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Original Research

Differences in Fitness Between Cadet and General Population Firefighter Academy Recruits

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Abstract

International Journal of Exercise Science 18(8): 774-793, 2025. https://doi.org/10.70252/PHHC4783 This longitudinal study explored entry route- and age-related fitness differences between cadet (CR) and general population (GR) firefighter recruits. Fitness data were collected from eight separate firefighter recruit academy cohorts (N = 317; 122 CR, 195 GR; 27.17 ± 7.58 yrs, 177.30 ± 8.72 cm, 88.65 ± 17.78 kg). In the first week of the academy, recruits completed an assessment battery including: body composition via skinfold measures to estimate body fat (BF, %) and fat-free mass (FFM, kg); aerobic fitness (VO_{2peak}, $mL \cdot kg^{-1} \cdot min^{-1}$) and heart rate recovery (HRR_{1min}, %) estimated from the five-minute Forestry Step Test; movement quality via a squat-based movement screen (MES, 0-100); muscular strength via the sum of right and left handgrip (SHG, kg); and muscular endurance via a two-minute push-up test. Due to non-normally distributed data, non-parametric statistical tests were used. Wilcoxon rank-sum tests ($\alpha < 0.05$) evaluated fitness differences between entry routes. Kruskal-Wallis tests evaluated differences between four age groups: A1 (19-21 yrs), A2 (22-29 yrs), A3 (30-39 yrs), and A4 (40+ yrs). CR had significantly ($p < 0.05$) lower age, BM, BF, and FFM, but greater MES, VO_{2peak}, HRR_{1min}, and PU. A1 had lower BM, BF, and FFM; and greater VO_{2peak}, HRR_{1min}, and PU ($p < 0.01$) than all other ages. The range of fitness in recruits upon academy entry necessitates careful programming to support optimization of fitness in all recruits, regardless of age. The fitness elements of an academy may present opportunities to build health and fitness literacy, necessary for career longevity.

Keywords: Age-related, aerobic capacity, body composition, occupational health, performance

Introduction

In the United States, the decline in the number of structural firefighters (FF) has created concerns for the recruitment and retention of both volunteer and career FFs.[1] The population of volunteer FFs has been trending downward for decades, from 8.05 per 1,000 civilians in 1987 to 5.66 per

1,000 civilians in 2020.[1] As such, there is an increased demand for FF academies to consistently enroll recruits into each recruit class to be trained and prepared for the field. To address this, the development of cadet training academies has been an emerging initiative.[1]

Traditionally, career major-metropolitan fire departments have utilized months-long recruit academies as the only formal training period to prepare future FFs for duty, with smaller departments using a combination of shorter academies and training provided by colleges prior to employment. These recruit academies aim to develop necessary FF-related knowledge, skills, and abilities in individuals entering from the general population, usually across a period of several weeks (smaller agencies) to several months (larger agencies). However, cadet academies have more recently been introduced within some fire departments, which precede the recruit academy, and are generally reserved for those recently graduated from high school. Cadet academies are apprentice-style programs, serving to develop the prerequisite certifications and fitness that are required for the recruit academy (e.g., basic fire science, paramedic school, etc.) across a period of up to two years.[2] Once successfully completed, the cadet matriculates into the recruit academy for that department.

As personnel demands continue to grow, however, it may be increasingly common to have a heterogenous mix of cadet and general population recruits participating in the academy simultaneously. This situation presents novel challenges based on age and physical fitness prior to entering the recruit academy. While cadets are typically young adults, those entering from the general population can come from a much larger range of ages. As age-related decrements to physical fitness are well documented in FFs,[3–6] this supports the potential for a discrepancy in fitness between cadets and general population recruits. Furthermore, cadets may be exposed to structured physical training prior to the recruit academy, while general population recruits are left to independently complete the required entry-level fitness testing. This further supports potential differences in fitness between cadet and general population recruits at the start of the recruit academy.

Firefighting is unique in its physical demands, requiring both rigorous and spontaneous exertion at near-maximal intensities.[7] As such, body composition,[8–10] aerobic fitness,[7,11–14] movement efficiency,[11,15,16] and muscular strength[5,13,17,18] and endurance[4,5,19–23] have all been linked to FF health and performance. However, there continues to be a paucity of normative fitness data specific to FF recruits. Furthermore, there is no such data available investigating differences between individuals entering the recruit academy via different entry routes (i.e., cadet versus general population). Filling this gap in normative data is needed to represent the diversity that is becoming present in recruit academies and support the development of physical training programs to optimize both health and performance in a diverse range of recruits. Thus, the purpose of this longitudinal study is to explore the initial fitness differences between individuals entering the recruit academy via cadet and general population entry routes, then to further identify fitness differences related to age. We hypothesize that cadets may have higher levels of physical fitness than general population recruits, and that older recruits will generally have lower physical fitness than younger recruits.

Methods

Participants

317 total FF recruits from the same career-major-metropolitan urban Midwest fire department volunteered to participate in this study. Of these, 122 entered the FF recruit academy upon completing the department's two-year FF cadet academy (CR; mean ± SD: males: n = 96, age, 20.3 ± 0.6 yrs, height, 178.8 ± 7.3 cm, body mass, 84.5 ± 15.4 kg; females: n = 26, age, 20.2 ± 0.7 yrs, height, 165.7 ± 7.6 cm, body mass, 73.2 ± 11.6 kg), while the remaining 195 matriculated directly from the general population (GR) application and selection process (mean ± SD: males: n = 175, age, 31.7 ± 6.8 yrs, height, 179.5 ± 7.3 cm, body mass, 94.3 ± 17.4 kg; females: n = 20, age, 29.6 ± 5.4 yrs, height, 166.1 ± 7.9 cm, body mass, 79.2 ± 18.3 kg). To be included in this study, all participants were required to be free of any current musculoskeletal injuries and cleared for full participation in their FF training academy. Prior to any data being collected, all participants provided written informed consent to the study protocols. This study was approved by the institutional review board at the University of Wisconsin-Milwaukee in accordance with the ethical standards set by the Helsinki Declaration. This research was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science*.[24]

Protocol

Health and fitness data were collected from eight separate classes of FF recruits as part of a larger longitudinal project, with each data collection occurring during the first week of the 16-week FF recruit academy. Data collection spanned from the years 2018 to 2024, not including 2020 due to the COVID-19 pandemic. Class sizes varied from 23 to 55 recruits, guided by department hiring needs. However, all recruits enrolled in the first week of the FF recruit academy completed testing.

