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EVIDENCE-BASED EXERCISE FOR STRUCTURAL FIREFIGHTERS—A BRIEF REVIEW

INTRODUCTION

Firefighting is a physically demanding profession that can benefit from physical fitness programming (12,13,16,21,24). Due to the high risk of cardiac events (as well as pulmonary and other vascular diseases, such as stroke) and injury in the profession, physical training should address and be programmed towards reducing these risks (4,6,9,13,25). While it has been shown that a variety of programming methods (e.g., periodization, circuit training) can be effective at improving firefighter fitness levels, it is unclear as to which are the key to improving occupational performance (17,19,22).

Although firefighters are expected to perform at high levels of fitness, fire departments often lack the funding for gym equipment, facilities, and training professionals to administer the training programs that are typically used in athletic populations. Additionally, heavy resistance training (which focuses on strength development) involves several minutes of rest between sets, so without the incorporation of additional cardiovascular training (which would require greater time commitments), the aerobic and anaerobic systems may not receive the stimulus necessary to produce adaptations (19,22). Circuit training, on the other hand, involves minimal rest between exercises and can be incorporated in a large group setting with the use of minimal equipment (e.g., bodyweight, kettlebells, sandbags, firefighting equipment), and has been shown to stress both the aerobic and anaerobic systems (1,3,17). Therefore, the purpose of this brief review is to address the key elements when designing a training program for firefighters, provide evidence for utilizing circuit training, and suggest recommendations on how to incorporate circuit training into the training program.

KEY ELEMENTS FOR FIREFIGHTERS' FITNESS PROGRAM

The term "tactical athlete" has been used in recent years to describe firefighters, due to the profession requiring both general physical preparedness (i.e., muscular strength, endurance and power, cardiovascular endurance), and technical and tactical skills (i.e., how to operate equipment, perform fire suppressions and rescues) for successful and effective completion of tasks, like traditional sport athletes (23). However, unlike traditional sport athletes, without definable on- and off-seasons to focus on specific fitness goals (e.g., cardiorespiratory fitness, muscular power, strength, hypertrophy, endurance), a firefighting training program will need to be optimized around a yearly ongoing schedule to ensure firefighters are prepared for the physical demands of their jobs. Furthermore, with a wide range of fitness levels, exercise experience, and equipment availability among departments, it is nearly impossible to set a standardized training program for all fire departments to attain. This has led to organizations like the National Strength and Conditioning Association (NSCA) to develop certifications (i.e., Tactical Strength and Conditioning Facilitator® [TSAC-F®]) to prepare both practitioners and firefighters to lead physical fitness programming for fire departments. The TSAC-F can become familiar with each individual fire department's needs and can devise a program based on this needs analysis (inclusive of a physiological and movement pattern analysis, and an occupational injury profile and analysis). Additionally, the TSAC-F should be prepared to address the common barriers of incorporating physical fitness training while on-duty, including call volume, task-specific and medical response training, additional job duties (e.g., public education, tours), and potentially the fear of reduced occupational performance associated with training fatigue (8).

PHYSIOLOGICAL ANALYSIS

The physiological analysis includes identifying the primary tasks involved in the profession, which energy system(s) are utilized, and what may influence the physiological demands. For example, during short duration (0 – 10 s) tasks, such as ladder raises and lifting objects, the phosphagen system is mainly utilized. For moderate duration (30 – 120 s) tasks, such as short distance load carriages and victim/hose drags, the glycolytic system is mainly used. Longer duration (more than 120 s) tasks, such as stair climbing and load carriages, mainly require the oxidative system (2). While Rhea et al. demonstrated that individual task performance (i.e., hose pull, stair climb, victim drag, equipment hoist) has greater correlations with anaerobic endurance compared to aerobic endurance, at a fire scene, these tasks are often performed repeatedly with minimal rest (21). Additionally, these tasks are performed while wearing personal protective equipment (PPE) and in environments that increase the physiological stress on firefighters. In fact, PPE has been shown to increase resting heart rate by about 44% and may increase the cardiovascular demand during fire suppression tasks due to the decreased ability to dissipate body heat through sweat (7,11,13). Therefore, it can be deduced that firefighting requires use of each energy system with an increased stress placed upon on the aerobic (i.e., oxidative) system (16,21,26,28). Accordingly, the training of firefighters should reflect both repeated bouts of both short-duration, high-intensity exercises, and sustained moderate-duration, low to moderate-intensity exercises.

