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Original Research

The Effects of a Core Stabilization Training Program on the Performance of Functional Tasks in Firefighters

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ABSTRACT

International Journal of Exercise Science 17(4): 602-610, 2024. The purpose of this study was to observe if core stabilization training plays a significant role in firefighter time-to-completion during a functional performance test. A within subjects study design was used in which subjects (n = 13, 84.6% male, 33.7 ± 7.4 years of age, 91.06 ± 13.29 kg, 25.79 ± 6.55 percent body fat, 8.96 ± 7.51 years of firefighting experience) completed two performance tests (pre and post core training), comprised of 7 firefighter-specific exercises performed while wearing a 22.68 kg weight vest to mimic typical firefighter equipment. Between testing sessions, subjects were prescribed specific core stabilization exercises to perform at least three days a week for a total of 4 weeks. Time-to-completion was significantly quicker between the first (300.89 ± 42.11s) and second (256.92 ± 34.31s) performance testing, on average by 43.8 seconds (p < 0.001). Body mass index (p = 0.065) and rating of perceived exertion during testing (p = 0.084) did not significantly decrease across the course of the study. Adequate fitness is essential to firefighters' job task performance. Data from this study suggests that regular core stabilization training may assist in optimizing the effectiveness, and potentially safety, of firefighters' performance in high intensity functional skills.

KEY WORDS: Core stability, CPAT (Candidate Physical Ability Test), tactical, performance test

INTRODUCTION

Firefighters are expected to be able to perform under highly fatigued states including cardiovascular, mental, and physical fatigue, in potentially toxic environments, and often under time constraints and extreme workloads (5). Due to the demands of the job and the requirement to operate under fatiguing conditions, firefighters are subjected to injury-prone positions in which the overall ability to stabilize bodily movements under such conditions, could be an influential factor in task performance such as forcible entries, equipment carries, search and rescues, etc. In addition to the demanding physical tasks firefighters encounter, they must be able to perform while wearing a minimum of 45 lbs of personal protective equipment ("turnout gear" or "bunker gear"), which adds a cumulative demand on aforementioned tasks (3). The basic protective gear includes a helmet, hood, pants, coat, boots, gloves, and air pack, while additional weight, such as air masks, will depend on the specific tools for a job (3). This

gear/weight is not relative to a firefighter's body size, rather it is a uniform 45lbs that all individuals must be able to operate efficiently under. With these considerations of fatigue, extreme workloads, and time constraints, it is imperative that firefighters are able to operate at peak performance to function safely and efficiently which can be the difference between life or death.

As suggested by the National Fire Protection Agency (NFPA), IAFF/IAFC Candidate Physical Ability Test (CPAT) testing is currently used by various departments across the United States and Canada as a way to evaluate and screen the physical abilities/limitations of pre-hire candidates (2). In 2011, a nationwide study utilizing 185 chief officers found that only 25% of fire departments have annual requirements involving physical performance/ability tests, while 88% use physical performance/ability tests as pre-screening requirements for firefighter candidates (1). CPAT testing utilizes a pass/fail time of 10 mins and 20 seconds to complete an eight-event test including a stair climb, ladder raise/extension, hose drag, equipment carry, forcible entry, search, rescue drag, and ceiling pull, while wearing a 50lb weight vest (2).

The variability of a firefighter's workday illustrates the need for driving the encouragement of firefighter health and fitness. When on call, firefighters must be able to combat their downtime between calls and minor cases with an ability to perform the cardiovascular, strength and muscular demands of a major emergency call without warning. Michaelides et al. looked at the relationship between various fitness components and performance on a firefighter ability test (5). The study demonstrated that abdominal strength, upper-body endurance, relative power, and upper body strength were significantly associated with completion time (5). Additionally, poor performance was associated with high body mass index (BMI), high body fat percentage (BF%), and increasing age (5). As a result of increased concern regarding fitness, there is growing interest in understanding the relationship between various fitness aspects and their impact on functional tasks in firefighters (5).

Currently, the most common measure of abdominal strength and endurance, is the sit-up test which is prevalent across a number of tactical populations including the military (5). However, the sit-up test (a measure of muscular endurance) and its ability to accurately relate to functional movements is questionable, including its relationship to firefighter performance. Observations by Rhea et al. involving 20 firefighters found the relationship between sit-ups and performance in functional tasks nonsignificant (r = -0.22) (9). Conversely, a study conducted by Williford et al. observed a significant correlation ($p < 0.01$) between the physical performance assessment administered and grip strength, height, pull-ups, push-ups, 1.5-mile run, sit-ups (r = -0.32), weight, and % fat (10).

