firefighters. Due to the lack of a measure of maximum strength, we were not able to analyze whether there was an influence of rank on this aspect of physical fitness. It is conceivable that age-related declines in maximum strength contribute to firefighters' perceived reductions in work ability as they age [17]. Considering that maximum strength tends to decrease after the age of 30 years [53], strength emerges as a critical fitness component necessary for meeting the force requirements of firefighting tasks [9]. Therefore, researchers and practitioners are encouraged to take into account age-related changes in strength when addressing future work in this field while also considering the minimum strength levels needed to perform firefighting occupational tasks [9].

Conclusion

The findings indicated that within a large fire department the physical fitness levels of firefighters can vary substantially and age, but not rank, impacted physical fitness levels. Noteworthy is the finding that firefighters who were older, female, and/or with poorer body composition measures were more likely to exhibit lower physical fitness levels. Thus, individualized and targeted physical fitness interventions informed by annual physical fitness assessments would be prudent to support the occupational performance, health, and career longevity of all firefighters in a fire department.

Ethical Approval

The George Mason University Institutional Review Board approved the retrospective analysis of deidentified data (IRB#: 1871116).

Informed Consent

The review board approved the study as a retrospective analysis of deidentified data provided directly from the fire department to researchers at George Mason University. As a result informed consent was not obtained from the firefighters.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgments

The authors have no acknowledgments

Funding

The authors report no funding.

References

[1] Andrews KL, Gallagher S, Herring MP. The effects of exercise interventions on health and fitness of firefighters: A meta-analysis. *Scand J Med Sci Sports* 2019; 29: 780–790.

[2] Griffin SC, Regan TL, Harber P, et al. Evaluation of a fitness intervention for new firefighters: injury reduction and economic benefits. *Injury Prevention* 2016; 22: 181–188.

[3] Smith DL. Firefighter fitness: improving performance and preventing injuries and fatalities. *Curr Sports Med Rep* 2011; 10: 167–172.

[4] Fyock-Martin MB, Erickson EK, Hautz AH, et al. What do Firefighting Ability Tests Tell Us About Firefighter Physical Fitness? A Systematic Review of the Current Evidence. *The Journal of Strength & Conditioning Research* 2020; 34: 2093.

[5] Rhea MR, Alvar BA, Gray R. Physical fitness and job performance of firefighters. *J Strength Cond Res* 2004; 18: 348–352.

[6] Lindberg A-S, Oksa J, Antti H, et al. Multivariate Statistical Assessment of Predictors of Firefighters' Muscular and Aerobic Work Capacity. *PLOS ONE* 2015; 10: e0118945.

[7] Michaelides MA, Parpa KM, Henry LJ, et al. Assessment of physical fitness aspects and their relationship to firefighters' job abilities. *J Strength Cond Res* 2011; 25: 956–965.

[8] Soteriades ES, Smith DL, Tsismenakis AJ, et al. Cardiovascular disease in US firefighters: a systematic review. *Cardiol Rev* 2011; 19: 202–215.

[9] Gledhill N, Jamnik VK. Characterization of the physical demands of firefighting. *Can J Sport Sci* 1992; 17: 207–213.

[10] Powell-Wiley TM, Poirier P, Burke LE, et al. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation* 2021; 143: e984–e1010.

[11] Cameron NA, Shen J, Rusk K, et al. Longitudinal Decline in Cardiorespiratory Fitness With Age Among Male Firefighters in San Diego, California, 2005-2015. *Am J Public Health* 2018; 108: 1388–1393.

[12] Poplin GS, Roe DJ, Burgess JL, et al. Fire fit: assessing comprehensive fitness and injury risk in the fire service. *Int Arch Occup Environ Health* 2016; 89: 251–259.

[13] Elsner KL, Kolkhorst FW. Metabolic demands of simulated firefighting tasks. *Ergonomics* 2008; 51: 1418–1425.

[14] Findley BW, Brown LE, Whitehurst M, et al. Age-Group Performance and Physical Fitness in Male Firefighters. *The Journal of Strength & Conditioning Research* 1995; 9: 259–260.

[15] Kirlin LK, Nichols JF, Rusk K, et al. The effect of age on fitness among female firefighters. *Occupational Medicine* 2017; 67: 528–533.

[16] Chowdhury R, Shah D, Payal AR. Healthy Worker Effect Phenomenon: Revisited with Emphasis on Statistical Methods - A Review. *Indian J Occup Environ Med* 2017; 21: 2–8.

[17] Firoozeh M, Saremi M, Kavousi A, et al. Demographic and occupational determinants of the work ability of firemen. *J Occup Health* 2017; 59: 81–87.

[18] Lane CL, Brady O, Mayer JM. Comprehensive Assessment of Implementation Factors Related to Worksite Exercise in Firefighters. *J Occup Environ Med* 2022; 64: e13–e19.

[19] Sothmann M, Saupe K, Jasenof D, et al. Advancing Age and the Cardiorespiratory Stress of Fire Suppression: Determining a Minimum Standard for Aerobic Fitness: Human Performance: Vol 3, No 4. *Human Performance* 1990; 3: 217–236.

[20] Sothmann MS, Gebhardt DL, Baker TA, et al. Performance requirements of physically strenuous occupations: validating minimum standards for muscular strength and endurance. *Ergonomics* 2004; 47: 864–875.

[21] Hare MM, Wohlgemuth KJ, Jesko A, et al. Climbing the Ranks: A Study of Firefighter Health Disparities. *Healthcare (Basel)* 2024; 12: 227.

[22] Martin J, Toczko M, Lockie RG. Individual responses to the implementation of mandatory fitness testing within a fire department. *Occup Environ Med* 2023; 80: 455–461.

[23] Vanderburgh PM, Edmonds T. The Effect of Experimental Alterations in Excess Mass on Pull-up Performance in Fit Young Men. *The Journal of Strength & Conditioning Research* 1997; 11: 230.

[24] Montgomery MM, Marttinen RH, Galpin AJ. Comparison of Body Fat Results from 4 Bioelectrical Impedance Analysis Devices vs. Air Displacement Plethysmography in American Adolescent Wrestlers. *International Journal of Kinesiology and Sports Science* 2017; 5: 18–25.

[25] Nickerson BS, McLester CN, McLester JR, et al. Agreement Between 2 Segmental Bioimpedance Devices, BOD POD, and DXA in Obese Adults. *Journal of Clinical Densitometry* 2020; 23: 138–148.

