Work 75 (2023) 1153–1163
DOI:10.3233/WOR-220612
IOS Press

Utilizing multimodal high-intensity interval training for a firefighter training academy during the COVID-19 pandemic

Zachary A. Mang*, Eric D. Vigil and Jason R. Beam
Occupational Safety and Health, Los Alamos National Laboratory, Los Alamos, NM, USA

Received 25 October 2022
Accepted 5 January 2023

Abstract.
BACKGROUND: Firefighters typically undergo a 16–24-week training academy during which they perform a variety of traditional exercise programs such as cardiovascular, resistance, and concurrent training. Because of limited facility access, some fire departments seek alternative exercise programs, such as multimodal high-intensity interval training (MM-HIIT), which essentially combines resistance and interval training.
OBJECTIVE: The primary purpose of this study was to assess the effect of MM-HIIT on body composition and physical fitness in firefighter recruits who completed a training academy during the coronavirus (COVID-19) pandemic. A secondary purpose was to compare the effects of MM-HIIT to previous training academies that implemented traditional exercise programs.
METHODS: Healthy and recreationally-trained recruits ($n = 12$) participated in 2-3 days/week of MM-HIIT for 12 weeks and had several components of body composition and physical fitness measured before and after the program. Because of COVID-19-related gym closures, all MM-HIIT sessions were performed outdoors at a fire station with minimal equipment. These data were retroactively compared to a control group (CG) that previously completed training academies with traditional exercise programs.
RESULTS: Subjects in the MM-HIIT group significantly improved several components of body composition and fitness, including fat mass, fat-free mass, body fat percentage, aerobic capacity, and muscular endurance. Moreover, there were no significant differences for any dependent variable when MM-HIIT was compared to the CG.
CONCLUSION: These results suggest that MM-HIIT may serve as an effective substitute for traditional concurrent training paradigms that are typically used for firefighter academies.

Keywords: Tactical strength and conditioning, time-efficient training, minimum equipment training, circuit training

1. Introduction

Firefighting is a physically demanding occupation that requires regular exercise training to ensure that fitness levels are sufficient to match job demands [1–5]. The acute physiological effects of firefighting are well documented, as research has indicated that various firefighting operations stimulate high blood lactate concentrations (6–13 mmol·L^{-1}) [6], heart rates (188–190 bpm) [7], and oxygen consumption (33.6–49.0 ml·kg^{-1}·min^{-1}) [8]. Therefore, it is logical that those with higher levels of fitness tend to perform better during simulated fire suppression drills [4] and are at significantly less risk for cardiovascular disease [9] and musculoskeletal injuries [10]. Together, this information implies that physical preparation, and the resulting increase in fitness, may benefit the health, performance, and survival of firefighters. Because fire ground tasks require utilization of the phosphagen (e.g., ladder raise), glycolytic (e.g., load carriage), and oxidative (e.g., stair climb) energy systems, it is recommended that physical prepara-

*Address for correspondence: Zachary A. Mang, 12001 Rocksberg St. NE, Albuquerque, NM 87111, USA. E-mail: zmang@lanl.gov.

tion for firefighters include a blend of cardiovascular, circuit, and resistance training [1, 2].

In most cases, the physical preparation process for firefighters begins with a 16–24-week training academy, during which the recruits learn basic occupational tasks (e.g., hose advance, victim rescue, and fire suppression) while performing a variety of exercise programs [11–17]. Previous investigations into firefighter academies have indicated that normal academy training (i.e., no physical preparation intervention) [14], traditional resistance training (RT) [16], high-intensity functional training (HIFT) [11, 15], and concurrent training [12, 13, 17] all improve the physical fitness of firefighter recruits. Despite these positive effects, some firefighter academies do not provide physical preparation for their recruits [14, 18], which likely stems from a lack of time and resources. In turn, it is critical for fitness professionals to design training interventions that can be performed with minimal equipment and without gym access.

Serving as a hybrid between resistance and interval training, HIFT involves multi-planar, whole-body resistance exercises that are performed for specific set durations (e.g., as many repetitions in 60 seconds) or session durations (e.g., as many rounds as possible for 15 minutes) [19]. The primary advantage of HIFT is that it incorporates several 'functional' patterns of movement (e.g., pushing, pulling, and squatting), which allows it to fit the specific movement demands for a variety of populations [19, 20]. For instance, Sempf & Thienes [20] argued that HIFT should be included in the physical preparation of firefighters because it may improve aerobic fitness, anaerobic capacity, and muscular strength in a time-efficient manner. Provided proper exercise selection, HIFT may also involve training patterns of movement that emulate job-specific tasks such as forcible entry, crawling in a confined space, and victim rescue [20]. It is noteworthy that Sempf & Thienes' description of HIFT as a training style, with prescribed work-to-rest ratios (e.g., 30:15 s), departs from the official definition of HIFT, as Feito et al. [19] specifically wrote that HIFT does not include prescribed rest intervals. Although similar to HIFT, the work-to-rest ratio style of RT is better characterized as multimodal high-intensity interval training (MM-HIIT), which was first described by Buckley et al. [21]. Regardless of semantic differences, HIFT and MM-HIIT both require minimal equipment and time [19–21], and may serve as effective styles of physical preparation that can be conducted at a fire station or drill yard when a gym is not accessible.

The onset of the coronavirus (COVID-19) global pandemic, and subsequent lockdowns associated with it, caused several commercial gyms and wellness centers to close in order to follow social distancing guidelines [22]. In turn, researchers recommended that fitness enthusiasts [23] and athletes [24] partake in convenient forms of physical activity such as aerobic, bodyweight, and low-intensity RT either outdoors or inside of a home gym. Data from a recent survey confirmed that recreational lifters followed this advice, as 82% of respondents indicated that they maintained their participation in an RT program during the COVID-19 pandemic by utilizing high-repetition and/or bodyweight training [25]. Considering the unusual circumstances, it was necessary for strength and conditioning professionals to develop dynamic and creative RT programs for their tactical athletes by using alternative training methods, such as MM-HIIT or HIFT, during the pandemic.