While this study did not seek to measure abdominal strength directly, it sought to evaluate the impact core stability has on quantitative measures of performance. The impact of core stability in physical activity has primarily been observed through its role in decreasing injury; however, there is lacking research on the role core stability plays in actual performance aspects of physical fitness. The operational definition of core stability as stated by Kibler et. al. will be used as the

basis of this study (4): "core stability is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer, and control of force and motion to the terminal segment in integrated athletic activities." This study intends to further the research conducted by Michaelides et. al. and current literature, by observing the role specifically core stabilization plays in firefighter performance (through time to completion), and whether it may serve as an important corrective action to employ in firefighter's everyday workout regimen (5).

The purpose of this study was to explore the effects of a 4-week core stabilization training program on performance in firefighter suppression tasks among experienced firefighters, and to observe how exercises that focus on stabilization throughout the hips, core, and trunk transfer to increased movement efficiency under fatiguing tasks. It was hypothesized that participation in a core stabilization training program will improve a firefighter's ability to efficiently perform functional tasks. In addition, higher body composition values indicated through percent body fat, were hypothesized to be correlated with increased performance times, suggestive of decreased fitness and conditioning.

METHODS

Participants

A power analysis determined that 9 participants were needed at a power level of 0.80 and an $a = 0.05$. Eighteen certified, active duty firefighters (2 females and 16 males) from several local fire districts volunteered for this study and were recruited via email correspondence with the health and safety captains of the respective departments. All participants were medically cleared for vigorous activity as required by their profession. Subjects had a mean body mass of 91.06 ± 13.29 kg and a mean height of 1.7 ± 0.1 m. The mean BMI of the participants was 29.7 ± 2.6 kg/m^2, with a mean age of 31.9 ± 6.5 yrs, and a mean of 9.0 ± 7.5 yrs of experience as a certified firefighter.

A certified active duty firefighter was defined as either full-time or volunteer firefighters who are at least 18 years of age and currently experiencing no musculoskeletal injury. The standard for this study was resembled off of The Candidate Physical Ability Test (CPAT), which is designed to measure a candidate's ability in 8 functional tests. After subject recruitment, it was found that the participating fire departments do not require their staff or volunteers to have previously completed CPAT testing. This requirement is held on a departmental basis; however, the participating departments recognize individuals who have completed the test and the departments are moving towards encouraging CPAT testing in the future. All subjects completed a written informed consent and PAR-Q prior to participating. This study was conducted through review and approval by the University of Lynchburg's Institutional Review Board. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (6).

Protocol

Demographic Data Collection: Participants in this study completed pre-intervention data collection including height, body mass, BMI, and body fat percentage. Height was measured using a stadiometer (Seca 217, Chino, CA) in which subjects stood with their heels against the support of the stadiometer, and height was measured in centimeters. Body mass was measured during the process of BodPod testing, prior to entering the BodPod (COSMED, Chicago, IL, USA). Subjects were measured for % body fat using the BodPod. Standard BodPod procedures were followed using estimated residual volumes. Subjects wore minimal, form-fitting clothing such as spandex and a sports bra (for females), as well as a swim cap to compress the hair. Subjects were surveyed regarding their current exercise routine/physical activity level including what type of exercise they primarily engage in (e.g. HIIT, CrossFit, aerobic), how often they engage in the exercise (frequency & duration), and their perceived current level of fitness.

Pre/Post Performance Testing: All subjects underwent two time-based performance tests (pre and post treatment), located outdoors on an astroturf athletic field. The test was comprised of 8 exercises and subjects wore a 22.68 kg weight vest (resembled off of the CPAT screening test) to simulate the load of safety gear and equipment. Prior to completion of the test, the testing protocol was explained to the subjects during a walk-through of the course in which they were provided the opportunity to ask questions. They were informed that the researcher would be following them through the course during their testing in order to provide instruction regarding sequence of tasks, as needed. A Polar heart rate monitor (Polar T31/FT1, Polar Electro, Inc., Lake Success, NY, USA) was applied to the subject's torso, with a snug fit, prior to fitting the weight vest (Sorinex Raptor weight vest, Sorinex, Lexington, SC, USA). A resting heart rate was obtained after the subject sat still for 5 minutes. Subjects then performed a self-directed warm-up with the vest on to allow for the opportunity to become comfortable with the additional weight and how it might alter/influence their movements during physical activity.