[26] Ryman Augustsson S, Bersås E, Magnusson Thomas E, et al. Gender differences and reliability of selected physical performance tests in young women and men. *Advances in Physiotherapy* 2009; 11: 64–70.

[27] Ojeda ÁH, Maliqueo SG, Barahona-Fuentes G. Validity and reliability of the Muscular Fitness Test to evaluate body strength-resistance. *Apunts Sports Medicine* 2020; 55: 128–136.

[28] McArdle WD, Katch FI, Pechar GS, et al. Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. *Med Sci Sports* 1972; 4: 182–186.

[29] Lehmann EL. *Elements of Large-Sample Theory*. Springer Science & Business Media, 2004.

[30] Cohen J. *Statistical power analysis for the behavioral sciences*. Hillsdale, N.J.: L. Erlbaum Associates, 1988.

[31] Chicco D, Warrens MJ, Jurman G. The coefficient of determination R-squared is more informative than SMAPE, MAE, MAPE, MSE and RMSE in regression analysis evaluation. *PeerJ Comput Sci* 2021; 7: e623.

[32] Hothorn T, Bretz F, Westfall P. Simultaneous Inference in General Parametric Models. *Biometrical Journal* 2008; 50: 346–363.

[33] Sanchez-Moreno M, Pareja-Blanco F, Diaz-Cueli D, et al. Determinant factors of pull-up performance in trained athletes. *J Sports Med Phys Fitness* 2016; 56: 825–833.

[34] Merrigan J, Burke A, Fyock-Martin M, et al. What Factors Predict Upper Body Push to Pull Ratios in Professional Firefighters? *International Journal of Exercise Science* 2020; 13: 1605–1614.

[35] Lentz L, Randall JR, Gross DP, et al. The relationship between physical fitness and occupational injury in emergency responders: A systematic review. *American Journal of Industrial Medicine* 2019; 62: 3–13.

[36] Lisman PJ, de la Motte SJ, Gribbin TC, et al. A Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 1-Cardiorespiratory Endurance. *J Strength Cond Res* 2017; 31: 1744–1757.

[37] de la Motte SJ, Gribbin TC, Lisman P, et al. Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 2-Muscular Endurance and Muscular Strength. *J Strength Cond Res* 2017; 31: 3218–3234.

[38] de la Motte SJ, Lisman P, Gribbin TC, et al. A Systematic Review of the Association Between Physical Fitness and Musculoskeletal Injury Risk: Part 3 - Flexibility, Power, Speed, Balance, and Agility. *J Strength Cond Res*. Epub ahead of print 11 December 2017. DOI: 10.1519/JSC.0000000000002382.

[39] Ras J, Soteriades ES, Smith DL, et al. Association between physical fitness and musculoskeletal health in firefighters. *Frontiers in Physiology*; 14, https://www.frontiersin.org/articles/10.3389/fphys.2023.1210107 (2023, accessed 1 September 2023).

[40] Ras J, Soteriades ES, Smith DL, et al. Association between physical fitness and musculoskeletal health in firefighters. *Front Physiol* 2023; 14: 1210107.

[41] Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? *Med Sci Sports Exerc* 2001; 33: S379-399; discussion S419-420.

[42] Blair SN, Kampert JB, Kohl HW III, et al. Influences of Cardiorespiratory Fitness and Other Precursors on Cardiovascular Disease and All-Cause Mortality in Men and Women. *JAMA* 1996; 276: 205–210.

[43] Ross R, Blair SN, Arena R, et al. Importance of Assessing Cardiorespiratory Fitness in Clinical Practice: A Case for Fitness as a Clinical Vital Sign: A Scientific Statement From the American Heart Association. *Circulation* 2016; 134: e653–e699.

[44] Yang J, Christophi CA, Farioli A, et al. Association Between Push-up Exercise Capacity and Future Cardiovascular Events Among Active Adult Men. *JAMA Network Open* 2019; 2: e188341.

[45] Dobson M, Choi B, Schnall PL, et al. Exploring occupational and health behavioral causes of firefighter obesity: a qualitative study. *Am J Ind Med* 2013; 56: 776–790.

[46] Inbar O, Oren A, Scheinowitz M, et al. Normal cardiopulmonary responses during incremental exercise in 20- to 70-yr-old men. *Med Sci Sports Exerc* 1994; 26: 538–546.

[47] Holloszy JO. The biology of aging. *Mayo Clin Proc* 2000; 75 Suppl: S3-8; discussion S8-9.

[48] Hale D, Kollock R, Thomas J, et al. A Submaximal Field Test of Aerobic Capacity does not Accurately Reflect VO2max in Career Firefighters. *International Journal of Exercise Science* 2022; 15: 221–230.

[49] Bennette C, Vickers A. Against quantiles: categorization of continuous variables in epidemiologic research, and its discontents. *BMC Medical Research Methodology* 2012; 12: 21.

[50] Naggara O, Raymond J, Guilbert F, et al. Analysis by Categorizing or Dichotomizing Continuous Variables Is Inadvisable: An Example from the Natural History of Unruptured Aneurysms. *AJNR Am J Neuroradiol* 2011; 32: 437–440.