To our knowledge, there is no available research regarding the physical preparation of recruits while navigating the complications of the COVID-19 pandemic (e.g., gym closures and social distancing). Hence, the primary purpose of the current study was to assess the effect of a 12-week MM-HIIT program on various measurements of physical fitness in a population of recruits during a training academy. Uniquely, training took place outdoors at the academy drill yard, with minimal equipment, and while maintaining social distance (greater than six feet apart). We hypothesized that body mass (BM), fat mass (FM), and body fat percentage (BF%) would significantly decrease while fat-free mass (FFM), aerobic capacity, back flexibility, muscular strength, and muscular endurance would significantly increase following the 12-week MM-HIIT program. A secondary purpose of the current study was to assess the effect of MM-HIIT on physical fitness compared to previous firefighter academies that were able to use traditional training approaches. We hypothesized that change scores for physical fitness would not significantly differ between MM-HIIT and traditional training.

2. Materials and methods

2.1. Experimental design

This was an observational, cohort design that assessed the effect of a 12-week MM-HIIT program on the body composition and physical fitness of 12 recreationally-trained recruits. Subjects visited a corporate wellness center for physical fitness testing on two occasions: before (pre) and after (post) the 12-week MM-HIIT intervention. The data collected during these visits included BM, FM, FFM, BF%, estimated maximal oxygen uptake (est-VO_2max), sit-and-reach, bicep strength, and push-up repetitions to failure. Due to the COVID-19 pandemic, all MM-HIIT sessions took place outdoors at the academy drill yard with minimal equipment and subjects spaced greater than six feet apart. This training intervention took place in the Fall of 2021 between the months of August and November. Because the subjects were training to become professional firefighters, they also performed daily physical activity for occupational tasks (e.g., rucking for wildland firefighting) and unplanned bouts of exercise (e.g., pull-ups for disciplinary reasons).

2.2. Subjects

Twelve recreationally-trained, healthy recruits (11 males, 1 female) who were enrolled in a training academy volunteered for this study (experimental group; EG), and the characteristics for the subjects are displayed in Table 1. As a research team, we were not involved in the recruitment process, as the local fire department was completely in charge of how many people were hired to partake in the training academy. Thus, we were not able to conduct an *a priori* power analysis for any of the dependent variables measured in this study. The subjects completed a physical activity survey during their first laboratory visit, which revealed that they were currently participating in cardiorespiratory exercise (15–90 min; 3–5 days/week) and RT (30–60 min; 3-4 days/week). Each subject received medical clearance from a physician which indicated that they were free of cardiovascular disease, metabolic disease, and had no orthopedic injuries that would limit their ability to perform physical activity. Subjects were informed about the potential risks of the MM-HIIT program, and they signed an informed consent to allow the use of pertinent data for potential publication. This protocol was approved by the Human Subjects Research Review Board (Protocol code 22-06X, approved 03 March 2022) and was done in accord with the Declaration of Helsinki of 1964 and its later amendments.

2.3. Control group

To compare the effect of MM-HIIT to previous training academies, we sampled a control group (CG) from a data set that contained 50+ individuals who were previously enrolled in our traditional training academies that were not confined by COVID-19-related restrictions. One researcher, who was blinded to names and corresponding data, followed recently published methodology by Chizewski et al. [11] and identified est-VO_2max-matched controls for subjects in the EG. If multiple matches were found, they were further matched based on their age, height, weight, and BF%. As shown in Table 1, there were no significant differences between EG and CG at baseline. For context, those in the CG participated in a 12-week exercise program during a training academy between 2010 and 2019, for which traditional physical preparation was implemented at a corporate wellness center with a variety of modalities: barbells, dumbbells, machines, battle ropes, kettlebells, and cardiovascular machines (e.g., stationary bikes). Like previous training academy studies [12, 13, 17], subjects in the CG performed a combination of resistance and cardiovascular exercise three days per week for approximately 60 minutes per session.

2.4. Physical fitness testing

To measure physical fitness, we used the Microfit Fas-2 system (Microfit, California, USA) because it was approved by the local fire department labor

Table 1
Baseline physical characteristics for the experimental group (EG) that underwent 12 weeks of multimodal high-intensity interval training and the control group (CG) that underwent 12 weeks of traditional physical preparation that is typically implemented during training academies. Data are displayed as means ± standard deviation

	EG ($n = 12$)	CG ($n = 12$)	p-value	Cohen's d	95% CI
Age (years)	27.6 ± 7.2	25.6 ± 6.3	0.48	0.30; small	[–0.51, 1.10]
Height (cm)	177.3 ± 6.9	176.0 ± 5.8	0.63	0.20; small	[–0.60, 1.00]
Body mass (kg)	79.9 ± 11.4	79.2 ± 6.3	0.84	0.08; small	[–0.72, 0.88]
BF%	16.8 ± 6.1	14.8 ± 4.6	0.37	0.38; small	[–0.44, 1.18]
est-VO_2max (ml·kg^{-1}·min^{-1})	48.6 ± 6.2	48.9 ± 7.0	0.91	0.05; small	[–0.85, 0.76]

EG and CG were matched based on age, height, body mass, body fat percentage (BF%), and estimated relative maximal oxygen consumption (est-VO_2max). CI = Confidence interval.

