Comparing Physical Fitness in Career vs. Volunteer Firefighters

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Abstract

Morris, CE, Arnett, SW, and Winchester, LJ. Comparing physical fitness in career vs. volunteer firefighters. *J Strength Cond Res* 36(5): 1304–1309, 2022—The purpose of this study was to assess the potential similarities and differences in health and physical fitness profiles between career firefighters (CFF) and volunteer firefighters (VFF). The research protocol consisted of a health and physical fitness assessment, testing the 5 components of health-related fitness using previously published and accepted protocols. The subject population consisted of a total of 138 firefighters, including 119 CFF and 19 VFF. Statistical significance was defined as a p level less than 0.05. An independent t test showed evidence of CFF having a significantly higher value/score for the following variables: height ($p = 0.034$), $\dot{V}O_2max$ ($p = 0.006$), push-ups completed ($p = 0.024$), and plank time ($p < 0.001$). Volunteer firefighters had a significantly higher value for the following variables: fat mass ($p = 0.002$), body fat percentage ($p < 0.001$), and absolute grip strength ($p = 0.029$). There were no significant differences between groups for the following variables: age ($p = 0.299$), body mass ($p = 0.166$), fat-free mass ($p = 0.281$), body mass index ($p = 0.057$), flexibility ($p = 0.106$), or relative grip strength ($p = 0.887$). With regard to physical fitness testing, the VFF had a significantly worse fitness profile across a number of variables than the CFF. Practical applications: Despite the financial and commitment status of volunteer firefighting departments, their members perform an equally dangerous and important job as do firefighters of professional/career firefighting departments, and more attention should be directed toward developing the fitness and performance of these firefighters.

Key Words: occupational ergonomics, tactical performance, first responders

Introduction

The National Fire Protection Association (NFPA) conducts a regular national fire experience survey to determine injury rates of firefighters based on the type and location of injury. Haynes and Molis (14) published the data from the 2016 survey and reported that an estimated 62,085 firefighter injuries occurred in the previous year, with 39.2% of these injuries occurring on the fire ground. Of those injuries occurring on the fire ground, the leading cause of injury was due to overexertion or strain (27.1%), closely followed by injuries due to falls, jumps, or slips (21.0%) (14). The wearing of personal protective equipment (PPE), along with related turnout gear worn by firefighters that is vital for their safety, has been shown to also create a considerable challenge for the body to manage heat dissipation. The symptoms of heat stress and muscular fatigue are substantially elevated along with a lowered range of motion while wearing turnout gear (5,6). The heavy layers of the turnout gear are necessary for protection; however, it can decrease water vapor permeability, preventing body heat dissipation through evaporation. The risk of thermoregulatory dangers increases in this situation (18).

As evidence exists that carrying added weight leads to an increased cardiovascular and metabolic load, a logical hypothesis would be that carrying additional unnecessary weight could also lead to added physiological stress. Excess body fat not only has an effect on decreasing exercise efficiency but also limits mobility and the capacity to dissipate heat (8). Kales et al. (17) conducted medical evaluations on 333 professional firefighters and found that the mean body mass index (BMI) was 28.9 $kg \cdot m^{-2}$ (placing them in the overweight category). These researchers reported that of the firefighters evaluated 51% were considered overweight (BMI $\geq$ 25.0 $kg \cdot m^{-2}$), 34% were considered obese (BMI $\geq$ 30.0 $kg \cdot m^{-2}$), and 2% were considered morbidly obese (BMI $\geq$ 40.0 $kg \cdot m^{-2}$) (15). Clark et al. (4) reported that of the 218 professional firefighters assessed in their study, the mean BMI was 28.8 $kg \cdot m^{-2}$ and 48% were considered overweight, 29.8% were considered obese, and 2.3% were considered morbidly obese. This means that 80.7% of the firefighters evaluated were considered overweight, obese, or morbidly obese (4). Poston et al. (26) estimated body fat percentage using bioelectrical impedance analysis and reported similar findings to previously published studies in which 79.5% of 478 career firefighters (CFF) and 78.4% of 199 volunteer firefighters (VFF) were overweight. With regard to obesity status, 33.5% of CFF were considered obese and 43.2% of volunteer firefighters were considered obese (26). Munir et al. (23) also estimated body fat percentage using bioelectrical impedance analysis and reported that of a sample of 1,232 firefighters, 53% were considered overweight and 13% were considered obese. In addition, significant inverse relationships were reported between BMI and blood pressure, aerobic capacity, and total cholesterol (4). These results demonstrate the potentially high prevalence of excess bodyweight and obesity in firefighting professionals (4,15). It has been well established that performing strenuous physical work often precedes, or even initiates, myocardial infarction (MI) (20). Cady et al. (2) reported

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that firefighters who are unfit are 2.6 times more likely to suffer from MI than firefighters who are considered fit. Washburn et al. (31) reported that the number one cause of death of firefighters is MI.