MOVEMENT PATTERN ANALYSIS

This analysis includes evaluation of the primary movement patterns and prescribing exercises that utilize similar joint and muscular actions. For example, the walking hose pull involves isometric actions of the trunk stabilizers and scapular retraction muscles, while including unilateral lower limb extension (2). Therefore, an exercise that requires similar muscular engagement can be incorporated to prepare firefighters for the task (i.e., sled and tire drags, planks, lunges).

INJURY PROFILE AND ANALYSIS

An injury profile includes identifying the common injuries sustained and their potential causes. Among firefighters, cardiac arrest and musculoskeletal injuries are among the most common ailments and should be addressed accordingly. With cardiac events being one of the leading causes of on-duty deaths among firefighters since 1977, cardiovascular fitness should be a priority when designing training programs (9). Additionally, in 2018 alone, there were a reported 22,975 musculoskeletal fireground injuries, with 38% being reported as muscular strain, sprains, and overall pain, while overexertion and strain accounted for an additional 28% of injuries (4). A larger portion of these injuries may be attributed to the repetitive use of poor movement patterns while performing occupation duties. Thus, addressing issues such as poor muscular strength, lack of mobility and muscular control, is essential for improving overall health and wellness, while decreasing this potential injury-risk (5,14,18). For example, firefighters who possess higher levels of physical fitness (i.e., increased VO_2max, muscular strength, and muscular endurance) are able to meet the demands of the job, display improved performance, and may reduce their risk of cardiac event and injury as compared to their more unfit peers (12,13,16,21,28).

While incorporating an exercise training regimen within the fire service is warranted, it should be noted that 32.9% of the injuries reported at a metropolitan fire department between 2004 and 2009 occurred during exercise training (20). However, with proper supervision, instruction, and program outcome focus, these injuries can be substantially reduced. For instance, Frost et al. (10) demonstrated that a resistance training program that focused on movement efficiency rather than the overall outcome (e.g., strength) significantly improved lifting and squatting mechanics. Although both groups improved fitness outcomes, a decrease in movement proficiency at the spine and knee was noted in the conventional training group while the movement-guided group improved movement proficiency (10). These changes in lifting mechanics may provide a greater transfer to both occupational tasks and exercise training potentially lowering injury risk.. Thus, this demonstrates the importance of qualified professionals (e.g., TSAC-F) to supervise and design training programs for firefighters with the goal of reducing cardiac arrest and injury risk.

ON-DUTY TRAINING BARRIER

As previously mentioned, higher levels of physical fitness are associated with improved performance, and reduced risk for cardiac events and injury (12,13,16,21,24,28). Thus, the National Fire Protection Association (NFPA) has placed recommendations of allocating on-duty time for physical training (15). While it is important for firefighters to participate in a physical fitness program, there are several barriers when implementing training programs on-duty (i.e., call volume, firefighting drills training, emergency medical service [EMS] training, station tours, public education, etc.). Additionally, many fire departments are concerned that training on-duty will reduce performance (8). Although all of these barriers cannot be addressed and controlled by the TSAC-F, the fear of reduced performance should be addressed when implementing an on-duty training program. While research has shown that there was a 9.6% increase in time to complete a simulated fire ground suppression test immediately following an exercise circuit, 81% of the firefighters that were already participating in an on-duty training program ("trained") completed the fire ground suppression test faster than those that were not currently participating in a training program ("un-trained") (8). Even following the exercise circuit, the trained firefighters (fatigue trial) were faster than 70% of the un-trained firefighters at the baseline testing (non-fatigue trial) (8). These results help emphasize the benefits of on-duty training in the long term, even though there is an initial decrease in performance immediately after training. Therefore, the role of the TSAC-F should be to provide education on the role of exercise training on firefighters' performance and health in the long term.

REVIEW OF PHYSICAL FITNESS PROGRAMS FOR FIREFIGHTERS

While research has shown that higher levels of physical fitness are associated with improved performance and reduced risk of injury, there are few physical standards set for the profession (8,12,13,16,21,24,28). However, recommendations have been placed by the NFPA for firefighters to possess a minimum aerobic capacity of 42 mL/kg/min to meet the cardiovascular demands of the profession and lower the risk of sudden cardiac arrest during intense fire suppression tasks (15). Additionally, research conducted with firefighters from the United Kingdom found that several minimum muscular strength and endurance assessments correlated with higher performance in occupational tasks (27). These assessments included a seated shoulder press greater than 35 kg, a 60-kg rope attachment pull-down, and 23 repetitions of a 28-kg rope pull-down (27). Although these recommendations and guidelines have been placed, there are no clear guidelines and set standards in place for fire departments in regard to physical fitness training. With firefighters being exposed to potentially life-threatening fire-suppression tasks and intense physical stimuli, progressive physical fitness programs may help improve performance and protect from the extreme hazards associated with the profession.