union and had been used to collect data for past training academies and professional firefighters at this specific fire department. Like Chizewski et al. [11], two researchers conducted the fitness assessments throughout the study, and the same tester performed the pre- and post-MM-HIIT assessments on the same group of subjects (i.e., 6 and 6) to maintain congruity between the tester and the subject. Furthermore, to ensure the consistency of data collection across pre- and post-MM-HIIT assessments, testing took place at the same time of day (7–9 am), and the subjects followed the same pre-test guidelines for both assessments: No strenuous physical activity for 48 hours, abstain from alcohol for 24 hours, drink ample fluids for 24 hours before the test to ensure normal hydration, avoid caffeine and nicotine for 3 hours, consume a small meal/snack 1-2 hours before, and wear loose fitting exercise clothing that they would typically train in. The specific test battery performed for this study, which was also used for the CG during their training academies, was as follows:

2.4.1. 3-site skinfold

Before the skinfold (SKF) measurement, subjects stood on the Microfit floor scale wearing their socks and gym clothes to provide a measurement for BM. When measuring the male subjects, the researcher used their forefinger and thumb to pinch the subcutaneous fat of the chest, abdomen, and thigh [26]. In contrast, the triceps, suprailliac, and thigh [27] were measured for the female subject. Measurements were taken in duplicate, and the average of the skinfolds was used to estimate BF%. A third measurement was taken if the difference between duplicate measurements was greater than 2 mm [17]. The value of BF% was used to calculate FM and FFM for each subject. Pilot data from our lab revealed high interrater reliability between the two testers for this study ($r = 0.95$).

2.4.2. Submaximal cycle ergometer test

Following a self-selected 2-3-minute warm-up, subjects were fitted with a heart rate (HR) monitor (Polar, H10, California, USA) that was worn around the chest. Next, seat height was adjusted so that the subject had approximately 5–10° of knee flexion at the bottom of each pedal stroke. Although subjects were instructed to maintain a cadence of 50–60 RPM, an electronically-braked cycle ergometer (Monark, LC4, Varberg, Sweden) was used to accommodate for any variation in pedaling cadence (i.e., power was constant during each stage). The initial stage was performed at 50 Watts (W), and workload was increased by 25–50 W, as stages progressed. Each stage lasted 2-3 minutes to allow HR to reach steady state, and the subject completed as many stages as necessary to achieve ~80% of estimated maximal HR (220-age). The researchers used two HRs between 110–150 bpm to extrapolate to an est-VO_2max, and the test-retest reliability coefficient for this method was $r = 0.95$ [17]. To accommodate for the limitations of submaximal VO_2max testing with HR data, we also recorded and analyzed the highest workload achieved during the test (High-WL) and the steady-state HR associated with this workload (High-HR).

2.4.3. Sit-and-reach

Subjects sat upright with their legs fully extended so their hamstrings were flat on the floor. Having removed their shoes, the subjects placed their feet approximately six inches apart with their heels resting against the sit-and-reach apparatus. They were instructed to point their toes upward, so their feet were in a neutral position. While keeping their legs extended, and with one hand placed over the other, the subjects were instructed to lean forward and reach as far as possible. The electronic device required the subject to hold their end range of motion for four seconds [28]. Subjects were given three attempts, and the highest measurement was recorded for analysis. The test-retest reliability coefficient for this method was $r = 0.94$ [17].

2.4.4. Bicep strength test

Subjects stood on the Microfit scale and grasped the biceps curl bar with a supinated grip so their hands were approximately as wide as their shoulders [28]. The length of the tether was adjusted so that the subject's elbows were flexed at approximately 90°. Further, the subject was instructed to stand tall with a slight bend in their knees and with their eyes straight ahead. When ready, the subject performed a maximal effort isometric contraction for ~4 seconds, and peak force was recorded by the Microfit system. They were given three attempts with 30 seconds of rest between them, and the highest measurement was recorded for analysis. Pilot data from our lab indicated a high test-retest reliability coefficient for this test ($r = 0.96$).

2.4.5. Push-up test

To assess local muscular endurance, subjects completed as many push-ups as possible until failure or volitional termination. For this assessment, the male subjects began in a prone position with their feet together, back straight, elbows fully extended, and hands slightly wider than their shoulders. The female subject adopted a similar starting position except with her knees on the floor and legs together. The subjects completed a successful push-up by descending until their sternum contacted a four-inch foam block and ascending until their elbows were almost fully extended (i.e., slight bend). Going at their own pace, subjects completed full-range-of-motion push-ups until they voluntarily stopped, reached concentric muscular failure, could not maintain proper form, or rested for longer than approximately one second between consecutive repetitions. The test-retest reliability coefficient for this method was $r = 0.93$ [17].

2.5. Physical training program

MM-HIIT took place 2-3 days per week at the academy drill yard, and each training session was separated by 48–96 hours. Each session of MM-HIIT was facilitated by two researchers who both hold certifications from the National Strength and Conditioning Association (e.g., Certified Strength and Conditioning Specialist) and American College of Sports Medicine (e.g., Certified Exercise Physiologist). Before the training session began, subjects completed a 5–10-minute dynamic warm-up that consisted of multi-planar mobility, stability, and calisthenics as previously described [20]. As shown in Table 2, subjects completed 2-3 rounds of 12 total-body exercises with various work-to-rest ratios (e.g., 30:15 s) and volume was gradually decreased as the week progressed. During each working set, subjects were encouraged to complete as many repetitions as possible, so their Ratings of Perceived Exertion (RPE) was between 8 and 9 at the end of each set [29]. However, for weeks 4, 8, and 12, they were instructed to finish each set with an RPE between 4 and 6, so that much less fatigue was incurred during the set. Exercises were arranged in clusters of three with a general grouping of total-body, lower-body, and upper-body movements. Prescribed rounds (e.g., 2-3) were performed consecutively for each cluster before moving on to the next cluster, and 60 seconds of rest was provided during these transitions. After MM-HIIT was completed, subjects performed 5–10 minutes of static stretching that focused primarily on the shoulder, hip, and ankle joints. Due to training academy commitments and expectations, the subjects also performed two weekly sessions of moderate intensity continuous training (MICT), during which they jogged for 30–60 minutes as a team.