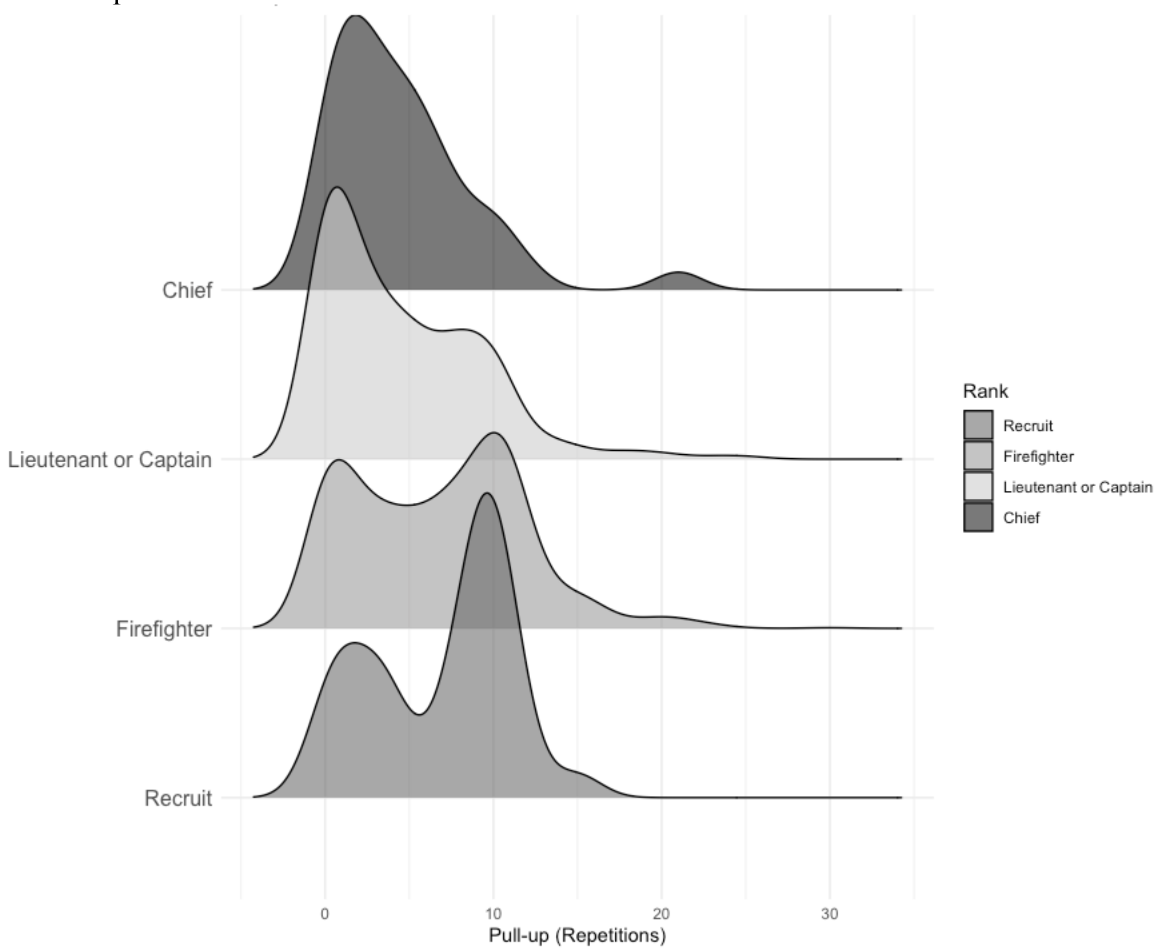
[51] Lockie RG, Orr RM, Montes F, et al. Differences in Fitness between Firefighter Trainee Academy Classes and Normative Percentile Rankings. *Sustainability* 2022; 14: 6548.

[52] Orr R, Dawes J, Lockie R, et al. The Relationship between Lower-Body Strength and Power, and Load Carriage Tasks: A Critical Review. *International Journal of Exercise Science* 2019; 12: 1001–1022.

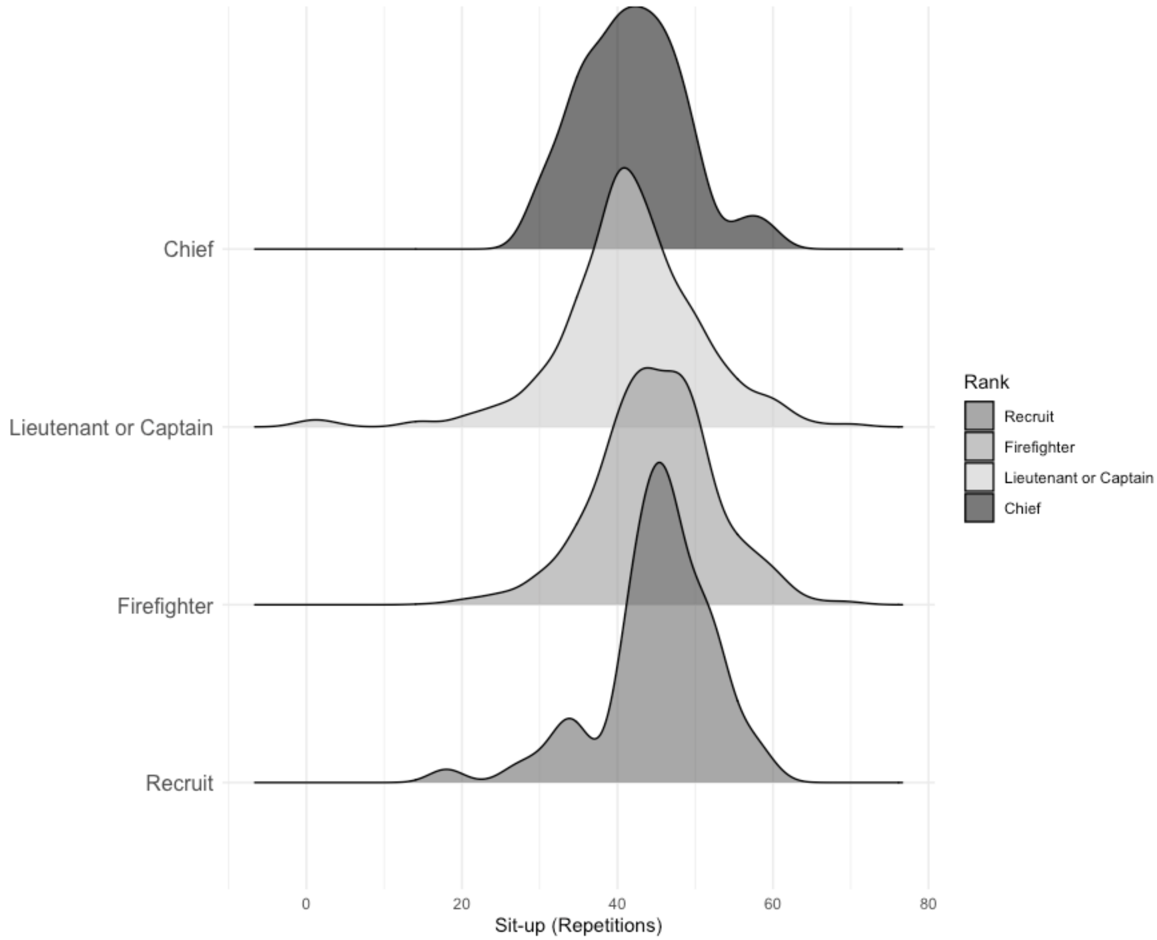
[53] Keller K, Engelhardt M. Strength and muscle mass loss with aging process. Age and strength loss. *Muscles Ligaments Tendons J* 2014; 3: 346–350.