Several studies (9,15,24) have noted that a near maximal heart rate (HR) combined with a substantial rise in core temperature can be experienced while conducting tasks related to firefighting. Therefore, performing these tasks, combined with wearing full turnout gear, could potentially be associated with an increased risk of experiencing a cardiovascular event, such as MI. Calavalle et al. (3) reported that the main factors that influence the performance of a firefighting-simulated stair-climbing test are the ability to carry a heavy load (22.8% of total variance), effect of excessive body fat (19.6% of total variance), age (19.3% of total variance), and fitness level (16.4% of total variance). This finding implies that although fitness level is important to perform tasks related to firefighting, carrying a load (which is common in firefighting) and potential excess body mass are the most important variables to be considered (3). This discovery supports previous findings by Perroni et al. (25) that even firefighters who are considered experts in their field can experience a severe physiological challenge based on unpredictable environmental conditions, especially if they lack an adequate level of fitness. Combining these results together, performing heavy physical labor while wearing a full turnout gear can elicit near maximal HRs that, for a person who is considered overweight or obese, can substantially increase the likelihood of experiencing a cardiac event (3,8,30).

Some firefighting departments are composed of professional firefighters (CFF), whereas some smaller towns cannot fully fund a professional firefighting department and rely on their citizens to volunteer their time and put their lives at risk to perform fire suppression and other related firefighting tasks when those events arise. The NFPA defines a volunteer firefighter as any active part-time (call or volunteer) firefighter (12). According to the most recently collected data by the NFPA, 65% of all firefighters in the United States in 2017 were considered VFF (12). A recent study reported that VFF had a poor physical fitness status and exhibited elevated risk factors for cardiovascular disease (CVD) (19). However, this study did not directly compare the physical fitness status and abilities of the VFF with firefighters from a career firefighting department.

Firefighters from career firefighting departments are required to perform exercise training as part of their daily work regimen, whereas volunteer firefighting departments do not have the same set of standards in place with regard to physical fitness training. It is possible that this lack of physical fitness training could lead those individuals to possess a lower level of physical fitness and potentially expose them to an increased risk of musculotendinous injury or a cardiac event. This leads to the research hypothesis that VFF may have a significantly poorer physical fitness profile than CFF. Therefore, the purpose of this study was to assess the potential similarities and differences in health and physical fitness profiles between CFF and VFF.

Methods

Experimental Approach to the Problem

The aim of this study was to assess the health and physical fitness profiles of firefighting departments using a cross-sectional design. The physical fitness measures that were chosen were centered around the 5-component model of health-related fitness: body composition, muscular strength, muscular endurance, cardiovascular fitness, and flexibility. Each subject had their physical fitness evaluated using standardized and recommended protocols contained within the Wellness-Fitness Initiative published by the International Association of Fire Fighters (IAFF) (16). All descriptions of testing that follows were conducted using protocols contained therein.

Subjects

Subjects were recruited to the study through the respective chiefs of each fire department. The CFF were all members of the Bowling Green Fire Department (BGFD) in Bowling Green, KY. The VFF were all members of the Warren County Fire Department (WCFD) in Warren County, KY. This study was approved by the Institutional Review Board of Western Kentucky University. All subjects read and signed the University's Institutional Review Board–approved informed consent. The total sample size consisted of 138 firefighters, comprising 119 CFF and 19 VFF.