2.6. Statistical analyses

Independent samples *t*-tests were conducted to determine if there were statistically significant differences at baseline between EG and CG for the following dependent variables: age, height, BM, SKF-BF%, and est-VO_2max (ml·kg^{-1}·min^{-1}). The Type 1 error rate for simultaneous comparisons was controlled using the Sidak-Bonferroni Procedure ($\alpha = 1–(1–\alpha_{FW})^{1/c}$, where α_{FW} is the familywise alpha level of 0.05 and $c = 5$ (the number of dependent variables compared in the prior analysis). Therefore, the corrected alpha level was 0.010. Paired-samples *t*-tests were performed to detect if there were statistically significant differences between pre- and post-training in the EG for the following dependent variables: body composition (BM, FFM, FM and SKF-BF%), aerobic capacity [est-VO2max (L·min^{-1}), est-VO2max (ml·kg^{-1}·min^{-1}), high-WL, and high-HR], back flexibility, biceps strength, and push-ups. Independent samples *t*-tests were performed to detect differences in the percent change (%Δ) values between EG and CG for the 11 dependent variables previously listed. The Type 1 error rate for simultaneous comparisons was controlled during the paired-samples and independent samples *t*-tests using the Sidak-Bonferroni Procedure ($\alpha = 1–(1–\alpha_{FW})^{1/c}$, where α_{FW} is the familywise alpha level of 0.05 and $c = 11$ (the number of dependent variables compared in each analysis). Therefore, the corrected alpha level was 0.005.

The assumption of normality was checked using the Shapiro-Wilk test for all *t*-tests. If the assumption was violated ($p < 0.05$) for the paired samples and one-sample *t*-tests, the Wilcoxon signed-rank test was used to determine if there were statistically significant differences between the means. If the assumption was violated ($p < 0.05$) for the independent samples *t*-tests, the Mann-Whitney U test was used to determine if there were statistically significant differences between the means. The assumption of homogeneity of variance was checked for the independent samples *t*-tests using the Levene's Test of Equality of Variances. If the assumption was violated ($p < 0.05$), indicating that the group variances were unequal, an adjusted t-statistic based on the Welch method was used to compare the means. The effect sizes for all *t*-tests were calculated and reported as Cohen's *d* and were interpreted as small ($d \approx |0.25|$), medium ($d \approx |0.5|$), or large ($d \approx |0.8|$) [30]. These interpretations are purely subjective, as the effect size calculation and

Table 2
A visual display of the multimodal high-intensity interval (MM-HIIT) training program

Week	Monday	Wednesday	Friday	
1	2 rounds 30:15 s	2 rounds 25:15 s	2 rounds 20:15 s	**Cluster #1** High knees in place
2	2 rounds 35:15 s	2 rounds 30:15 s	2 rounds 25:15 s	Versa log zercher squat Dumbbell bent over row
3	2 rounds 40:15 s	2 rounds 35:15 s	2 rounds 30:15 s	**Cluster #2** Medicine ball slam
4	3 rounds 20:15 s	3 rounds 20:15 s	3 rounds 20:15 s	Dumbbell lateral lunge Push up w/ shoulder tap
5	2 rounds 35:10 s	2 rounds 30:10 s	2 rounds 25:10 s	**Cluster #3** Jumping jacks
6	2 rounds 40:10 s	2 rounds 35:10 s	2 rounds 30:15 s	Versa log single leg RDL Dumbbell push press
7	2 rounds 45:10 s	2 rounds 40:10 s	2 rounds 35:10 s	**Cluster #4** Medicine ball chop/lift
8	3 rounds 20:10 s	3 rounds 20:10 s	3 rounds 20:10 s	Versa log burpee + deadlift Dumbbell biceps curl
9	2 rounds 40:10 s	2 rounds 35:10 s	2 rounds 30:10 s	
10	2 rounds 45:10 s	2 rounds 40:10 s	2 rounds 35:10 s	
11	2 rounds 50:10 s	2 rounds 45:10 s	2 rounds 40:10 s	
12	3 rounds 20:10 s	3 rounds 20:10 s	3 rounds 20:10 s	

Weeks 4, 8, and 12 served as recovery weeks where volume and effort were intentionally reduced *(left)*. Also, an example of a MM-HIIT exercise routine that was used during the study *(right)*. As a general template, each cluster consisted of a total-body or body-weight cardio exercise, an upper-body exercise, and a lower-body exercise. For each session, subjects completed 2-3 rounds of each cluster with various work-to-rest ratios (30:15 s) before resting for 60 s and moving on to the next cluster. RDL = Romanian deadlift; DL = deadlift.

subsequent reporting simply allows for stronger comparisons between studies in the literature [31]. The 95% confidence interval (CI) for the effect sizes was also calculated and reported. The statistical package JASP (Version 0.16.1, Amsterdam, The Netherlands) was used to conduct all analyses.

3. Results

Baseline physical characteristics for the EG and CG are displayed in Table 1. There were not statistically significant between-group differences at baseline for all five variables ($p > 0.010$). Several measures of physical fitness improved significantly from pre- to post-training in the EG ($p < 0.005$), including SKF-BF%, FFM, FM, est-VO_2max (L·min^{-1}), est-VO_2max (ml·kg^{-1}·min^{-1}), and push-ups (Table 3). There were no statistically significant differences in the %Δ values between EG and CG (Table 4).