Health and fitness data were collected using field-based protocols consistent with the Wellness Fitness Initiative (WFI)[25] and the American College of Sports Medicine (ACSM),[26] with each measure having been previously used within the firefighter scientific literature.[9,13,15] All testing was performed indoors at the FF recruit academy in the morning immediately following recruit reporting time at approximately 0800 hours. All participants were required to wear department issued athletic shirt and shorts as well as athletic footwear. Pre-testing hydration and nourishment were encouraged, but not monitored.

Per WFI guidelines, fitness data were collected in the following order during each collection period: body composition, movement quality, muscular strength, aerobic capacity, and muscular endurance. Approximately ten minutes of rest and opportunity for hydration were provided between muscular strength, aerobic capacity, and muscular endurance tests. Prior to testing, standardized instruction was given to the entire cohort, with reminders given at each testing station.

Body Composition.

Body composition was comprised of the following measures: body height (Ht), body mass (BM), body fat (BF), and fat-free mass (FFM). All measures of body composition were collected per the guidelines created by the ACSM.[26]

Height.

The Ht of each participant was self-reported in inches and recorded to the nearest 0.25 inch. This measure was then converted to cm.

Body Mass.

BM of each participant was measured using a digital scale (Health-o-Meter Professional; Pelstar LLC, McCook, IL) and recorded to the nearest 0.1 lb. This measure was then converted to kg.

Body Fat.

Three-site skinfold assessment was used to estimate body density and subsequently the BF of each participant.[26] Specifically, skinfolds were obtained using a Lange skinfold caliper and measured to the nearest 1 millimeter (mm) (Beta Technology, Santa Cruz, CA). For males, skinfolds were taken from the pectoral, triceps, and subscapular locations. For females, skinfolds were taken from the triceps, suprailiac, and abdominal locations. Two skinfold measurements were taken from the right side of each participant's body and averaged together. If the two initial measurements differed by 2mm or greater, a third measurement was included. Using these skinfold measures, the body density of each participant was estimated using the Jackson and Pollock method, then BF (%) was calculated using the Siri equation.

Fat-Free Mass.

The FFM of each participant was determined using their respective BF (%), BM (kg), and the following equation[27]:

$$\mathrm{FFM} = \left(1 - \frac{\mathrm{BF}}{100}\right) \cdot \mathrm{BM}$$

Aerobic Fitness.

Aerobic fitness was comprised of the following measures: estimated aerobic capacity (VO_{2peak}) and relative one-minute heart rate recovery (HRR_{1min}). These measures of aerobic fitness were calculated by collecting HR data during and after the Forestry Step Test,[28] which has been previously used among the FF population.[9,15,27] This testing protocol requires participants to step up on and off a 40-cm box to the beat of a metronome set to 90 bpm for five minutes. Equipment changes between the years 2018 to 2023 resulted in step heights ranging from 40 to 48 cm. All HR data were collected using Polar T31i HR monitors (Polar Electro, Lake Success, NY).

Estimated Aerobic Capacity.

After completing the required 5 minutes of stepping associated with the Forestry Step Test,[28] participants immediately sat on their respective steps and post-test HR data were recorded immediately (HR_{0s}) and 1 minute later (HR_{1min}). The HR_{0s} was used to estimate a sex-specific, age-adjusted, estimate of VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$) for each participant while accounting for step height (cm) differences using the following equation[29]:

$$VO_{2peak} = 1.12 - 0.0073 \cdot age \cdot \frac{131.5 \cdot (7.9 + 0.539 \cdot \text{step height})}{HR_{0s} + (10 \text{ for male; } 0 \text{ for female}) - 72}$$

Heart Rate Recovery.

HRR_{1min} (%) associated with the Forestry Step Test, relative to each participant's age-predicted maximal HR,[30] was estimated using the following equation:

$$HRR_{1min} = \frac{HR_{0s} - HR_{1min}}{208 - (0.7 \cdot age)}$$

Movement Quality.

Functional movement quality was estimated through the Fusionetics™ Movement Efficiency Screen (MES).

Movement Efficiency Screen.

The MES (Fusionetics™, Inc., Alpharetta, GA) is a tool that has been used previously in FF populations to estimate functional movement quality.[16] MES administration was performed following the methodology used previously by Cornell et al[16] where all participants are testing in unobstructive athletic apparel and without shoes. All participants are then instructed through a series of sub-tests including a two-leg squat, two-leg squat with a heel lift, and one-leg squat. Each squat variation is performed approximately five times and participants are instructed to squat to a depth equal to the height of a chair for each squat variation. MES sub-tests were scored in real-time using a binomial (yes/no) checklist based on a standard set of movement compensations commonly observed during each squat variation from front, side, and rear viewpoints. After scoring each sub-test, these binomial data were then entered into the Fusionetics™ Human Performance System. This online platform utilizes a proprietary algorithm to calculate a movement efficiency score for the overall assessment, ranging from 0 – 100 (worst – best).

Muscular Strength.

Muscular strength was assessed via sum handgrip strength (SHG) measures.

Sum Handgrip Strength.

The SHG of each participant was determined by measuring handgrip of both hands using a Jamar hydraulic dynamometer (Lafayette Instrument Company, Lafayette, IN). Using the protocol recommended within the WFI,[25] each participant started the test protocol standing upright with their elbow flexed to 90-degrees and their wrist in neutral position. Each participant squeezed the dynamometer as hard as possible, and the resulting force output was recorded by the researcher to the nearest 1 lb. Two trials were completed bilaterally and the trials resulting in the greatest force output for each hand were then added together to create one measure of SHG. This measure was then converted to kg.