Procedures

All testing and evaluation was conducted "on site" at the respective department fire houses within the selected region. All measures described therein were completed by team members who possessed a number of nationally and internationally recognized field-related certifications. The certifications included the following: National Strength and Conditioning Association–Certified Strength and Conditioning Specialists (CSCS), American College of Sports Medicine–Certified Exercise Physiologist (ACSM-EP), National Athletic Trainers Association–Certified Athletic Trainer (ATC), and USA Weightlifting Sports Performance Coach. Before arrival for any testing session, all subjects were requested to follow their normal dietary habits and patterns, with the exception that they were requested to be at least 1 hour after their most recent meal. Each subject completed a 24-hour dietary recall to ensure that they met the proper requirements to complete the visit on that day. The Physical Activity Readiness Questionnaire (PAR-Q) (29) was used during the screening process to screen for any potential contraindications to exercise. The resting HR and blood pressure were evaluated after a 5-minute seated rest to ensure that resting values fall within normal limits.

On completing resting HR and blood pressure measurements, each subject had height and body mass measured using standard scales. The BMI was calculated from these height and body mass values. Next, body composition was estimated using a skinfold measurement technique. This involves the measurement of skinfold thickness at 7 predetermined sites on the subject's body (chest, triceps, subscapula, midaxillary, abdomen, suprailliac, and thigh) using Lange skinfold calipers (Beta Technology, Santa Cruz, CA). Each site was measured 3 times, and if the difference between the measurements exceeded 3–5 mm, an additional measurement was made. The average measurement thickness at each site was then used in standardized equations to predict body fat percentage using previously published equations and protocols (1). After estimation of body composition, each subject completed a hand grip strength test using a hand grip dynamometer (Takei Scientific Instruments Co., Ltd., Niigata City, Japan). To complete this test, the subject grasped a hand grip testing device and squeezed it as hard as they could. Three repetitions were completed for each hand, and the maximum for each hand was used to calculate absolute hand grip strength (in kg). Relative grip strength was also calculated with the absolute grip strength divided by body mass (kg). The muscular endurance assessment included 2 separate tests, a push-up test and a prone static plank test, following previously published protocols (16). The push-up test began with the subject starting in the standard "up" position (hands pointing forward and under the shoulder, back straight, and head up, using the toes as the pivot point). Next, the subject lowered their body by bending the elbows until the chin (or chest) touched a cup that was 5 inches tall and then returned to the "up" position. The test was stopped when the subject strained forcibly, was unable to maintain the appropriate technique within 2 repetitions (or volitional fatigue), or performed a maximum of 80 push-ups. The prone static plank test involved the subject holding a prone plank position on a padded mat for as long as they could (up to a maximum of 4 minutes).

The next test of physical fitness involved a sit-and-reach test to evaluate flexibility. To conduct this test, the subject sat on the floor with their legs extended and feet flat against a sit-and-reach trunk flexibility box (Baseline Evaluation Instruments, White Plains, NY). To complete this test, the subject slowly reached forward with both hands as far as possible and held that position for approximately 2 seconds. They were encouraged to exhale and drop their head between their arms when reaching and informed that their knees must remain extended.

The final test involved an evaluation of aerobic capacity ($\dot{V}O_2max$). After a brief warm-up, the subject completed a Gerkin Protocol Aerobic Capacity Test (10,11,16). This assessment as outlined by the IAFF must involve a step test or a treadmill test based on the equipment available at the fire house. The treadmill test was conducted for each subject in this particular study and involved walking/running on a treadmill, beginning at a pace of 3.0 mph and 0% grade and increased incrementally each minute. During this aerobic capacity test, the HR was measured continuously, and the aerobic capacity was estimated based on the subject's HR response to the workload. After the completion of the aerobic capacity assessment, the subject was permitted to leave.

Statistical Analyses

An independent t test was used to compare all dependent variables for each subject within their respective group [height, aerobic capacity ($\dot{V}O_2max$), plank time, and absolute grip strength]. In the event that the homogeneity of variance assumption was violated (using Levene's Test for Equality of Variances), then Welch's t-test was calculated instead. This applied to the following variables: age, body mass, fat mass (FM), fat-free mass (FFM), BMI, body fat percentage, push-ups completed, flexibility, and relative grip strength. All analyses were conducted using SPSS software (Version 24, SPSS, Inc., Chicago, IL). Statistical significance was defined as a p-level less than 0.05, and the effect size was calculated using Cohen's d. Previously published recommendations (7) were used for determining parameters for small ($d = 0.2$), medium ($d = 0.5$), and large effects ($d = 0.8$).