4. Discussion

The primary finding of the current study is that a 12-week MM-HIIT program had a positive effect on body composition and several components of physical fitness in recruits who participated in a training academy during the COVID-19 pandemic. Moreover, data from this research suggest that the 12-week MM-HIIT program had similar effects on physical fitness compared to previous academies that used traditional training methods (e.g., concurrent training with regular gym access). These findings bear practical significance for fitness professionals who work with tactical athletes and seek to improve several components of fitness with limited resources, gym access, and time.

In support of our original hypotheses, subjects in the EG increased their FFM, while FM and BF% both decreased. Indeed, losing fat and gaining muscle simultaneously has been reported elsewhere in the RT literature [32, 33]. However, because SKF anal-

Table 3
Mean values for all body composition and physical fitness dependent variables as measured by Microfit for the subjects that underwent 12 weeks of multimodal HIIT training (MM-HIIT), respectively ($n = 12$). Data are displayed as mean ± standard deviation

	Pre-MM-HIIT	Post-MM-HIIT	*p*-value	Cohen's *d*	95% CI
Body mass (kg)	79.9 ± 11.5	78.7 ± 9.5	0.27	–0.34; small	[–0.91, 0.25]
BF%	16.8 ± 6.1	12.3 ± 4.1*	<0.001	–1.60; large	[–2.45, –0.71]
FM (kg)	13.5 ± 5.5	9.7 ± 3.3*	0.001	–1.24; large	[–1.99, –0.46]
FFM (kg)	66.5 ± 10.0	69.0 ± 8.8*	<0.001	1.53; large	[0.67, 2.36]
est-VO_2max (ml·kg^{-1}·min^{-1})	48.6 ± 6.2	60.5 ± 4.9*	<0.001	2.10; large	[1.06, 3.13]
est-VO_2max (L·min^{-1})	3.22 ± 0.54	4.17 ± 0.62*	<0.001	2.43; large	[1.27, 3.57]
High-WL (watts)	181 ± 36	206 ± 24	0.020	0.78; large	[0.12, 1.42]
High-HR (bpm)	148 ± 7	145 ± 6	0.126	–0.48; medium	[–1.07, 0.13]
Sit-and-reach (cm)	42.5 ± 9.5	42.6 ± 9.1	0.27[a]	0.37; small	[–0.25, 0.77]
Biceps strength (kg)	50.0 ± 7.7	52.8 ± 6.4	0.04	0.64; medium	[0.01, 1.25]
Push-up repetitions	41 ± 11	54 ± 8*	<0.001	1.35; large	[0.54, 2.13]

*Significantly different compared to pre-training ($p < 0.005$), BF% = body fat percent, CI = confidence interval, FM = fat mass, FFM = fat-free mass, est-VO_2max = estimated maximal oxygen uptake, High-WL = highest workload achieved during submaximal cycle ergometry test, High-HR = highest heart rate achieved during submaximal cycle ergometry test. [a]Normality was violated, and the Wilcoxon signed-rank test was used to determine if there were statistically significant differences between the means.

Table 4
A comparison of percent change (% Δ) for several measurements of physical fitness between the experimental group (EG; $n = 12$) that underwent 12 weeks of multimodal high-intensity interval training and the control group (CG; $n = 12$) that underwent 12 weeks of traditional physical preparation that is typically implemented during training academies. Each subject had their percent change determined, and the mean of these percent changes was calculated. Data are displayed as means ± standard deviation

	EG % Δ	CG % Δ	*p*-value	Cohen's *d*	95% CI
Body mass (kg)	–1.2 ± 4.5%	–3.2 ± 3.4%	0.24	0.50; medium	[–0.32, 1.30]
BF%	–25.4 ± 11.6%	–13.4 ± 18.3%	0.07	–0.78; large	[–1.61, 0.06]
FM (kg)	–26.0 ± 13.6%	–16.1 ± 17.8	0.14	–0.63; medium	[–1.44, 0.20]
FFM (kg)	4.3 ± 3.7%	–0.6 ± 4.4%	0.01	1.21; large	[0.32, 2.07]
est-VO_2max (ml·kg^{-1}·min^{-1})	30.9 ± 14.1%	24.2 ± 14.9%	0.27	0.46; medium	[–0.35, 1.27]
est-VO_2max (L·min^{-1})	25.6 ± 13.9%	24.9 ± 12.9%	0.89	0.06; small	[–0.75, 0.86]
High-WL (watts)	17.2 ± 22.5%	23.3 ± 16.1	0.45	–0.31; small	[–1.11, 0.50]
High-HR (bpm)	–1.97 ± 4.29	–0.21 ± 3.0	0.25	–0.49; medium	[–1.29,0.33]
Sit-and-reach (cm)	1.5 ± 12.6%	9.4 ± 15.1%	0.23[a]	–0.30; small	[–0.65, 0.16]
Biceps strength (kg)	6.6 ± 9.9%	9.5 ± 20.5%	0.71[a]	–0.10; small	[–0.36, 0.52]
Push-up repetitions	38.9 ± 39.1%	40.3 ± 25.0%	0.67[a]	–0.11; small	[–0.53, 0.35]

BF% = body fat percentage; CI = confidence interval; cm = centimeters; est-VO_2max = estimated maximal oxygen consumption; FM = fat mass; FFM = fat-free mass; kg = kilograms; L = liter; min = minute; ml = milliliter; High-WL = highest workload achieved during submaximal cycle ergometry test; High-HR = highest heart rate achieved during submaximal cycle ergometry test. [a]Normality was violated, and the Mann-Whitney U test was used to determine if there were statistically significant differences between the means.

ysis is a two-component model for measuring body composition [34], and not a direct measure of muscle mass [35], these outcomes should be considered with caution. Although statistically significant differences were not detected between the EG and CG, subjects in the EG increased their FFM by several magnitudes more than the CG, which is reflected by the large effect size ($d = 1.21$; Table 4). However, due to the high degree of variability between recruits and the occupational demands of each training academy, it is difficult to declare that the perceivable difference in FFM were caused by the MM-HIIT program. It is noteworthy that authors from previous training academy studies have reported similar decreases in BF% by using SKF analysis (2.5–5.5%) [12, 13, 17]. In other words, the literature generally agrees that recruits improve their body composition after performing a variety of exercise programs during training academies (e.g., concurrent, HIFT, and RT). Future research can focus on training interventions to help firefighters maintain these positive adaptations, as they tend to gain weight and increase their body mass index as their careers progress [36].