Figure 1: Distribution of physical fitness outcomes by rank

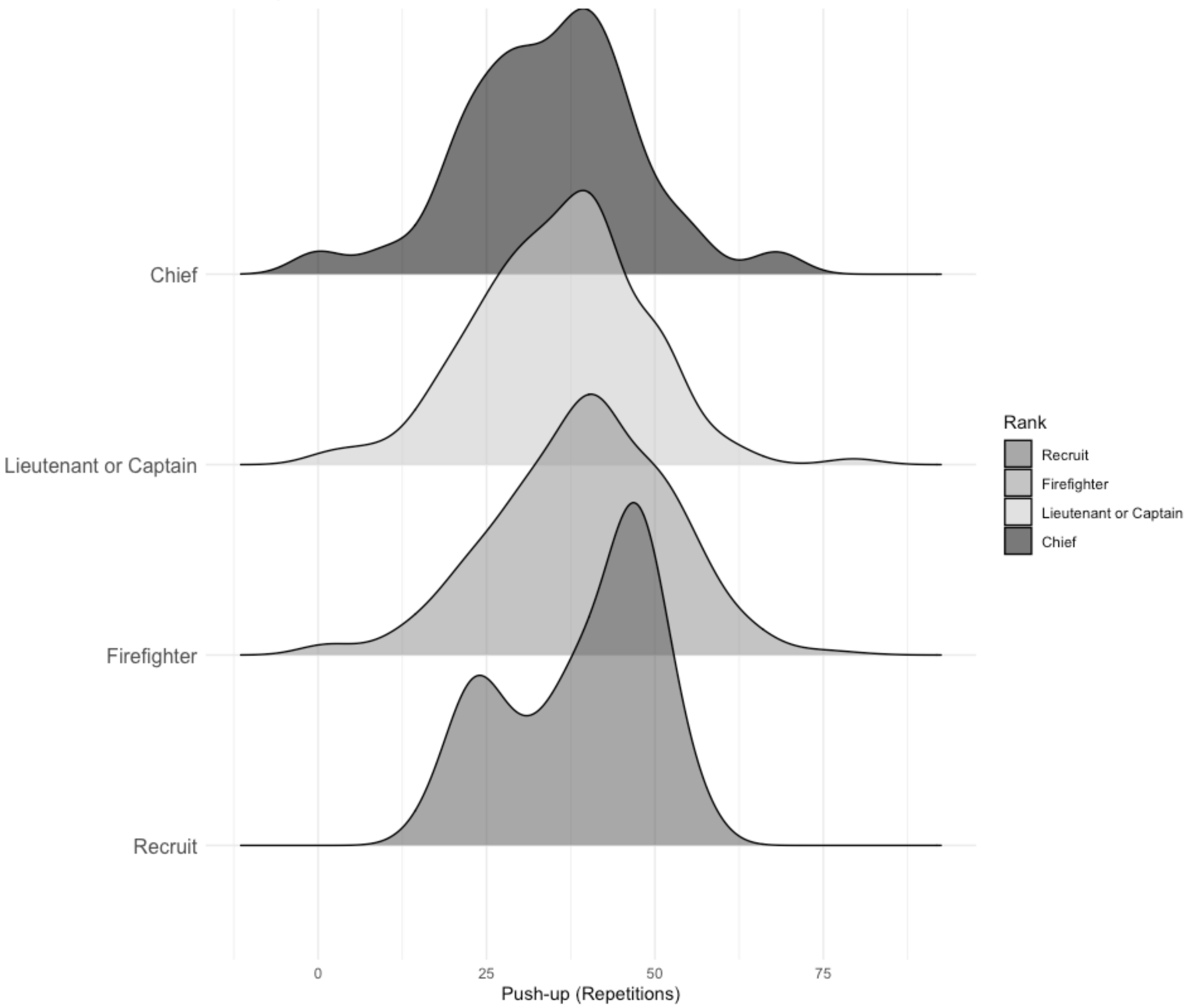
A. Pull-ups



B. Sit-ups

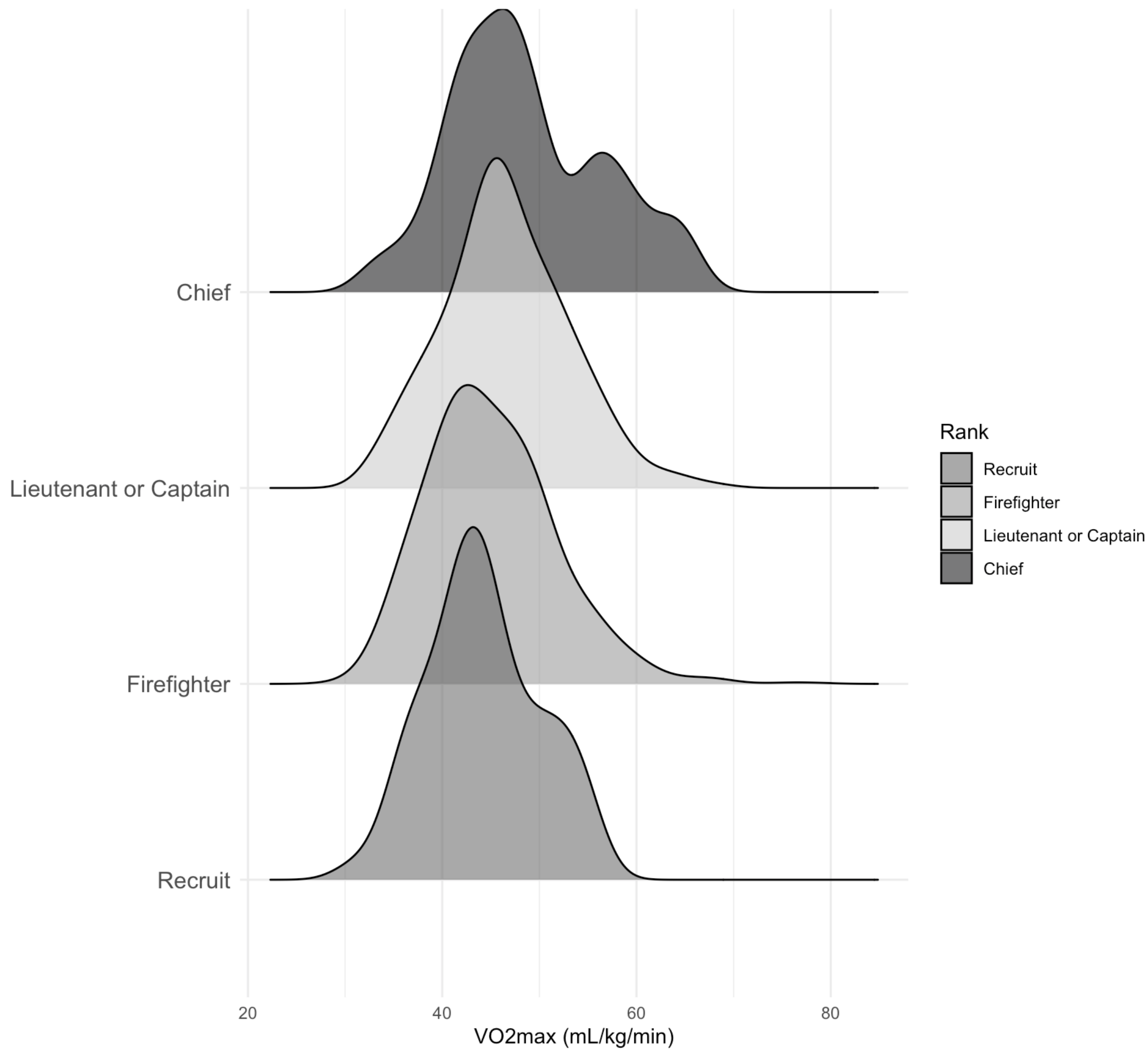

Chief
Lieutenant or Captain
Firefighter
Recruit
0
20
40
60
80
Sit-up (Repetitions)