Results

Physical and Demographic Characteristics of the Sample

Table 1 displays the physical and demographic characteristics of the sample, separated by group (VFF or CFF). Table 2 displays the physical fitness testing data. There was evidence of a significant difference between groups for the following variables: height ($p = 0.034$, $d = 0.53$), FM ($p = 0.002$, $d = 0.88$), BF ($p < 0.001$, $d = 1.37$), $\dot{V}O_2max$ ($p = 0.006$, $d = 1.25$), push-ups completed ($p = 0.024$, $d = 0.88$), plank time ($p < 0.001$, $d = 1.15$), and absolute grip strength ($p = 0.027$, $d = 0.55$). There were no significant differences between groups for the following variables: age ($p = 0.299$), body mass ($p = 0.166$), BMI ($p = 0.057$), FFM ($p = 0.281$), flexibility ($p = 0.106$), or relative grip strength ($p = 0.887$).

Table 1

Characteristics of Career vs. Volunteer Firefighters.*

	Group	Mean	*SD*
Age (y)	CFF	38.2	7.3
	VFF	34.7	14.0
Height (m)	CFF	1.81‡	0.07
	VFF	1.77‡	0.08
Body mass (kg)	CFF	92.4	14.0
	VFF	102.8	30.8
FFM (kg)	CFF	74.3	9.1
	VFF	69.6	17.9
FM (kg)	CFF	18.1‡	6.4
	VFF	33.7‡	19.0
BMI (kg·m^{-2})	CFF	28.4	4.0
	VFF	32.4	8.5
Body fat (%)	CFF	19.3‡	4.6
	VFF	29.4‡	7.7

*CFF = career firefighters; VFF = volunteer firefighters; FFM = fat-free mass; FM = fat mass; BMI = body mass index.
‡Represent a significant difference between groups.

Discussion

To the best of the authors' knowledge, the current study is the first to compare the health and fitness status of VFF versus firefighters from professional firefighting departments. Firefighters from the BGFD, which is a professional firefighting department made up entirely of CFF, are required to perform exercise training as part of their daily work regimen. The exercise programming is designed and implemented by trainers and instructors who have national certifications relevant to exercise programming. These fitness trainers have a variety of training backgrounds and certifications from nationally relevant and legitimate bodies including the National Strength and Conditioning Association (NSCA), the American College of Sports Medicine (ACSM), and the American Council on Exercise (ACE). These trainers are also members of the BGFD as well, so they are well-versed on the

Table 2

Physical Fitness Testing of Career vs. Volunteer Firefighters.*

	Group	Mean	*SD*
$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})	CFF	47.8‡	6.1
	VFF	38.9‡	7.2
Push-ups	CFF	34.8‡	9.9
	VFF	25.0‡	17.1
Plank (min)	CFF	2.23‡	1.1
	VFF	0.99‡	0.7
Flexibility (in)	CFF	12.0	3.4
	VFF	10.0	5.0
Absolute strength (kg)	CFF	100.5‡	15.0
	VFF	109.4‡	22.0
Relative strength	CFF	1.11	0.2
	VFF	1.11	0.3

*CFF = career firefighters; VFF = volunteer firefighters.
‡Represent a significant difference between groups.

physical requirements of a firefighter to perform their job safely and effectively. By contrast, the VFF of the WCFD are not required to perform any fitness training as part of their job. Some departments provide some exercise equipment, but the availability and usefulness of that equipment is often based on available funding. This funding, or lack thereof, is often a limiting factor for these departments in providing exercise training equipment. Because of the nature of the VFF performing their jobs on a volunteer basis, whether they decide to perform exercise training on their own or not is entirely up to them.