Muscular Endurance.

Dynamic muscular endurance was assessed via the number of push-ups completed (PU).

Push-ups.

Dynamic muscular endurance was measured via the PU assessment recommended by the WFI.[25] Specifically, participants were instructed to complete repetitions at a cadence of 80 bpm (i.e., one complete repetition every two beats) with their hands shoulder width apart and feet together. Complete range of motion during the repetitions was ensured by instructing participants to lower their body toward the floor until their chin touched a five-inch prop placed on the floor beneath the participant. Accordingly, proper depth during each repetition was enforced by the researchers. Participants continued to perform repetitions until: 1) the participant volitionally terminated the test due to fatigue; 2) the participant could not maintain the cadence of 80 bpm, and thus the test was terminated by the researchers; or 3) the maximum test time of two minutes (or 80 repetitions) was achieved. The total number of repetitions completed during the test was then recorded by the researchers and was normalized to the 80-repetition maximum and multiplied by 100 to create a PU value (%) for each participant.

Statistical Analysis

Since there were missing data for some participants for select tests, the total number of participants who completed each test has been noted within each table. All descriptive and statistical analyses were performed using Statistical Analysis Software (SAS Studio) (SAS Institute Inc., Cary, NC). All data were first examined for normality using the Shapiro-Wilks test in addition to visual inspection of histogram and Q-Q plots, which revealed that all measures were not normally distributed. As such, data were analyzed using non-parametric tests of Wilcoxon-Rank Sum tests and the Kruskal-Wallis. Group differences were first examined by entry route, CR versus GR, using Wilcoxon Rank-Sum tests. Next, to examine the potential influence of age, four separate age groups were created consistent with those used in prior literature.[3] In order to separate the CR from GR participants, the CR group, which consisted of cadets who were exclusively 19 to 21 years of age, constituted the youngest age group (A1). The GR group then formed the remaining three age groups: 22 to 29 yrs (A2), 30 to 39 yrs (A3), and 40 yrs or greater (A4). Kruskal-Wallis tests were used to examine for differences between age groups, followed by the pairwise comparisons testing using Dwass-Steel-Critchlow-Fligner (DSCF) procedure.[31] An alpha of 0.05 was used to determine statistical significance for all analyses.

Effect size for comparisons between CR and GR were examined using rank-biserial correlation coefficient *(r)*.[32] An *r* of less than 0.30 was considered a small effect, 0.30 to 0.50 a medium effect, and 0.50 or greater a large effect.[32] Effect sizes were calculated for all age group comparisons using eta squared (η^2).[32] An η^2 of less than 0.06 was considered a small effect; 0.06 to 0.14 a medium effect; greater than 0.14 a large effect. Lastly, percentile rankings (Tables 3-8) were generated separately for CR and GR for BF, MES, SHG, VO_{2peak}, HRR_{1min}, and PU for descriptive purposes. The data is presented based on the recruit entry route (i.e., CR or GR), age group, and biological sex with the number of recruits within each rank detailed.

Results

Descriptive statistics (mean ± SD) and comparative statistics are reported for all measures of body composition, movement quality, muscular strength, aerobic fitness, and muscular endurance for CR and GR (Table 1) as well as for each individual age group (Table 2).

Table 1. Health & Fitness Differences Between Cadet (CR) and General Population (GR) Firefighter Recruits.

Measure[a]	CR[b]	GR[c]	Test Statistics[d]
Age (yrs)	20.31 ± 0.59	31.47 ± 6.72	z = -15.08, P < 0.001, r = -0.85
Body Composition			
Ht (cm)	176.05 ± 9.10	178.09 ± 8.40 (n = 194)	z = -1.71, P = 0.088, r = -0.10
BM (kg)	82.10 ± 15.37	92.75 ± 17.99	z = -5.51, P < 0.001, r = -0.31
BF (%)	17.16 ± 7.18 (n = 107)	21.20 ± 6.34	z = -4.87, P < 0.001, r = -0.28
FFM (kg)	67.01 ± 11.19 (n = 107)	72.71 ± 12.34	z = -3.96, P < 0.001, r = -0.23
Aerobic Fitness			
VO_{2peak} (mL · kg^{-1} · min^{-1})	45.30 ± 7.00 (n = 116)	38.23 ± 5.77 (n = 188)	z = 8.51, P < 0.001, r = 0.49
HRR_{1min} (%)	23.48 ± 5.96 (n = 117)	19.32 ± 5.51 (n = 188)	z = 5.96, P < 0.001, r = 0.34
Movement Quality			
MES (0-100)	64.37 ± 13.04	60.98 ± 14.47	z = 2.03, P = 0.042, r = 0.11
Muscular Strength			
SHG (kg)	96.47 ± 21.45	101.26 ± 23.22	z = -1.49, P = 0.137, r = -0.08
Muscular Endurance			
PU (repetitions)	33.39 ± 11.96 (n = 119)	29.11 ± 11.60 (n = 194)	z = 3.38, P < 0.001, r = 0.19

[a] Results are presented as mean ± SD; Ht = height; BM = body mass; BF = body fat; FFM = fat-free mass; VO_{2peak} = estimated aerobic capacity; HRR_{1min} = heart rate recovery; MES = movement efficiency screen; SHG = sum handgrip strength; PU = push-ups. [b] n = 122, unless otherwise noted; [c] n = 195, unless otherwise noted; [d] Test statistics are results of Wilcoxon Rank Sum tests

Comparison of CR and GR

Results of the Wilcoxon Rank Sum tests demonstrated statistically significant differences between CR and GR for all measures except Ht and SHG (Table 1). In comparison to the GR, the

Table 2. Health and Fitness Differences Between Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group