Rank
Recruit
Firefighter
Lieutenant or Captain
Chief

C. Push-ups

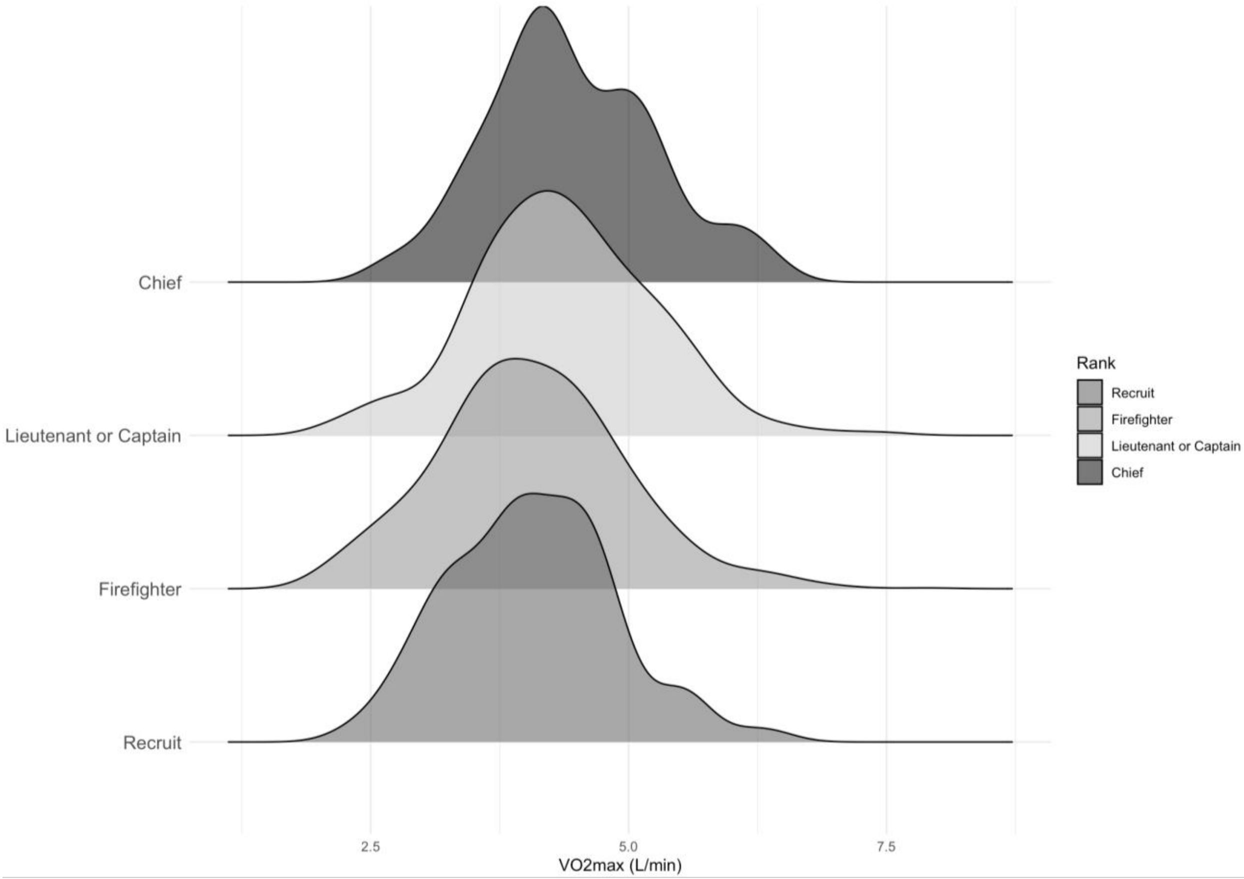


Chief
Lieutenant or Captain
Firefighter
Recruit
0
25
50
75
Push-up (Repetitions)
Rank
Recruit
Firefighter
Lieutenant or Captain
Chief