The present data indicate that MM-HIIT helped increase cardiovascular fitness, as est-VO_2max significantly increased for subjects in the EG. As shown in Table 4, the percent increases did not differ from the CG, suggesting that traditional and non-traditional training techniques similarly influence aerobic capacity during training academies. Both of these findings support our hypotheses. Taken as an absolute value, the post-MM-HIIT data point ($60.5 \cdot ml \cdot kg^{-1} \cdot min^{-1}$) is much higher than previously reported est-VO_2max following various training academy programs (41.1–$46.9\ ml \cdot kg^{-1} \cdot min^{-1}$) [11, 12, 14, 15, 17]. However, when considered as a percent increase (+25%), the current data is nearly identical to previously reported improvements in est-VO_2max (+25–28%) [12, 17], but is still considerably larger than others (+6.4–11.6%) [11, 15]. Disparities between studies are likely explained by differences in the est-VO_2max protocol employed (e.g., submaximal cycle ergometer, forestry step test, and 1.5-mile run test), which reflects that tactical populations may not have access to, or clearance to perform, maximal laboratory-based aerobic assessments. Despite the unusually high est-VO_2max, we contend that our subjects increased their cardiovascular fitness as reflected by a large ($d = 0.78$; Table 3), albeit non-significant ($p = 0.02$; Table 3), increase in High-WL (25W) and a non-significant decrease in High-HR (3 bpm) during the cycle ergometer test [37]. Given the inverse relationship between VO_2max and cardiovascular disease risk factors in firefighters [38], it is important to maintain cardiovascular fitness beyond the training academy.

For upper-body muscular endurance, data revealed that the EG significantly improved their push-up performance, and their percent increase did not differ from the CG. Both results supported our hypotheses. These outcomes are consistent with previous studies that reported significant increases in push-up performance during a training academy (25–37%) [11, 12, 17]. In contrast, Hollerbach et al. [15] reported a non-significant increase in push-up performance (4.4 reps) following a 10-week HIFT program. This divergence from the typical increase in push-up performance could be explained by smaller sample size ($n = 7$), or the fact that their training sessions were unsupervised [15]. In other populations, there is evidence that HIFT/MM-HIIT increased squat endurance performance [20], sit-up performance [39, 40], bench press repetitions with submaximal loads [39, 40], and time-to-exhaustion during cardiovascular tasks [40]. Thus, HIFT/MM-HIIT can be used to increase muscular endurance for training academies and beyond, which may ultimately have a positive effect on firefighting performance [41].

Contrary to our hypothesis, subjects in the EG did not significantly increase their muscular strength during the 12-week MM-HIIT intervention. As shown in Table 4, percent changes did not differ between EG and CG, which suggests that recruits from the current fire department do not typically improve their strength during training academies. Alternatively, the biceps dynamometry test may only reflect changes in strength for the elbow flexors, and the subjects may not spend enough time performing isolated elbow flexion exercises [42]. The current results do not reflect previous studies, as the literature generally agrees that recruits increase their strength during training academies [12, 15, 16]. For instance, it has been reported that recruits increase their hand-grip strength [15], estimated 1-RM for bench press and back squat [12], and true 1-RM for bench press and back squat [16]. Although speculative, it is possible that differences between studies stem from inconsistent measurement techniques, as the firefighter academy literature includes several field- and laboratory-based assessments for strength. Because muscular strength tends to increase at a variety of repetition ranges and associated external loads [43, 44], it would be interesting for future researchers to compare different work-to-rest configurations with light, moderate, and heavy loads during MM-HIIT.

Similar to the muscular strength outcomes, back flexibility did not improve for the EG or CG, which means that our hypothesis was not supported. However, this result is consistent with previous research, as recruits tend to not increase their sit-and-reach scores during training academies [11, 15, 16]. Collectively, these data imply that recruits may not perform enough isolated flexibility and mobility work during their physical preparation process. For example, there is evidence that 6 weeks of yoga training improved back flexibility and total-body movement competency (i.e., Functional Movement Screen; FMS) in shift-based professional firefighters [45]. In a similar manner, Cornell et al. [13] reported that FMS scores improved after 14 weeks of academy training, although back flexibility was not measured or reported in this study. Because the FMS includes total-body movements that require mobility and stability in multiple planes (e.g., squatting, stepping, and lunging) [13, 45], it may be a more appropriate tool for assessing mobility and flexibility for the firefighting population.

For practitioners, it is interesting that circuit training with tactical gear [3] and traditional periodization models [16] both improve firefighter performance because this presents two extremes of a spectrum, where exercising with minimal and maximal gym access both elicit positive effects. The current MM-

HIIT program required only four forms of resistance that were easy to transport and use outside at the fire station: body weight, dumbbells (6.8–13.6 kg), Dynamax medicine balls (4.5–9.1 kg), and Versa Logs (9.1–18.2 kg). Considering that physical preparation during our traditional academies was completed with state-of-the-art equipment for cardiovascular and resistance training, the data in Table 4 are intriguing. In fact, the lack of difference between EG and CG for nearly every component of fitness suggests that MM-HIIT (i.e., like HIFT) [19–21] could be a suitable substitute for traditional training techniques, which corroborates recent research in firefighters [11, 15].