Measure[a]	CR A1 19-21 yrs[b]	A2 22-29 yrs[c]	GR A3 30-39 yrs[d]	A4 40+ yrs[e]	Test Statistics[f]	Pairwise Comparisons[g]
Age (yrs)	20.31 ± 0.59	25.98 ± 2.18	33.96 ± 2.84	44.29 ± 4.66	$H_3 = 289.18$, $P < 0.001$, $\eta^2 = 0.91$	A1 < A2 A2 < A3 A3 < A4
Body Composition						
Ht (cm)	176.05 ± 9.10	178.89 ± 8.67	177.18 ± 8.27	178.02 ± 7.76 (*n* = 23)	$H_3 = 6.19$, $P = 0.103$, $\eta^2 = 0.01$	
BM (kg)	82.10 ± 15.37	91.39 ± 18.81	94.76 ± 18.05	91.37 ± 14.21	$H_3 = 32.02$, $P < 0.001$, $\eta^2 = 0.09$	A1 < A2, A3, A4
BF (%)	17.16 ± 7.18 (*n* = 107)	20.57 ± 6.45	22.04 ± 6.29	20.85 ± 5.97	$H_3 = 25.35$, $P < 0.001$, $\eta^2 = 0.08$	A1 < A2, A3
FFM (kg)	67.01 ± 11.19 (*n* = 107)	72.23 ± 13.39	73.42 ± 11.68	72.22 ± 10.42	$H_3 = 16.08$, $P = 0.001$, $\eta^2 = 0.04$	A1 < A2, A3
Aerobic Fitness						
VO_{2peak} (mL · kg^{-1} · min^{-1})	45.30 ± 7.00 (*n* = 116)	39.07 ± 5.95 (*n* = 90)	37.67 ± 6.02 (*n* = 74)	36.79 ± 3.65	$H_3 = 75.78$, $P < 0.001$, $\eta^2 = 0.25$	A1 > A2, A3, A4
HRR_{1min} (%)	23.48 ± 5.96 (*n* = 117)	19.58 ± 5.82 (*n* = 91)	18.58 ± 4.95 (*n* = 74)	20.70 ± 5.81 (*n* = 23)	$H_3 = 38.64$, $P < 0.001$, $\eta^2 = 0.13$	A1 > A2, A3
Movement Quality						
MES (0-100)	64.37 ± 13.04	61.88 ± 14.41	58.60 ± 14.15	65.38 ± 14.92	$H_3 = 7.76$, $P = 0.051$, $\eta^2 = 0.02$	
Muscular Strength						
SHG (kg)	96.47 ± 21.45	100.56 ± 23.96	101.60 ± 24.04	102.78 ± 17.70	$H_3 = 2.61$, $P = 0.456$, $\eta^2 < 0.01$	
Muscular Endurance						
PU (repetitions)	33.39 ± 11.96 (*n* = 119)	28.33 ± 11.12	29.15 ± 12.21 (*n* = 78)	32.00 ± 11.37	$H_3 = 13.51$, $P = 0.004$, $\eta^2 = 0.03$	A1 > A2, A3

[a] Results are presented as mean ± SD; Ht = height; BM = body mass; BF = body fat; FFM = fat-free mass; VO_{2peak} = estimated aerobic capacity; HRR_{1min} = heart rate recovery; MES = movement efficiency screen; SHG = sum handgrip strength; PU = push-ups

[b] *n* = 122, unless otherwise noted

[c] *n* = 92, unless otherwise noted

[d] *n* = 79, unless otherwise noted

[e] *n* = 24, unless otherwise noted

[f] Test statistics are results of Kruskal-Wallis tests

[g] Statistically significant *post hoc* pairwise findings determined using DSCF procedure

CR had significantly lower Age, BM, BF, and FFM, and greater MES, VO_{2peak}, HRR_{1min}, and PU, than their GR counterparts.

Comparison of Age Groups

Results of the Kruskal-Wallis tests revealed the presence of significant age group differences for all measures except Ht, MES, and SHG. Each group was significantly different in terms of age (H_3 = 289.18). The DSCF procedure identified further differences existed only between A1 and one or more of the remaining age groups, such that A1 had significantly lower BM, BF, and FFM, and greater VO_{2peak}, HRR_{1min}, and PU. See Table 2 for specific significant pairwise comparisons between age groups.

Percentile Ranks

Percentile ranks are reported in Tables 3-8, displayed in increments of 10, from 100 to 10.

Table 3. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Body Fat (BF, %)

CR (*n* = 107)				GR (*n* = 195)							
Percentile	Range (%)	A1		Percentile	Range (%)	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	5.53 - 8.28	11	0	100	4.91 - 12.49	11	0	7	0	2	0
90	8.29 - 10.27	11	0	90	12.50 - 15.09	10	0	6	0	3	0
80	10.28 - 12.48	12	0	80	15.10 - 18.21	9	0	8	0	3	0
70	12.49 - 14.09	9	0	70	18.22 - 19.56	9	0	5	1	4	0
60	14.10 - 16.00	11	0	60	19.57 - 21.49	9	1	8	0	2	0
50	16.01 - 18.17	10	1	50	21.50 - 22.86	9	0	9	0	1	0
40	18.18 - 21.11	8	2	40	22.87 - 24.85	8	1	8	0	3	0
30	21.12 - 24.49	5	6	30	24.86 - 26.05	5	3	10	0	1	0
20	24.50 - 27.06	5	6	20	26.06 - 29.88	10	1	4	3	2	0
10	27.07 - 34.37	4	6	10	29.89 - 38.98	1	5	6	4	2	1

Table 4. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Movement Efficiency Screen (MES, 0-100)