Traditional strength and conditioning programs utilize progressive training approaches to optimize training adaptations with periodization and exercise recommendations, and are most often used for advanced trainees and athletes. The training adaptations include increased force production, power output, and fatigue resistance through physiological mechanisms compromising of neuromuscular, metabolic, and hormonal-capacity modifications (19). Traditional "linear" periodization models of training divide a training calendar into separate blocks or phases (i.e., mesocycles) that are systematically structured to focus on the development of specific fitness characteristics (e.g., muscular endurance, strength, power/speed) in each specified mesocycle. Undulating periodization, on the other hand, involves frequent (daily or weekly) fluctuations in the training stimulus, in which the training stimulus fluctuates nonlinearly. In a nine-week study comparing both traditional and undulating periodization in a group of firefighter trainees, both training protocols were able to elicit favorable improvements in the measured fitness and occupational performance characteristics (19). However, while both training protocols have been shown to improve fitness characteristics and performance in a firefighter physical ability test, this style of training involves several minutes of rest between sets. Without the incorporation of additional cardiovascular training, which would require greater time commitments, the cardiovascular system may not receive the stimulus necessary to produce adaptations (19,22). Additionally, these training programs typically require access to traditional resistance training equipment. Due to limited budgets, departments often rely on equipment donations or partnerships with the local communities for access to facilities.

Circuit training, on the other hand, involves short rest periods between exercises and has been shown to be effective for promoting both strength and cardiovascular adaptations (3). Additionally, circuit training can be incorporated with minimal equipment (often utilizing equipment found in a firehouse) and can be conducted in large group settings. This large group training can increase team morale and support of physical training. It has been shown that 12 weeks of progressive circuit training was able to improve both the occupational performance and body composition of firefighter trainees (17). The circuit training consisted of bodyweight exercises for each major muscle group (push-ups, sit-ups, bodyweight squats, and lunges), and progressions were made through the gradual addition of fire equipment to increase the relative load of the exercises and by decreasing the rest intervals between exercises from 30 s at the beginning to no rest at the end (17). Furthermore, it has been found that a single bout of circuit training produces similar anaerobic responses to fire suppression tasks, even though it was unable to elicit a matching cardiovascular response (79.4 ± 5.4% maximum heart rate [HRmax] compared to 88 ± 6% HRmax) in a group of firefighters (1,21). This discrimination in cardiovascular intensity could be explained by the stress placed on firefighters with the addition of PPE. It has been found that heart rate increases as much as 44% after putting on 28 kg of firefighting equipment (65 beats per minute [bpm] at rest to 119 bpm when standing with gear) (5). In order to increase the intensity of training, fire gear is often worn during training. While wearing PPE during exercise constitutes a controlled condition, unlike fighting a fire, the addition of the gear may increase the risk of heat-related injuries and decrease sweat efficiency (11,13). Thus, the practitioner should closely monitor an individual's thermoregulatory process (e.g., sweat rates, body temperature), particularly during high-intensity movements or hot/humid sessions, and precautions should be made. Therefore, a weighted vest may serve as a suitable alternative to wearing gear during training, although further research is needed to examine these strategies and recommendations.

LIMITATIONS AND SOLUTIONS

There is limited literature on the effect of the different training protocols on improving firefighter fitness levels, and more importantly, reducing the risk of injury and cardiac events among firefighters. Additionally, most of the literature has been conducted on novice firefighter trainees, who may respond differently than experienced firefighters. Therefore, further research is needed to look at the effect of different training protocols on both novice and experienced firefighters. Research should also begin to explore the long-term effects and practicality of incorporating a physical fitness program at fire departments (e.g., budget, time, etc.). State and federal funding is usually limited and may be impractical for a fire department to have a private training facility. However, through partnerships with the local community (e.g., universities, gyms, etc.), fire departments may be able to receive access to a fitness facility at a discounted rate. Additionally, fire departments can apply for grants (e.g., Staffing for Adequate Fire and Emergency Response [SAFER], Assistance to Firefighters Grants [AFG], etc.) to receive additional funding for the purchase of workout equipment. Sandbags, kettlebells, and medicine balls can be effective for including in large group circuit training. This equipment can often be purchased at discounted rates to first responders. Additionally, fire departments may seek out local universities and colleges that have faculty and students with expertise in the field; thereby, developing a mutually beneficial partnership. Internships may also provide a mechanism of community outreach for the institution as a cost-effective method of service delivery.