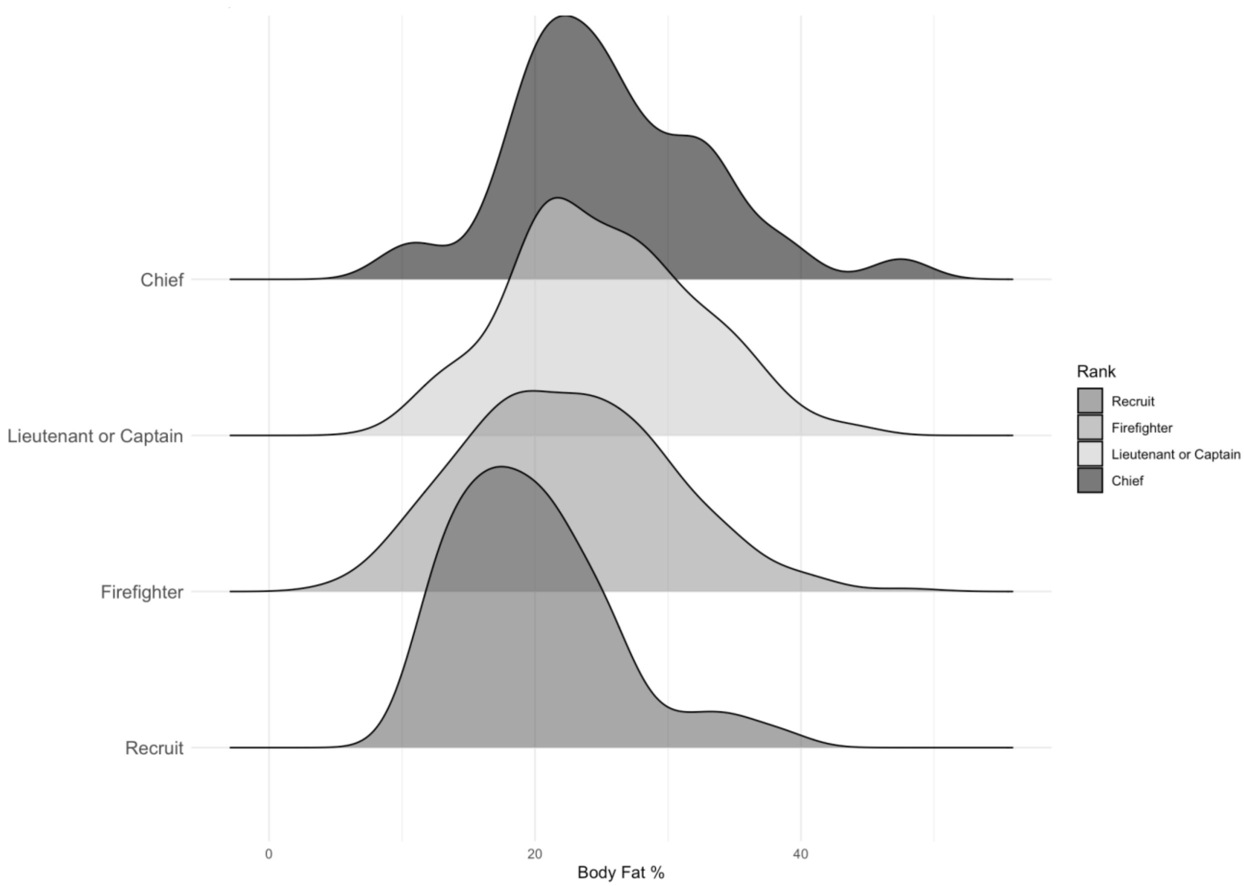
D. Relative Estimated VO_2max



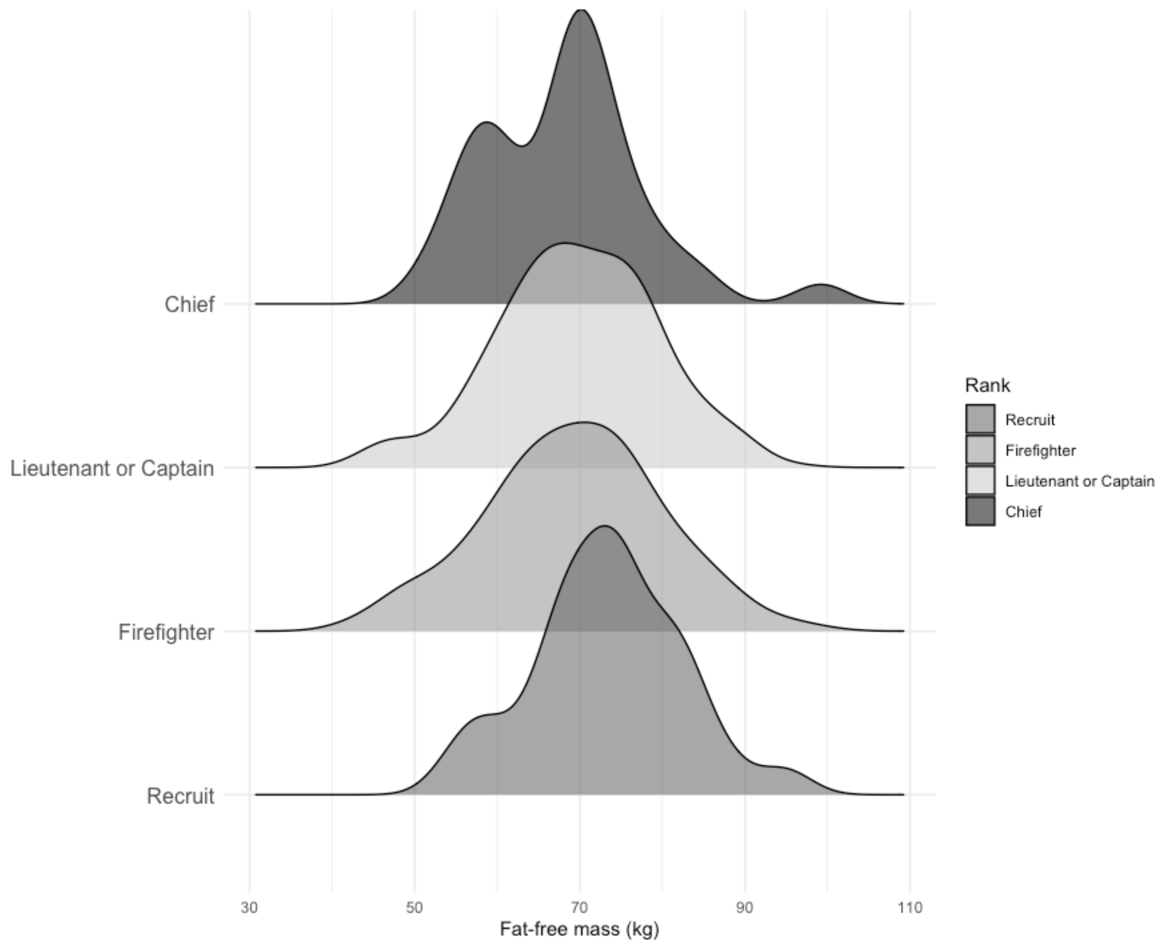
E. Absolute Estimated VO_2max



F. Body Fat Percentage (BF%)



G. Fat-Free Mass



H. Fat Mass

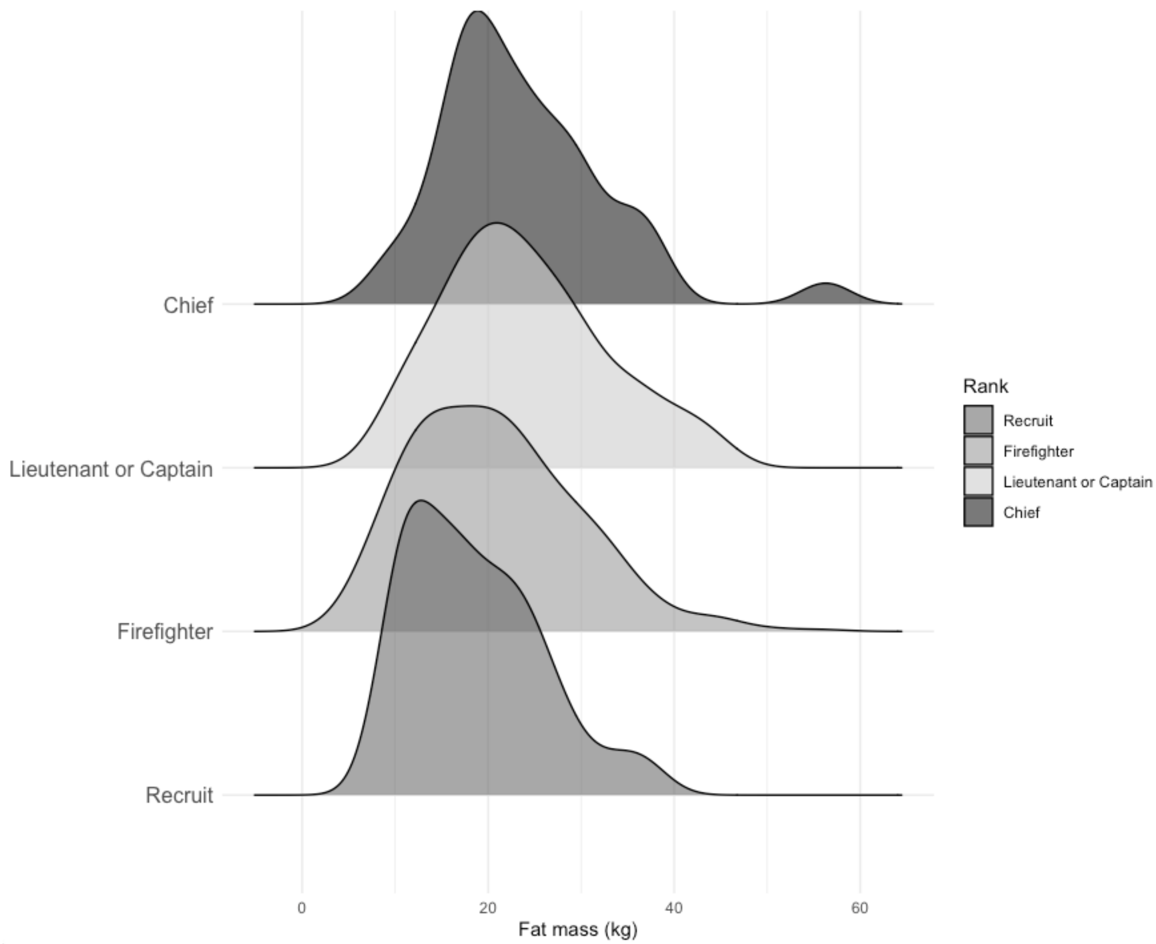

Chief
Lieutenant or Captain
Firefighter
Recruit
0
20
40
60
Fat mass (kg)
Rank
Recruit
Firefighter
Lieutenant or Captain
Chief

Table 1. Participant demographics and anthropometrics by rank (n=1361).

Variable	Mean (SD) / n(%)	Recruit (n=60)	Firefighter (n=973)	Lieutenant/ Captain (n=290)	Chief (n=38)
Age (years)	37.4 (10.1)	26.7 (6.2)	35.5 (9.6)	44.4 (7.3)	49.9 (4.4)
20-29 years	355 (26.1%)	44 (3.2%)	310 (22.8%)	1 (0.1%)	0 (0%)
30-39 years	442 (32.5%)	16 (1.2%)	342 (25.1%)	84 (6.2%)	0 (0%)
40-49 years	363 (26.7%)	0 (0%)	223 (16.4%)	125 (9.2%)	15 (1.1%)
50-59 years	197 (14.5%)	0 (0%)	97 (7.1%)	77 (5.7%)	23 (1.7%)