CR (*n* = 122)				GR (*n* = 195)							
Percentile	Range	A1		Percentile	Range	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	81.06 - 93.20	10	2	100	79.48 - 96.31	10	1	3	1	4	0
90	74.22 - 81.05	11	1	90	74.12 - 79.47	10	0	7	0	2	1
80	71.11 - 74.21	11	1	80	69.58 - 74.11	7	1	7	2	2	0
70	67.48 - 71.10	9	3	70	65.31 - 69.57	10	2	5	1	1	0
60	65.29 - 67.47	11	2	60	61.58 - 65.30	8	1	8	0	3	0
50	62.75 - 65.28	7	5	50	58.11 - 61.57	9	0	8	0	2	0
40	58.53 - 62.74	8	4	40	52.95 - 58.10	6	1	8	1	4	0
30	55.91 - 58.52	8	4	30	48.27 - 52.94	6	1	9	1	3	0
20	47.90 - 55.90	10	2	20	42.53 - 48.26	8	1	7	1	2	0
10	28.31 - 47.89	11	2	10	23.89 - 42.52	7	3	9	1	0	0

Table 5. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Sum Handgrip Strength (SHG, kg)

CR (*n* = 122)				GR (*n* = 195)							
Percentile	Range (kg)	A1		Percentile	Range (kg)	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	123.39 - 145.15	12	0	100	130.65 - 181.44	10	1	7	0	1	0
90	116.13 - 123.38	11	0	90	119.99 - 130.64	9	0	7	0	4	0
80	111.14 - 116.12	8	0	80	112.96 - 119.98	7	0	8	0	4	0
70	104.34 - 111.13	17	0	70	106.38 - 112.95	8	0	11	0	1	0
60	97.53 - 104.33	11	0	60	97.99 - 106.37	12	0	5	0	2	0
50	90.73 - 97.52	13	0	50	93.00 - 97.98	9	0	5	0	3	0
40	83.92 - 90.72	10	3	40	88.46 - 92.99	6	0	12	0	4	0
30	75.31 - 83.91	8	3	30	81.43 - 88.45	7	3	7	1	2	0
20	65.78 - 75.30	4	9	20	73.49 - 81.42	8	0	6	1	1	1
10	53.52 - 65.77	2	11	10	49.90 - 73.48	5	7	3	6	1	0

Table 6. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Estimated Aerobic Capacity (VO_{2peak}, $mL \cdot kg^{-1} \cdot min^{-1}$)

CR (*n* = 116)				GR (*n* = 188)							
Percentile	Range ($mL \cdot kg^{-1} \cdot min^{-1}$)	A1		Percentile	Range ($mL \cdot kg^{-1} \cdot min^{-1}$)	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	55.28 - 65.75	10	1	100	44.62 - 64.54	8	3	6	0	0	0
90	51.16 - 55.27	10	2	90	41.87 - 44.61	8	0	9	0	2	0
80	47.92 - 51.15	9	2	80	40.59 - 41.86	9	2	6	1	2	0
70	46.94 - 47.91	10	2	70	39.14 - 40.58	13	0	4	0	2	0
60	45.68 - 46.93	10	2	60	37.67 - 39.13	6	2	4	1	5	0
50	42.90 - 45.67	9	2	50	36.01 - 37.66	7	1	6	3	2	0
40	40.58 - 42.89	9	3	40	35.01 - 36.00	9	0	7	0	2	1
30	39.33 - 40.57	7	4	30	33.67 - 35.00	10	0	5	2	2	0
20	36.67 - 39.32	8	4	20	32.21 - 33.66	4	1	10	0	4	0
10	32.05 - 36.66	10	2	10	25.86 - 32.20	6	1	10	0	2	0

Table 7. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Heart Rate Recovery (HRR_{1min}, %)

CR (*n* = 117)				GR (*n* = 188)							
Percentile	Range (%)	A1		Percentile	Range (%)	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	30.42 - 39.18	7	3	100	25.73 - 38.48	8	4	4	0	1	1
90	28.46 - 30.41	9	4	90	23.37 - 25.72	7	0	6	3	3	0
80	26.39 - 28.45	8	4	80	22.34 - 23.36	13	1	3	1	1	0
70	25.36 - 26.38	8	2	70	20.80 - 22.33	8	0	6	0	5	0
60	23.29 - 25.35	12	1	60	19.42 - 20.79	10	0	4	1	4	0
50	21.66 - 23.28	10	1	50	18.25 - 19.41	4	2	10	0	2	0
40	20.63 - 21.65	8	2	40	16.71 - 18.24	10	0	8	1	0	0
30	19.01 - 20.62	10	4	30	15.46 - 16.70	4	2	11	0	2	0
20	15.47 - 19.00	11	0	20	12.45 - 15.45	8	0	8	0	3	0
10	5.15 - 15.46	10	3	10	-1.56 - 12.44	9	1	7	1	1	0

Table 8. Percentile Ranks in Cadet (CR) and General Population (GR) Firefighter Recruits by Age Group and Sex for Push-ups (PU, repetitions)

CR (*n* = 117)				GR (*n* = 194)							
Percentile	Range (repetitions)	A1		Percentile	Range (repetitions)	A2		A3		A4	
		Male	Female			Male	Female	Male	Female	Male	Female
100	50 - 67	11	0	100	45 - 78	6	0	8	0	2	0
90	44 - 49	10	0	90	39 - 44	10	0	6	0	6	0
80	41 - 43	8	0	80	35 - 38	8	0	8	0	3	0
70	36 - 40	18	0	70	32 - 34	8	1	7	0	2	0
60	34 - 35	6	0	60	30 - 31	9	1	7	0	0	0
50	32 - 33	14	1	50	26 - 29	9	2	9	0	4	0
40	31	3	1	40	24 - 25	7	0	5	2	2	0
30	26 - 30	15	6	30	21 - 23	11	2	3	2	0	0
20	17 - 25	6	8	20	17 - 20	8	1	12	0	2	0
10	4 - 16	2	10	10	1 - 16	5	4	6	3	2	1