TAKEAWAYS AND RECOMMENDATIONS

Both linear and undulating periodization training has been shown to improve fitness levels and job performance in novice firefighters. However, with the high risk of cardiac events, firefighters may benefit from training that concurrently stresses both muscular and cardiovascular systems (i.e., circuit training). Circuit training can be easily incorporated with limited equipment and in large group settings while on shift. After choosing 8 – 10 exercises that replicate common fire suppression tasks and utilize the available equipment (Table 1), the exercises can be set up in an open space that allows for quick and easy transitions. For those newer to training, start at 30 s of work and 30 – 60 s of rest for each exercise, and repeat for 2 – 4 rounds in normal workout attire. To progress the training, the rest periods can be decreased gradually (working towards 0 – 15 s of rest between exercises), the work time can be increased (working towards 40 – 60 s), or additional weight can be worn during training (PPE or weighted vest). Additionally, a cardiovascular exercise (e.g., rowing, jogging, sprinting, biking) can be incorporated at the end of each circuit to increase the cardiovascular demand for the training. By allowing each crew member the chance to choose an exercise and lead the circuit, team camaraderie and support of training can be increased, which will lead to improved exercise adherence. However, regardless of the training program followed, firefighters may benefit from exercise participation to help reduce the risk of cardiac arrest and injury.

TABLE 1. SAMPLE EXERCISES AND EQUIPMENT THAT CAN BE UTILIZED TO REPLICATE FIREGROUND SUPPRESSION TASKS

FIRE SUPPRESSION TASKS	EXERCISES	FIREHOUSE EQUIPMENT	OTHER EQUIPMENT
Stair Climb	Step-up and lunge variations	High rise pack	Weighted vest Sandbags Kettlebells dumbbells
Charged Hose Pull	Drags Forward lunge	Fire hose	Sleds
Ladder Raise	Ladder raises Shoulder press Turkish get-ups	Ladders	Kettlebells Dumbbells
Equipment Carry	Farmer's walk	Foam bucket Rescue tools Power saws	Kettlebells Dumbbells
Forcible Entry	Slams Strikes	Sledgehammer	Slam balls
Pulling Ceiling	Push press Wood chops Pulldowns	Pike pole connected to a rope and weight	Barbell Kettlebells Dumbbells Medicine balls
Search	Crawls Planks Plank with crossbody drags	Halligan	Sandbags Kettlebells Dumbbell
Victim Drag	Reverse drags Across chest carries Deadlift	Rescue dummy	Sleds Sandbags Kettlebells Barbells

Structural firefighters are required to be able to perform these common fireground suppression tasks while wearing personal protection equipment (~20 kg). Stair climb: Often performed carrying ~19 kg hose bundles (high rise pack) along with hand tools and other equipment; Charged hose pull: Hose line filled with water that is dragged and pulled into positions at fire scenes; Ladder raise: Placing ladders against buildings to get into multi-story buildings; Equipment carry: Moving and positioning equipment at fire scenes; Forcible entry: Utilizing sledgehammers or axes to enter locked or blocked pathways; Pulling ceiling: Ventilating rooms with a pike pole and utilizing overhead presses and pulls; Search: Crawling on the hands and knees and sweeping the perimeter of rooms and hallways; Victim drag: Lifting and moving individuals to safety.

REFERENCES

1. Abel, MG, Mortara, AJ, and Pettitt, RW. Evaluation of circuit-training intensity for firefighters. *The Journal of Strength and Conditioning Research* 25(10): 2895-2901, 2011.

2. Abel, MG, Palmer, TG, and Trubee, N. Exercise program design for structural firefighters. *Strength and Conditioning Journal* 37(4): 8-19, 2015.

3. Alcaraz, PE, Sánchez-Lorente, J, and Blazevich, AJ. Physical performance and cardiovascular responses to an acute bout of heavy resistance circuit training versus traditional strength training. *The Journal of Strength and Conditioning Research* 22(3): 667-671, 2008.

4. Campbell, R, and Molis, JL. United States Firefighter Injuries-2018. Quincy: MA: NFPA Research, Data, and Analytics Division, 2019.

5. Chorba, RS, Chorba, DJ, Bouillon, LE, Overmyer, CA, and Landis, JA. Use of a functional movement screening tool to determine injury risk in female collegiate athletes. *North American Journal of Sports Physical Therapy: NAJSPT* 5(2): 47-54, 2010.

6. Davis, PO, Biersner, RJ, Barnard, RJ, and Schamadan, J. Medical evaluation of fire fighters: How fit are they for duty? *Postgraduate Medicine* 72(2): 241-248, 1982.

7. Del Sal, M, Barbieri, E, Garbati, P, Sisti, D, Rocchi, MB, and Stocchi, V. Physiologic responses of firefighter recruits during a supervised live-fire work performance test. *The Journal of Strength and Conditioning Research* 23(8): 2396-2404, 2009.