With regard to the physical fitness testing of the current sample, the health and physical fitness profiles of VFF were significantly worse across a number of variables than that of CFF. In particular, when evaluating the body composition data, the CFF were considered to be the normal and healthy ranges for degree of body fat, whereas the VFF were considered significantly overweight and possibly obese (1). The BMI of the CFF (28.4 $kg \cdot m^{-2}$) falls in the overweight range (25.0–29.9 $kg \cdot m^{-2}$); however, considering that the average degree of body fat for the CFF (19.3%) is in the 55th percentile (based on gender- and age-based norms) and falls within normal and healthy ranges, this value can offset the overweight BMI score (1). The BMI of the VFF (32.4 $kg \cdot m^{-2}$) falls squarely in the class I obesity range (30.0–24.9 $kg \cdot m^{-2}$). Combining that finding along with the average degree of body fat for the VFF (29.4%) being in the ninth percentile (based on gender- and age-based norms), it is potentially alarming that these individuals with such a lack of fitness, in terms of body composition, are consistently experiencing heat stress when performing fire suppression (1). This degree of excess body fat is alarming and greatly increases the chances for a cardiac event to occur during a fire suppression task. Unfortunately, this level of overweight and obesity status in the current sample of VFF is similar to values reported elsewhere (19). As described by multiple authors (8,9,15,24), possessing a high degree of excess body fat greatly reduces the capacity for heat dissipation, which not only hampers the ability to perform the job properly but also decreases the level of safety of firefighters themselves. Recent evidence also shows that just the weight of the gear alone (without even taking into consideration the trapping of heat commonly occurring with PPE) significantly elevates the degree of physiological strain experienced by normal weight, healthy adults (22). It is likely that each additional increase in fat mass could place an increasing amount of cardiovascular stress on the body. Increases in additional fat mass carried by firefighters could also greatly impact job performance biomechanics, perhaps hampering their ability to perform tasks effectively and safely. It can therefore be reasonably assumed that being substantially overweight or obese while wearing PPE, combined with carrying the heavy equipment required of a firefighter, creates a dangerous situation where the firefighter is at a significant risk of injury or perhaps death. In fact, Washburn et al. (31) have described MI as the number one cause of death in firefighters.

When considering the physical fitness evaluations, VFF performed significantly poorer in measures of muscular endurance than did CFF. Muscular endurance is vitally important for the performance of fire suppression. The tasks that a firefighter must perform are often of a repeated nature that must be performed over several minutes or even hours. Although a firefighter may not have to specifically perform push-ups or a plank hold to failure on the fire ground, these values can at least provide some insight into each individual's local muscular endurance in the upper extremity and trunk. A firefighter will perform varying tasks requiring local muscular endurance of both the upper extremity and trunk such as forced entry, crawling, and carrying potential victims and other heavy equipment for an extended period of time. Without a sufficient level of muscular endurance, the successful performance of these tasks on the fire ground may be compromised.

The average aerobic capacity ($\dot{V}O_2max$) of the CFF is 47.8 $ml \cdot kg^{-1} \cdot min^{-1}$, placing them in the 69th percentile (based on gender- and age-based norms), whereas the average $\dot{V}O_2max$ of the VFF is 38.9 $ml \cdot kg^{-1} \cdot min^{-1}$, placing them in the 36th percentile (based on gender- and age-based norms) (1). Combining the degree of obesity that VFF have, along with a lowered degree of aerobic fitness, it is likely that their bodies are under a great degree of added and unnecessary stress during fire suppression. By contrast, it seems that the CFF have an adequate degree of aerobic fitness to be prepared for the additional thermal stress. The only fitness measure where the VFF performed better than the CFF was in absolute grip strength, implying that they may possess a greater degree of muscular strength than the CFF. However, this difference completely disappeared when the absolute strength was made relative to body mass. There was not a significant difference in FFM between the CFF and VFF; hence, this difference disappearing with the comparison to body mass perhaps demonstrates the concept that they have a similar degree of muscular strength. The physical fitness profile of VFF reported in the current study reflects similar relationships reported elsewhere (19).

Recent evidence has shown that even in fit and active adults, reaction time is significantly hampered and perceived exertion is significantly elevated when wearing a 75-lb weighted vest to simulate the wearing of PPE while performing a simulated firefighting task (21). Firefighters must be able to respond both quickly and accurately to stimuli during fire suppression not only for the safety of themselves but also to any potential victim of the fire as well. Morris et al. (21) exhibited evidence that just the added mass alone of the simulated PPE significantly hampered reaction time. This finding leads to the implication that if reaction time is hampered, decision-making may be delayed, potentially leading to an increase in risk of injury to the firefighter or person they are attempting to rescue. This particular study was conducted in recreationally active and fit adults, and they experienced a significant change during the simulated PPE condition. Combining the findings of Morris et al. (21) with previous findings by Perroni et al. (25), that firefighters who are considered experts can experience a severe physiological challenge, it is concerning that this physiological challenge could be exacerbated if firefighters lack an adequate level of fitness. Even if a firefighter is considered adequately fit, performing strenuous physical labor while wearing PPE can provoke near maximal HRs. For the firefighter who is overweight or obese, carrying the extra fat mass (as well as this fat mass trapping a substantial amount of extra heat) can potentially lead to the increased likelihood of experiencing excess heat stress and a cardiac event (3,8,30).