Discussion

The purpose of this work was to explore the initial fitness differences between firefighter recruits admitted into the recruit academy from a CR (i.e., cadet) and GR (i.e., general population) pathway as well as to examine age-related differences in fitness. The results indicated that the CR have significantly greater movement efficiency, aerobic capacity, and muscular endurance than the GR, while being younger, lighter, and leaner. The only significant age differences found were between A1 (i.e., cadets) and one or more of the GR age groups. However, there were no significant age-group differences within the GR population on any measure. These results add to the limited available normative data across ages for FF recruits.[3] As fire departments across the United States explore new strategies for recruiting FFs, including FF cadet programs, these results fill an important gap in the void on available FF cadet fitness data.[1]

With the CR group performing better than the GR group in all fitness measures except absolute strength, and the lack of age-related differences within the GR, there may be an important benefit from the general longer-term structured fitness programming in a cadet program regarding physical preparedness for a recruit academy. Interestingly, the group that differed the most from the CR group (i.e., A1) in physical fitness was also the next youngest group (i.e., A2). That is, the CR group, composed of 19-to-21-year-old individuals, was significantly better than the A2 and A3 groups (those 22-to-39 years old) in several fitness measures, yet the A1 group was not different from the oldest group (i.e., A4) in most fitness measures. Further, except for VO_{2peak} and HRR_{1min}, the percentile data highlights that A4 has a higher proportion of recruits scoring at or above the 70th percentile, and a lower proportion of recruits scoring at or below the 30th percentile than both A2 and A3. For example, 46% of the A4 group scored at or above the 70th percentile in PU, while the proportions of A3 and A2 were only 28% and 26%, respectively. Yet, the recruits scoring at or below the 30th percentile in PU for A4, A3, and A2 were 21%, 33%, and 34%, respectively. A similar pattern in percentile distribution was observed within BF, MES, and SHG. These findings are consistent with the age-related differences in FF fitness measures reported by Parpa and Michaelides[3] for body composition and upper and lower body muscular endurance, but different from their findings for age-related differences in SHG. The greater proportion of high performers in the A4 group may contribute to the lack of age-related statistical differences between A1 and A4 and may also suggest that the fitness differences may not be exclusively due to age. It is possible that some of those in the A4 group in the current study represent older individuals making a career change, and as a result, are better prepared for the academy from a physical perspective. Future research should investigate these implications of age and career change as well as other contextual and psychosocial factors in general population FF recruits.

Body Composition

Obesity, commonly reported in FFs using a combination of BF and FFM, is an important modifiable health and performance factor.[8,27] The recruit participants in this study would generally be classified as non-obese according to age-based adiposity normative values from the ACSM.[26] Furthermore, despite prior literature suggesting a relationship between age and BF and FFM,[8] the results of this study suggested that the youngest (i.e., A1) and oldest (i.e., A4) age groups did not differ in BF or FFM, while the middle two (i.e., A2, A3) age groups had higher BF and FFM than A1. These results create an interesting perspective on the health and performance role that BF and FFM may play in meeting the physical development needs of FF recruits.

Elevated BF has been linked to increased risk for cardiovascular disease (CVD),[8] musculoskeletal injury,[10] and all-cause mortality.[8] Further, abdominal obesity, prevalent in the FF population, is a key component of metabolic syndrome which has been reported to exist in 22% of the FF population.[33] As such, elevated BF may be a key factor to address the job-related CVD risk in the FF population.[33] Prior literature has reported decreases in BF following recruit academy participation,[27] thus, suggesting that many recruit academy graduates may have a healthier BF at the time of entry onto the job. Within the general population, BF is known to increase across the lifespan while FFM decreases.[26] It is possible that decreases in exposure or access to structured and regular physical training on the job may be a key factor in the development of health-related risk factors through elevated BF and compounded by the age-related changes reported in the FF literature. The results of the current study, which are inconsistent with this trend, suggest that the older recruits entering the recruit academy may not be representative of the general population. More work is required to understand what modifiable factors, such as pre-academy training, may be involved in this observation. Decreases in BF may also contribute to decreases in FFM, requiring that recruit academies carefully consider strategies for maintaining or optimizing FFM while BF changes occur.[34] Considering the current results, the recruits in the A1 and A4 groups may experience more optimal health changes by maintaining BF while increasing FFM, yet the A2 and A3 groups may benefit from improving both BF and FFM. Therefore, body composition plays a multifaceted role in supporting health. While exercise is a large factor in modifying and maintaining body composition, the role of nutrition is equally important. Consistent caloric consumption that exceeds total daily energy expenditure is one of the main drivers of negative changes to metabolic function and eventual body composition, with micronutrient density within the diet playing a large role in long-term dietary consistency.[35] As such, the results of the current study warrant strategic physical programming considerations within the recruit academy while emphasizing education on nutritional quantity and quality.

While body composition is influential to FF health profiles, its influence on FF performance is also well-established.[22,23,36,37] However, unlike the ACSM health-related classification criteria available for body composition, performance-related criteria for BF and FFM are less clear. Recent literature has reported significant relationships between BF and FFM with task completion time,[22,23] work efficiency,[36] and workload are all closely related to this aspect of fitness.[37] For example, FF task completion times can be predicted by body composition,[22,23] where higher BF may increase overall load being carried, increasing relative metabolic demands which requires the individual to slow their effort to effectively complete the task, especially if paired with lower FFM. It has also been reported through air tank consumption studies that those with higher BF and lower FFM consume more air during a given task,[36] which suggests work efficiency may be an important measure of job performance. As such, poor body composition will decrease the amount of work that can be performed continuously, increasing recovery needs following high-demand tasks.[38] For example, Marciniak et al[37] reported that FFs with lower BF spent less time at or above 90% maximum heart rate (MHR) during fire suppression tasks. The results of this study suggest that, from a performance perspective, physical training programs that are aimed to optimize both BF and FFM in recruits will support development of workload and efficiency in fire ground skills.