8. Dennison, KJ, Mullineaux, DR, Yates, JW, and Abel, MG. The effect of fatigue and training status on firefighter performance. *The Journal of Strength and Conditioning Research* 26(4): 1101-1109, 2012.

9. Fahy, RF, and Molis, JL. Firefighter fatalities in the United States-2018. Quincy: MA: NFPA Research, Data, and Analytics Division; 2019.

10. Frost, DM, Beach, TA, Callaghan, JP, and McGill, SM. Exercise-based performance enhancement and injury prevention for firefighters: contrasting the fitness and movement related adaptations to two training methodologies. *The Journal of Strength and Conditioning Research* 29(9): 2441-2459, 2015.

11. McLellan, TM, and Selkirk, GA. The management of heat stress for the firefighter: a review of work conducted on behalf of the Toronto Fire Service. *Industrial health* 44(3): 414-426, 2006.

12. Michaelides, MA, Parpa, KM, Thompson, J, and Brown, B. Predicting performance on a firefighter's ability test from fitness parameters. *Research Quarterly for Exercise and Sport* 79(4): 468-475, 2008.

13. Morris, C, and Chander, H. The impact of firefighter physical fitness on job performance: a review of the factors that influence fire suppression safety and success. *Safety* 4(4): 60, 2018.

14. Myer, GD, Ford, KR, Palumbo, OP, and Hewett, TE. Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *The Journal of Strength and Conditioning Research* 19(1): 51-60, 2005.

15. National Fire Protection Association 1583. Standard on health-related fitness programs for fire department members. Quincy, MA: NFPA Fire Analysis and Research Division, 2015.

16. Nazari, G, MacDermid, JC, Sinden, KE, and Overend, TJ. The relationship between physical fitness and simulated firefighting task performance. *Rehabilitation Research and Practice* 2018: 2018

17. Pawlak, R, Clasey, JL, Palmer, T, Symons, TB, and Abel, MG. The effect of a novel tactical training program on physical fitness and occupational performance in firefighters. *The Journal of Strength and Conditioning Research* 29(3): 578-588, 2015.

18. Peate, WF, Bates, G, Lunda, K, Francis, S, and Bellamy, K. Core strength: a new model for injury prediction and prevention. *Journal of Occupational Medicine and Toxicology* 2(1): 3, 2007.

19. Peterson, MD, Dodd, DJ, Alvar, BA, Rhea, MR, and Favre, M. Undulation training for development of hierarchical fitness and improved firefighter job performance. *The Journal of Strength and Conditioning Research* 22(5): 1683-1695, 2008.

20. Poplin, GS, Harris, RB, Pollack, KM, Peate, WF, and Burgess, JL. Beyond the fireground: injuries in the fire service. *Injury Prevention* 18(4): 228-233, 2012.

21. Rhea, MR, Alvar, BA, and Gray, R. Physical fitness and job performance of firefighters. *The Journal of Strength and Conditioning Research* 18(2): 348-352, 2004.

22. Roberts, MA, O'dea, J, Boyce, A, and Mannix, ET. Fitness levels of firefighter recruits before and after a supervised exercise training program. *The Journal of Strength and Conditioning Research* 16(2): 271-277, 2002.

23. Scofield, DE, and Kardouni, JR. The tactical athlete: a product of 21st century strength and conditioning. *Strength and Conditioning Journal* 37(4): 2-7, 2015.

24. Smith, D. Firefighter fitness: improving performance and preventing injuries and fatalities. *Current Sports Medicine Reports* 10(3): 167-172, 2011.

25. Soteriades, ES, Hauser, R, Kawachi, I, Liarokapis, D, Christiani, DC, and Kales, SN. Obesity and cardiovascular disease risk factors in firefighters: a prospective cohort study. *Obesity Research* 13(10): 1756-1763, 2005.

26. Sothmann, MS, Saupe, K, Jasenof, D, and Blaney, J. Heart rate response of firefighters to actual emergencies. Implications for cardiorespiratory fitness. *Journal of Occupational Medicine: Official Publication of the Industrial Medical Association* 34(8): 797-800, 1992.

27. Stevenson, RD, Siddall, AG, Turner, PF, and Bilzon, JL. Physical employment standards for UK firefighters: minimum muscular strength and endurance requirements. *Journal of Occupational and Environmental Medicine* 59(1): 74, 2017.

28. Williams-Bell, FM, Villar, R, Sharratt, MT, and Hughson, RL. Physiological demands of the firefighter candidate physical ability test. *Medicine and Science in Sports and Exercise* 41(3): 653-662, 2009.

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