To the best of the authors' knowledge, the current study represents the first direct comparison of physical fitness in CFF vs. VFF. A recent retrospective study of French firefighters described CVD risk factors and found that their sample did not seem to represent a population as high risk of CVD (27). The authors hypothesized that it could be related to the medical testing required before and throughout employment that could provide a means of catching any potential CVD issues early (27). Interestingly, and contrary to the current findings in these U.S.-based firefighters, these authors did not see any significant differences in the health profiles between CFF and VFF (27). In a similar previous study of French firefighters, similar results were reported with the exception that the BMI and blood lipids were poorer in VFF than in CFF (28). In addition, these authors recommended that exercise training of firefighters should be further reinforced to improve the physical readiness of these firefighters (28).

There are a number of limitations that may influence the generalizability of the results. In particular, the exact number of VFF in the current sample is much smaller than the number of CFF, and it is possible that the VFF may not be truly representative of the total population of VFF in the WCFD. The sample of VFF represents the firefighters at 2 of the 9 volunteer departments contained within the WCFD. Future studies should recruit a higher percentage of the total available firefighters within the volunteer firefighting community. The BGFD requires annual fitness testing of their firefighters, whereas the WCFD does not, so it was not possible to secure the data of all of the VFF like the CFF. The exact number of VFF in the WCFD is not readily available, so it is possible that the current data are missing a number of VFF who may influence future work. In addition, this research study did not collect data on the day-to-day occupations of the VFF. In the future, it will be important to determine the typical occupations of the VFF. This information could be useful in evaluating how their occupation may affect their physical fitness in terms of the activity typically required at their day-to-day job. In addition, no information was collected on the exercise or physical activity habits of the VFF. It will be important in future studies to establish the level of exercise and physical activity that the VFF are, or are not, performing to determine the effects of activity on their relative lack of physical fitness as a group.

Based on the amount of time VFF commit to performing this job, and other jobs they perform for their financial well-being, VFF are often very limited on time to perform exercise on their own outside of their time at the fire house. It is perhaps reasonable to hypothesize that if these VFF were provided the same means of exercise training and equipment, they would have the available time and equipment necessary to perform proper exercise training. Because of the cross-sectional nature of this project, as well as following years of exercise training by the CFF and the inability to specifically define how much exercise has been performed by the VFF over the same period, a cause-and-effect relationship is not possible to determine at this time. However, given the plethora of evidence supporting the notion that exercise programming leads to substantial improvements in physical fitness, it is reasonable to expect that the fitness programming performed by the CFF of the BGFD played an important role in the development of an adequate level of fitness for those particular firefighters. Based on documented evidence of the BGFD, their firefighters have had this level of fitness training and expectation for more than 10 years at the time of assessment.

Practical Applications

Despite the lack of financial support that volunteer firefighting departments tend to see relative to their career counterparts, they have to perform similar job responsibilities with the same inherent dangers. Despite the financial and commitment status of volunteer firefighting departments, their members perform an equally dangerous and as important of a job as firefighters of professional/career firefighting departments. Accordingly, an emphasis should be placed on developing cost-effective and outcome-focused exercise interventions aimed at improving fitness and performance levels of VFF. A recently published study of a 4-week exercise intervention using circuit training in VFF exhibited a significant improvement in cardiovascular variables (13). In this particular study, the VFF performed the circuit training with equipment that could all be found at any fire house without the need to purchase any additional equipment (13). Thus, there is a need and potential opportunity for strength and conditioning professionals to work with firefighting departments to develop and implement training programs designed specifically for the firefighting profession. In addition, a future goal of firefighting organizations may be to have an increased presence of Tactical Strength and Conditioning Facilitators (TSAC-F) within each governing region or individual departments. It is clear that the firefighting profession requires a specifically designed training program, and this is an area that continues to increase the number of opportunities for the strength and conditioning professionals.

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