Several limitations should be considered when interpreting the results from this research, and it is worth highlighting that these limitations are consistent with previous training academy studies [11–17]. Most noteworthy, because subjects were not randomly assigned to different experimental conditions, it was impossible to isolate the effect of MM-HIIT from other competing factors (e.g., physical activity performed during occupational tasks). Also, because this was not a true, randomized-controlled trial, we selected a *post-hoc* CG from pre-existing data [11], which limits the veracity of the comparisons made between the EG and CG in the current study. Dietary information was not collected during this study, so the influence of caloric intake and macronutrient distribution are unknown. Furthermore, because we had to use measurement tools that were approved by the local fire department and the associated labor union, we were confined to field-based techniques for measuring components of fitness. Last, these data were collected in healthy, previously trained recruits and should be cautiously generalized to other populations.

5. Conclusions

The present study demonstrated that 12 weeks of MM-HIIT helped improve several measurements of body composition and physical fitness in a class of recruits who participated in a training academy amidst the COVID-19 pandemic. Despite training outdoors and with minimal equipment, MM-HIIT led to similar outcomes as previous academies that had unlimited gym access and were able to use a variety of traditional training modalities. These results are critical for fitness professionals who train occupational athletes, such as firefighters, who may have limited time, equipment, and/or access to a formal gym setting. The current training sessions involved 12 total-body exercises that were arranged in four clusters of three exercises, which generally followed a pattern of total-body calisthenics + lower-body movement + upper-body movement. We encourage practitioners to consider our MM-HIIT program as a malleable template that can be modified to accommodate the specific needs of their athletes and access to equipment.

Acknowledgments

The authors would like to thank the recruits who volunteered for this study and congratulate them for successfully completing the academy. In addition, they would like to thank Adam Martinez for his assistance with the conditioning sessions and fitness testing during the academy.

Conflict of interest

The authors report no conflicts of interest.

Funding

The authors did not receive funding for this project.

References

[1] Abel MG, Mortara AJ, Pettitt RW. Evaluation of circuit-training intensity for firefighters. J Strength Cond Res 2011;25(10):2895-901.

[2] Abel MG, Palmer TG, Trubee N. Exercise program design for structural firefighters. Strength Cond J. 2015;37(4):8-19.

[3] Pawlak R, Clasey JL, Palmer T, Symons TB, Abel MG. The effect of a novel tactical training program on physical fitness and occupational performance in firefighters. J Strength Cond Res. 2015;29(3):578-88.

[4] Smith DL. Firefighter fitness: Improving performance and preventing injuries and fatalities. Curr Sports Med Rep. 2011;10(3):167-72.

[5] Smith DL, Graham E, Stewart D, Mathias KC. Cardiovascular disease risk factor changes over 5 years among male and female us firefighters. J Occup Environ Med. 2020;62(6):398-402.

[6] Gledhill N, Jamnik VK. Characterization of the physical demands of firefighting. Can J Sport Sci. 1992;17(3):207-13.

[7] Horn GP, Kesler RM, Motl RW, et al. Physiological responses to simulated firefighter exercise protocols in varying environments. Ergonomics. 2015;58(6):1012-21.