60+ years	4 (0.3%*)	0 (0%)	1 (0.1%)	3 (0.2%)	0 (0%)
Years of Service (years)	10.3 (8.8)	0.0 (0.0)	8.2 (7.7)	17.8 (6.6)	24.1 (4.2)
0-5 years	496 (36.4%)	60 (4.4%)	435 (32.0%)	1 (0.1%)	0 (0%)
6-10 years	258 (19.0%)	0 (0%)	214 (15.7%)	44 (3.2%)	0 (0%)
11-15 years	192 (14.1%)	0 (0%)	132 (9.7%)	59 (4.3%)	1 (0.1%)
16-20 years	194 (14.3%)	0 (0%)	102 (7.5%)	84 (6.2%)	8 (0.6%)
21+ years	221 (16.2%)	0 (0%)	90 (6.6%)	102 (7.5%)	29 (2.1%)
Sex *Male*	1255 (90.0%)	60 (4.4%)	864 (63.5%)	265 (19.5%)	36 (2.6%)
Female	136 (10.0%)	0 (0.0%)	109 (8.0%)	25 (1.8%)	2 (0.1%)
Height (cm)	173.0 (13.1)	174.4 (14.7)	173.0 (12.9)	172.9 (13.4)	172.3 (13.6)
Mass (kg)	90.8 (14.8)	91.9 (12.2)	89.9 (15.1)	93.6 (14.2)	91.8 (12.6)
BMI (kg^2/m)	30.6 (5.7)	30.7 (6.2)	30.3 (5.7)	31.6 (5.6)	31.4 (5.9)

Note: Values are presented as mean (standard deviation) or frequency (%).