Aerobic Capacity

Lockie et al[21] have highlighted the importance of aerobic capacity in recruits, with increased VO_{2peak} being associated with successful graduation from FF recruit academies. Additionally, age-related decreases in VO_{2peak} are frequently reported in FF populations.[6] The results of the current study found that the only age-related difference in VO_{2peak} was the youngest age-group (A1) having a significantly greater VO_{2peak} than the other age groups. A low VO_{2peak} is associated with increased risk of metabolic syndrome and CVD,[39] both of which are health concerns in the FF population. CVD accounts for 44% of duty-related deaths in the fire service, with the majority of these deaths being attributed to coronary heart disease.[39] According to the ACSM health-related classification criteria available for VO_{2peak}, the current results indicate that the recruits generally have poor-to-fair aerobic fitness.[26] Thus, at time of entry into the recruit academy, the recruits have aerobic fitness levels that would be associated with increased health risk.

There are also consequences to FF performance created by poor aerobic fitness levels. FFs commonly reach or exceed MHR during fire suppression tasks,[37] and VO_{2peak} has been reported as a strong predictor of task completion time.[12] Elsner et al[12] demonstrated that simulated FF tasks required a VO_{2peak} of about 29 $mL \cdot kg^{-1} \cdot min^{-1}$ to be sustained for over eight minutes. Windisch et al[40] further demonstrated that air tank depletion times are longer in FFs with higher a VO_{2peak}, signifying greater work efficiency in those with greater aerobic capacity. Sothmann et al[41] further emphasized this point as they found that those FFs with VO_{2peak} values less than 41 $mL \cdot kg^{-1} \cdot min^{-1}$ had a 20% lower chance of safely and effectively completing fire suppression tasks while those with VO_{2peak} values less than 33.5 $mL \cdot kg^{-1} \cdot min^{-1}$ had a 50% lower chance of safely and effectively completing fire suppression tasks. Subsequently, VO_{2peak} criteria ranging from 33.9 to 44.0 mL · kg^{-1} · min^{-1} have been proposed as the minimum necessary to perform FF job demands.[12] In the current study, only the youngest group (A1) had a VO_{2peak} above these performance criteria. Thus, improving aerobic capacity in FF recruits may have potential long-term health benefits, while supporting the optimal development of the recruit into a FF. Previous work by Cornell et al[27] demonstrated a 10-point increase in relative VO_{2peak} following 14 weeks of recruit academy completion. While the VO_{2peak} improvement those authors found was a product of both aerobic fitness and body weight adaptations, such improvement would put each of the four age groups in the current study above the aforementioned performance criteria. Therefore, the current results suggest that recruit academies should, regardless of age, incorporate aerobic training for recruits to reduce the relative aerobic workload of FF tasks while improving FF performance and ultimately, overall health.

Heart Rate Recovery

Post-exercise heart rate recovery reflects the status of the autonomic nervous system (ANS).[38] Heart rate recovery is usually assessed after 1- (HRR_{1min}) or 2-minutes of rest following exercise, with the first minute indicating the "fast" phase of recovery while all subsequent time considered the "slow" phase.[38] The fast phase reflects the reactivation of the parasympathetic nervous system (PSNS) and the slow phase represents the more gradual decrease in sympathetic nervous system (SNS) activity that corresponds with post-exercise thermoregulation and metabolite clearance.[38]

Low HRR_{1min} reflects poor cardiovascular health, as the inability to reintegrate PSNS activity quickly following exercise is associated with increased risk of CVD and cardiovascular injury.[14] Vivekananthan et al[14] reported that HRR_{1min} is also sensitive to changes in the severity of CVD, which is prevalent in the fire service and a likely component of the sudden cardiac death that contributes about half of the active-duty deaths in FFs.[39] Thus, HRR_{1min} may be a useful health monitoring tool in the fire service. Low HRR_{1min} has been characterized by the inability to recover at least 12 bpm in the 1-minute seated rest period following exercise.[14] Similar to the body composition results, the only age-related difference in HRR_{1min} in the current study was the youngest (A1; 22.5% or 45 bpm) and oldest (A4; 20.7% or 37 bpm) age groups having significantly higher HRR_{1min} than the middle two age groups (A2; 19.6% or 37 bpm, A3; 18.6% or 34 bpm). Based on these HRR_{1min} criteria, the FF recruits in the current study had relatively low cardiovascular injury risk, regardless of age, including the two lowest performing age groups ([A2; 19.6% or 37 bpm] and [A3; 18.6% or 34 bpm]). Given the job demands of FFs will require spontaneous and repeated exposure to near maximal intensity, HRR may also be related to the ability to perform repeated maximal efforts. Future research should explore the relationship between HRR and job-specific performance in FFs.

Movement Efficiency

Movement efficiency screening is an emerging tool within the fire service due to its potential for predicting injury[11] and overall job performance,[15] which both impact career longevity. FFs are routinely exposed to repetitive squatting, stooping, and crawling positionings with concurrent upper body tasks. As such, the current study provides valuable insight into recruits' ability to efficiently perform the fundamental movement of these job-specific movement demands upon entry into the academy. Unlike body composition and aerobic fitness, the current study found no entry route- or age-related differences in MES between groups.

Poor movement efficiency negatively impacts the health of FFs and FF recruits as it translates to an increase in musculoskeletal strain and subsequently increased injury risk.[11] The current study utilized the MES which is scored on a 100-point scale, though cut-offs that indicate when injury is likely to occur have not been reported in the literature. In addition to injury, poor movement efficiency may also contribute to lower performance on specific tasks. Recently, Marciniak et al[15] reported that dynamic balance in FF recruits was positively associated with MES scores which ranged from 40.0 to 98.4. It is possible that the poor movement quality increases the overall demand on the tissues of the joints resulting in a decrement in available movement to perform a task, thereby increasing the risk of injury on the job or in a sport. The range of MES scores in the current study between age groups was small, with A3 scoring the lowest (58.6) and A4 scoring the highest (65.4). Although there are no injury-related cut-offs to compare these recruits to, these scores generally represent movement quality that is moderate to poor.[15] While there is limited evidence surrounding the MES assessment specifically, movement efficiency in FFs is necessary to sustain health and performance in the FF profession. This is further warranted as McQuerry[42] demonstrated that donning the full turnout ensemble creates an immediate reduction of shoulder and hip flexion range of motion by 29% and 18%, respectively. This consideration is key, as movement efficiency in the current study was measured with the recruits in athletic clothing and without shoes on. Therefore, any deficit in mobility under these non-restrictive conditions would be expected to be more limiting upon the donning of turnout gear. As such, to optimize both health and performance in FF recruits, recruit academies may need to incorporate programming that emphasizes movement efficiency in all recruits, irrespective of entry route to the academy or age.