Subjects were expected to complete the test in under 10 minutes and 20 seconds. The test consisted of a series of exercises that replicated tasks seen in firefighter rescue missions (Figure 1). Subjects began with a 25 yd sprint followed by a zig-zagged 5 yd, farmer's carry with two 30 lbs dumbbells to replicate an equipment carry. A 50 ft battle rope totaling 50 kg, was drug a total of 32 yd where the subject then dropped to one knee and pulled the rope the rest of the way to resemble a hose drag. Following, the subjects zigzagged 10 yd with one sandbag over their shoulder, weighing approximately 22.6 kg, to replicate a fireman carry. They then completed 5 tire slams using a 4.54 kg sledge-hammer to strike a rubber tire simulating a forceful entry. Next, subjects completed a 10 yd low crawl immediately followed by a 15 yd high crawl with one 90° turn each crawl. Lastly, using a weight sled (74.84 kg) while walking backwards, subjects pulled the sled 20 yd, with one 90° turn to resemble a dummy drag. Subjects were required to keep the pace of walking throughout every task (except the sprint), and each task was also followed by a 28 yd walk. This served to help ensure a safe workload intensity for the participants.

Immediately upon finishing, time to completion and rating of perceived exertion (RPE) using a Borg RPE Scale ranging from 6-20, were recorded. Throughout the duration of both performance tests, subject heart rate was recorded to ensure a heart rate below 90% of age-predicted heart

rate max was maintained in order to ensure safe workload intensity. The maximum heart rate reached during testing was also recorded.

Exercise Intervention: Immediately following the completion of the performance pre-test, subjects were given a list of six core stabilization exercises to be performed at least 3 days a week for a total of 4 weeks. Subjects participated in this 4-week self-guided exercise program in addition to being asked to maintain their habitual exercise regimen. Compliance was assessed through reminder emails throughout the 4-week treatment period, followed by a post-performance test and BodPod analysis at the completion of the four weeks. The researcher instructed the subject on how to perform the exercises or variations depending on their current ability level. The corrective exercises consisted of variations of dead-bug exercises, kettlebell chops, glute bridges, bird dog exercises, side planks, and plank rows. All subjects were provided with a physical copy of the instructions and illustrations for each of the prescribed exercises during the first visit. Each subject progressed in the exercise variations on an individual basis depending on their current ability level or development of strength throughout the course of the four weeks.

Statistical Analysis

Data was analyzed using SPSS (version 25) (SPSS, Inc., Chicago, IL). Descriptive statistics (mean and SD) were calculated and reported to describe subject demographics. Performance test scores were reported in minutes, with seconds represented by decimals. A time change variable was computed for each subject between visit 1 and visit 2 time to completion; a negative change score indicated an improvement in performance. Paired sample *t* tests compared pre-treatment and post-treatment performance test time scores. Statistical significance was set a priori at an alpha level of 0.05. Pearson product moment correlations were used to determine the relationships between percent body fat and performance test time (pre-treatment), age and performance test time, and RPE and performance test time.

RESULTS

Subject mortality between sessions of 5 participants was due to a change in firefighter shift schedule, subject travel, and on the job injury. A total of 13 subjects completed the study, with a mean age and body fat of 33.7 ± 7.4 years and 25.79 ± 6.55 %, respectively. The average years of experience for firefighters was 8.96 ± 7.51 years. Surveys indicated that the majority participated in aerobic or weightlifting/powerlifting exercises with an average of 2.73 ± 1.72 days per week. Therefore, the role of this core stabilization program was to act as a treatment in addition to their current exercise routine, if any.

Correlations were strongly associated between visit 1 and visit 2 with BMI (r = 0.99; 29.73 ± 2.64 and 29.97 ± 2.71, respectively), and body fat (r = 0.95; 25.39 ± 5.73 and 25.79 ± 6.55, respectively), and weakly associated between visit 1 and visit 2 with resting heart rate (r = 0.15; 72.63 ± 11.08 and 77.25 ± 4.89, respectively). Strong correlations were also found between heart rate maximum reached during testing (r = 1.00; 187.54 ± 6.57 and 187.38 ± 6.42, respectively), time to completion

(*r* = 0.96; 300.69 ± 44.92 and 256.92 ± 34.31, respectively), and RPE (*r* = 0.70; 14.00 ± 2.24 and 15.00 ± 2.65, respectively). Body fat and time to completion (Table 1) were positively correlated for both visits. Time change between visits 1 and 2 was found to be negatively associated with age (Table 1).

Table 1. Age and body fat in relation to time change and time to completion during each visit.

	Time change	Time (visit 1)	Time (visit 2)
Age (yrs)	*r* = -0.56 *p* = 0.047* *n* = 13		
Body fat (%)		*r* = 0.61 *p* = 0.01* *n* = 18	*r* = 0.64 *p* = 0.02* *n* = 13

*Significant at alpha level of 0.05

When comparing the means across the two testing sessions, the paired samples *t* test was used to suggest significance for each of the variables: BMI, Body fat, Resting HR, HR max, Time to completion (seconds), and RPE. A significant difference was found when comparing the time to completion pre and post treatment. The time to completion post treatment was significantly lower, on average by 43.8 seconds, than the time to completion pre-treatment. No significant differences between pre and post treatment were found for BMI, body fat, resting HR, HR max, or RPE (Table 2).