Table 2. Descriptive statistics to profile physical fitness of firefighters in the department (n=1361)

A. Physical fitness distribution statistics

Statistic	**Pull-ups (reps)**	**Sit-ups (reps)**	**Push-ups (reps)**	**Relative VO_2max (mL/kg/min)**	**Absolute VO_2max (L/min)**	**Body Fat (%)**	**Fat-free Mass (kg)**	**Fat Mass (kg)**
Skewness	0.61	-0.46	-0.20	0.63	0.27	0.28	-0.06	0.61
Kurtosis	0.24	2.11	0.29	0.83	0.31	-0.13	-0.10	0.23
Minimum	0	0	0	29.0	1.9	3.7	40.2	3.1
Maximum	30	70	81	78.2	7.9	49.3	99.8	56.3
Range	30	70	81	49.1	6.0	45.6	59.6	53.2

B. Physical fitness percentiles

Percentile	**Pull-ups (reps)**	**Sit-ups (reps)**	**Push-ups (reps)**	**Relative VO_2max (mL/kg/min)**	**Absolute VO_2max (L/min)**	**Body Fat (%)**	**Fat-free Mass (kg)**	**Fat Mass (kg)**
1%	0	22	3	33.2	2.2	8.2	45.6	6.0
10%	0	35	22	37.4	3.0	13.4	55.8	10.5
20%	1	39	28	40.4	3.4	16.4	60.9	13.3
25%	2	40	30	41.2	3.5	17.7	62.7	14.4
30%	2	40	32	42.0	3.7	18.7	64.0	15.8
40%	4	43	36	43.3	3.9	20.6	67.2	18.1
50%	6	44	40	45.4	4.1	22.6	69.7	20.4
60%	8	46	42	46.2	4.3	24.6	72.4	22.7
70%	10	48	45	48.3	4.5	26.8	75.0	25.3
75%	10	49	47	49.2	4.7	28.0	76.5	26.9
80%	10	50	50	50.0	4.8	29.3	78.1	28.7
90%	12	54	55	54.2	5.3	33.0	82.9	33.2
99%	20	61	66	64.3	6.4	41.1	94.5	45.0

Table 3. Correlations between physical fitness variables and age

	Pull-ups (reps)	Sit-ups (reps)	Push-ups (reps)	Relative VO_2max (mL/kg/min)	Absolute VO_2max (L/min)	Body Fat (%)	Fat-free Mass (kg)	Fat Mass (kg)
Age (years)	-0.385***	-0.386***	-0.323***	0.170***	0.232***	0.387***	-0.072**	0.352***
Pull-ups (reps)		0.494***	0.735***	0.199***	-0.134***	-0.667***	0.056*	-0.639***
Sit-ups (reps)			0.505***	0.035	-0.130***	-0.427***	0.063*	-0.409***
Push-ups (reps)				0.209***	-0.025	-0.514***	0.117***	-0.475***
Relative VO_2max (mL/kg/min)					0.682***	-0.253***	-0.207***	-0.176***
Absolute VO_2max (L/min)						0.146***	0.713***	0.408***
Body Fat (%)							-0.195***	0.923***
Fat-free Mass (kg)								0.161***

Notes: 1) *, $p<0.05$; **, $p<0.01$; ***, $p<0.001$**.** 2) Strength of correlations were interpreted as weak, $r \geq 0.10$-0.39; moderate, $r \geq 0.40$-0.69; strong, $r \geq 0.70$. Strong and moderate correlations are shaded dark and light gray, respectively.

Table 4. Effect of firefighter rank on physical fitness measures for all firefighters (n=1361)

Rank	**Pull-ups (reps)**	**Sit-ups (reps)**	**Push-ups (reps)**	**Relative VO_2max (mL/kg/min)**	**Absolute VO_2max (L/min)**	**Body Fat (%)**	**Fat-Free Mass (kg)**	**Fat Mass (kg)**
Overall	6.2 (5.0)	44.0 (8.1)	38.5 (12.7)	45.4 (6.6)	4.1 (0.9)	23.0 (7.5)	69.5 (10.5)	21.3 (8.9)
Recruit (n=60)	6.9 (4.1)	45.1 (7.4)	39.1 (10.9)	44.2 (5.7)	4.1 (0.8)	19.9 (6.1)	73.3 (9.0)	18.6 (7.1)
Firefighter (n=973)	6.8 (5.1)	44.8 (7.6)	39.4 (12.8)	45.0 (6.6)	4.1 (0.9)	22.4 (7.6)	69.3 (10.8)	20.6 (8.9)
Lieutenant / Captain (n=290)	4.6 (4.6)	41.6 (9.2)	35.8 (12.2)	46.6 (6.4)	4.4 (0.9)	25.1 (7.0)	69.7 (9.7)	23.9 (8.7)
Chief (n=38)	4.5 (4.3)	41.8 (6.7)	34.4 (12.9)	48.7 (7.9)	4.5 (0.8)	25.6 (7.5)	68.0 (9.6)	23.8 (9.1)
Rank p-value	**0.028**	**0.036**	0.076	0.133	0.077	0.819	0.0513	0.510
Rank Effect Size (η^2)	0.006	0.005	0.005	0.003	0.005	<0.001	0.006	0.001
Rank Post-hoc	None	Recruit > Chief						

Note: Values are presented as mean (standard deviation).

Table 5. Sensitivity analysis results for association of firefighter rank on physical fitness measures for firefighters with non-zero scores for pull-ups, curl-ups and push-ups (n=1122)

Rank	**Pull-ups (reps)**	**Sit-ups (reps)**	**Push-ups (reps)**	**Relative VO_2max (mL/kg/min)**	**Absolute VO_2max (L/min)**	**Body Fat (%)**	**Fat-free Mass (kg)**	**Fat Mass (kg)**
Overall	7.5 (4.5)	45.3 (7.5)	41.4 (11.0)	46.0 (6.4)	4.1 (0.9)	21.2 (6.5)	69.9 (9.9)	19.3 (7.5)
Recruit (n=55)	7.5 (3.7)	46.1 (6.1)	40.2 (10.5)	43.9 (5.6)	4.0 (0.8)	18.9 (5.2)	73.8 (9.2)	17.6 (6.2)
Firefighter (n=821)	8.0 (4.5)	45.9 (7.1)	42.2 (11.1)	45.6 (6.5)	4.0 (0.9)	20.8 (6.6)	69.6 (10.2)	18.8 (7.6)
Lieutenant / Captain (n=213)	6.1 (4.4)	43.0 (8.9)	39.6 (10.5)	47.4 (6.0)	4.3 (0.8)	22.7 (5.8)	70.0 (9.0)	20.9 (7.1)
Chief (n=33)	5.2 (4.2)	42.8 (6.5)	36.6 (11.5)	48.9 (7.0)	4.5 (0.8)	24.7 (6.8)	68.7 (9.7)	22.8 (7.5)
Rank p-value	**0.020**	0.197	**0.019**	0.408	0.370	0.910	0.041	0.863
Rank Effect Size (η^2)	0.009	0.004	0.009	0.003	0.003	<0.001	0.007	<0.001
Rank Post-hoc	Firefighter > Recruit		Firefighter> Recruit Lieutenant < Recruit				Recruit > Firefighter	

Note: Values are presented as mean (standard deviation).