[8] Sothmann MS, Saupe KW, Jasenof D, et al. Advancing age and the cardiorespiratory stress of fire suppression: Determining a minimum standard for aerobic fitness. Hum Perform. 1990;3(4):217-36.
[9] Davis SC, Jankovitz RZ, Rein S. Physical fitness and cardiac risk factors of professional firefighters across the career span. Res Q Exerc Sport. 2002;73(3):363-70.
[10] Jahnke SA, Poston WSC, Haddock CK, Jitnarin N. Obesity and incident injury among career firefighters in the central United States. Obesity. 2013;21(8):1505-8.
[11] Chizewski A, Box A, Kesler RM, Petruzzello SJ. High intensity functional training (HIFT) improves fitness in recruit firefighters. Int J Environ Res Public Health. 2021;18(24):1-16.
[12] Cornell DJ, Gnacinski SL, Meyer BB, Ebersole KT. Changes in health and fitness in firefighter recruits: An observational cohort study. Med Sci Sports Exerc. 2017;49(11):2223-33.
[13] Cornell DJ, Gnacinski SL, Ebersole KT. Functional movement quality of firefighter recruits: Longitudinal changes from the academy to active-duty status. Int J Environ Res Public Health. 2021;18(7):1-10.
[14] Gnacinski SL, Ebersole KT, Cornell DJ, Mims J, Zamaow A, Meyer BB. Firefighters' cardiovascular health and fitness: An assessment of heart rate recovery and maximal oxygen uptake training adaptations that occur during firefighter training academies. Work. 2016;54(1): 43-50.
[15] Hollerbach BS, Jahnke SA, Poston WSC, Harms CA, Heinrich KM. Examining a novel firefighter exercise training program on simulated fire ground test performance, cardiorespiratory endurance, and strength: A pilot investigation. J Occup Med Toxicol. 2019;14(12): 1-10.
[16] Peterson MD, Dodd DJ, Alvar BA, Rhea MR, Mike F. Undulation training for development of hierarchical fitness and improved firefighter job performance. J Strength Cond Res 2008;22(5):1683-95.
[17] Roberts MA, O'Dea J, Boyce A, Mannix ET. Fitness levels of firefighter recruits before and after a supervised exercise training program. J Strength Cond Res. 2002;16(2):271-7.
[18] Williams-Bell F, Kapralos M, Hogue B, Murphy A, Weckman A. Using serious games and visual simulation for training in the fire service: A review. Fire Technol. 2015;51:553-84.
[19] Feito Y, Heinrich KM, Butcher SJ, Poston WSC. High-intensity functional training (HIFT): Definition and research implications for improved fitness. Sports. 2018;6(3):76.
[20] Sempf F, Thienes G. High-intensity functional training for firefighters. Strength Cond J. 2021. ePub ahead of print; doi: 10.1519/SSC. 0000000000000659.
[21] Buckley S, Knapp K, Lackie A, Lewry C, Horvey K, Benko C, Trinh J, Butcher S. Multimodal high-intensity interval training increases muscle function and metabolic performance in females. Appl Physiol Nutr Metab. 2016;40(11):1157-62.
[22] Kaur H, Singh T, Arya KY, Mittal S. Physical fitness and exercise during the COVID-19 pandemic: A qualitative enquiry. Front Psychol. 2020. https://doi.org/10.3389/fpsyg.2020.590172.
[23] Hammami A, Harrabi B, Mohr M, Krustup P. Physical activity and coronavirus disease 2019 (COVID-19): Specific recommendations for home-based physical training. Man Sport Leisure. 2020. https://doi.org/10.1080/23750472.2020.1757494.
[24] Jukic I, Calleja-Gonzales J, Cos F, et al. Strategies and solutions for team sports athletes in isolation due to COVID-19. Sports. 2020;8(4):56.
[25] Steele J, Androulakis-Korakis P, Carlson L, et al. The impact of Coronavirus-19 (COVID-19) related public-health measures on training behaviors of individuals participating in resistance training: A cross-sectional survey study. Sports Med. 2021;51(7):1561-80.
[26] Jackson AS, Pollock ML. Generalized equations for predicting body density of men. Br J Nutr. 1978;40(3):497-504.
[27] Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. Med Sci Sports Exerc. 1980;12(3):175-81.
[28] Verdan PJR, Marzilli TS, Barna GI, et al. Effect of the Power Balance band on static balance, hamstring flexibility, and arm strength in adults. J Strength Cond Res. 2012;26(8):2113-8.
[29] Greig L, Hemingway BHS, Aspe RR, Cooper K, Comfort P, Swinton PA. Autoregulation in resistance training: Addressing the inconsistencies. Sports Med. 2020;50(11): 1873-87.
[30] Cohen J. Statistical power analysis for the behavioral sciences (2nd Edition) Hillsdale, NJ: Erlbaum, 1988.
[31] Laken D. Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. Front Psych. 2013. https://doi.org/10.3389/fpsyg.2013.00863.
[32] Longland TM, Oikawa SY, Mitchell CJ, Devries MC, Phillips SM. Higher compared with lower dietary protein during an energy deficit combined with intense exercise promotes greater lean mass gain and fat mass loss: A randomized trial. Am J Clin Nutr. 2016;103(3):738-46.
[33] Stratton MT, Tinsley GM, Alesi MG, et al. Four weeks of time-restricted feeding combined with resistance training does not differentially influence measures of body composition, muscle performance, resting energy expenditure, and blood biomarkers. Nutrients. 2020;12(4):1126.
[34] Kasper AM, Langan-Evans C, Hudson JF, et al. Come back skinfolds, all is forgiven: A narrative review of the efficacy of common body composition methods in applied sports practice. Nutrients. 2021;13(4):1075.
[35] Franchi MV, Longo S, Mallinson J, Quinlan JI, Taylor T, Greenhaff PL, Narici MV. Muscle thickness correlates to muscle cross-sectional area in the assessment of strength training-induced hypertrophy. Scand J Med Sci Sports. 2018;28(3):846-53.
[36] Mathias KC, Bode ED, Stewart DF, Smith DL. Changes in firefighter weight and cardiovascular disease risk factors over five years. Med Sci Sports Exerc. 2020;52(11):2476-82.
[37] Hellsten Y, Nyberg M. Cardiovascular adaptations to exercise training. Compr Physiol. 2015;6(1):1-32.
[38] Baur DM. Christophi CA, Tsismenakis AJ, Cook EF, Kales SN. Cardiorespiratory fitness predicts cardiovascular risk profiles in career firefighters. J Occup Enviromen. 2011;53(10):1155-60.
[39] Posnakidis G, Aphamis G, Giannaki CD, et al. High-intensity functional training improves cardiorespiratory fitness and neuromuscular performance without inflammation or muscle damage. J Strength Cond Res. 2022;36(3):615-23.
[40] Wilke J, Kaiser S, Niederer D, et al. Effects of high-intensity functional circuit training on motor function and sport motivation in healthy, inactive adults. Scand J Med Sci Sports. 2019;29(1):144-53.

[41] Michaelides MA, Parpa KM, Thompson J, Brown B. Predicting performance on a firefighter's ability test from fitness parameters. Res Q Exerc Sport. 2008;79(4):468-75.
[42] Mannarino P, Matta T, Lima J, Simao R, Freitas de Salles B. Single-joint exercise results in higher hypertrophy of elbow flexors than multi-joint exercise. J Strength Cond Res. 2021;35(10):2677-81.
[43] Schoenfeld BJ, Grgic J, Ogborn D, Krieger JW. Strength and hypertrophy adaptations between low- vs. high-load resistance training: A systematic review and meta-analysis. J Strength Cond Res. 2017;31(12):3508-23.
[44] Schoenfeld BJ, Grgic J, Van Every DW, Plotkin DL. Loading recommendations for muscle strength, hypertrophy, and local endurance: A re-examination of the repetition continuum. Sports. 2021;9(2):32.
[45] Cowen VS. Functional fitness improvements after a worksite-based yoga initiative. J Bodyw Mov Ther. 2010;14(1):50-4.