Handgrip Strength

Generally, SHG has been shown to decrease with age,[43] however, the current study found no entry route (i.e., cadet or general population) or age-related differences in SHG in the FF recruits. There is currently a gap in the available literature related to SHG in FF recruits generally, and specifically regarding age-related outcomes. However, the lack of age-related differences in the current recruits is consistent with the work of Parpa and Michaelides[3] using volunteer FFs. Despite this, the range of scores was notably lower in the current recruits (96.5 - 102.8 kg) compared to that sample of volunteer FFs (113.6 - 117.1 kg) as well as the SHG reported by Williford et al[5] in active-duty FFs (116.8 kg). Yet, according to the ACSM classification criteria available for SHG, the current recruits have good-to-very good muscular strength.[26] Further, based on a recent review by Vaishya et al,[43] the current recruits are above any of the identified cut-off values that would be associated with increased risk of psychological disability, CVD, or mortality. Therefore, while SHG may be a useful metric for determining health-related risk in the general population, more work is needed to distinguish these relationships across ages in the fire service.

From a performance perspective, poor SHG can lead to increased task completion times.[5,13,17,18] Many common fire suppression and rescue tasks are demanding of SHG, including roof ventilation, vehicle extrication, hose management, and hoisting.[5,17] Williford et al[5] highlighted the connection between SHG and FF suppression tasks, reporting that SHG was the best predictor of a hose pull task when compared to other general fitness measures such as body composition and VO_{2peak}. Rhea et al[18] later reported that dominant handgrip was significantly related to the time to complete a FF-specific task course, with the strongest individual correlation being between dominant handgrip and hose pull completion time (r = -0.85). Furthermore, unique to the fire service is the role that PPE may play in the ability to express strength. It is interesting to note that the work of Lockie et al[21] found muscular strength is predictive of successfully graduating from FF recruit academies. Thus, SHG may not only represent overall strength[43] and ability to perform tasks, but poor SHG may also contribute to an increased risk of being released from the recruit academy. Future research is warranted to further explore the predictive value of SHG for FF recruits.

Muscular Endurance

Age-related decreases in muscular endurance, specifically using PU, have been reported in the fire service,[4,5] however, the current study did not follow this pattern. Rather, the only differences observed were the A1 group having higher PU than the A2 and A3 groups. No differences were observed between the oldest (A4) group and any other groups. Ras et al[4] reported age-related findings in their active-duty FF population, and they also reported PU scores ranging from 20 repetitions in their oldest age group (50+ years) to 39 repetitions in their youngest age group (20 – 29 years). These PU scores are consistent with those reported by Williford et al[5] who reported a range of 26 to 41 repetitions in the oldest and youngest groups of FFs, respectively. However, specific to FF recruits, there is normative data suggesting that average PU may be higher, with Chizewski et al[20] reporting 42 repetitions in their recruits. In contrast, the current recruits ranged from 28 (A2) to 33 (A1) repetitions. Yang et al[19] reported that those FF who were able to perform more than 40 push-up repetitions had markedly lower risk of developing CVD. Michaelides et al[23] reported that muscular endurance can predict FF task completion times. More recently, Chizewski et al[20] reported that muscular endurance uniquely accounts for 19% of the variance in task completion times, specifically within FF recruits at the start of the academy. There is also evidence to suggest that poor muscular endurance may contribute to an increased risk of being released from the recruit academy, as Lockie et al[21] reported that FF recruits who graduated performed 67 repetitions of PU, while those who were released performed only 56 repetitions. Interestingly, however, even those released recruits performed well in comparison to the normative data available in FFs. Regardless of entry route or age group, the current recruits fall below this 40-repetition threshold.[19] Thus, incorporating training that targets an increase in muscular endurance may improve the health and performance profile of a recruit and may also be an important component of successfully completing the recruit academy.

While all data were collected using the same methods, it is possible that differences in testing environment across the five years of data collection occurred. It is also possible that there were individual differences in pre-testing nutrition. Each of these may have potentially impacted the outcomes. Since the sample was one of convenience and based on who was admitted into the recruit class, the range in performance abilities resulted in a non-normal distribution of the data. While non-parametric testing was used to manage the data, the result are data values that are more difficult to compare to prior studies. In addition, the sample of convenience had less than 15% females in the total analysis. While this percent is larger than the typical female representation in the fire service (9%)[1], it still resulted in an unbalanced sample by sex.

The range in fitness across ages indicate a diversity of needs regarding the programming of physical fitness for recruit academies at the point of entry into an academy. Collectively, these results highlight the unique fitness needs of FF recruits at the start of an academy and prospective career, that are entry route (i.e., CR or GR) and age specific. It is interesting to note that all participants in the current study passed the Candidate Physical Ability Assessment (CPAT) prior to entering the recruit academy. Thus, despite this common performance ability, the physical attributes that are important to performing more fireground specific skills may be underdeveloped in recruits at the start of the academy. Considering this diversity of needs, physical training programs developed for the recruit academy require strategic periodization to facilitate sufficient growth in those with lower physical fitness upon entry without compromising growth in those with higher physical fitness upon entry. Finally, the recruit academy is the ultimate stage of training before recruits are deployed into the field to complete firefighting tasks without the benefit of a controlled environment, planned exercises or proper preparation prior to being tasked with demanding activities. Given that previous literature has shown that recruit academies do create performance improvements in recruits,[20,27] it may be impactful to leverage the physical fitness training elements of an academy as an educational experience to build health and fitness literacy that is one key component to career longevity.

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