Table 2. Paired sample t-test results of pre- and post-treatment comparisons.

	Pre-Treatment (V1)		Post-Treatment (V2)			
	M	SD	M	SD	t	Sig.
BMI (kg/m^2)	29.04	3.41	29.97	2.71	-2.03	0.07
Body fat (%)	25.39	5.73	25.79	6.55	-0.67	0.52
Resting HR (bpm)	72.63	11.08	77.25	4.89	-1.15	0.29
Maximal HR reached (bpm)	187.54	6.57	187.38	6.42	1.00	0.34
Time to completion (s)	300.69	44.92	256.92	34.31	6.71	< 0.001*
RPE	13.61	2.00	15.00	2.65	-1.88	0.08

*Significant at alpha level of 0.05

DISCUSSION

This study sought to determine the effects of 4 weeks of core stability training on tactical performance. The original hypotheses were supported in that participation in the training program resulted in faster completion times of the performance test, and that higher body composition values correlated to longer completion times. The time to complete the testing course improved by an average of almost three-quarters of a minute across the course of this study. This improvement was made without a perceived increase in level of effort.

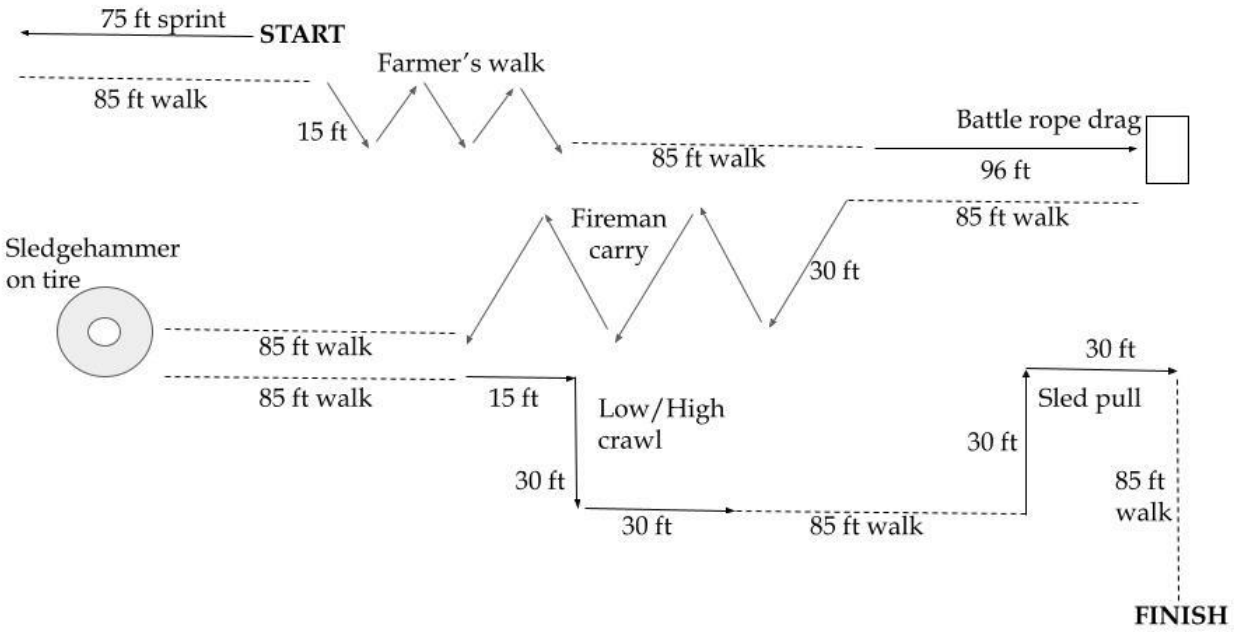

Figure 1. Diagram of testing course used for performance testing.

Previous studies have also found an improvement in time to completion of a firefighter-specific functional test. Pawlak et al. found 1.5% decrease in total time in their simulated fire ground test following a 12-weeks of circuit training (7). Another study administered a 9-week resistance training program to firefighters and assess their performance in a number of fitness test as well as a job-specific testing battery. This study found a 28.9% improvement in the treatment group's job-specific performance, in addition to greater gains in the fitness tests (8). Similar to these other training studies, our research also supports the idea that the implementation of exercise training with firefighters can lead to improvements in the performance of firefighter-specific tasks. We showed a 14.6% reduction in time to completion, which falls in the range presented by these previous studies. It remains difficult to directly compare these studies due to the lack of standardized testing protocol, however our findings are aligned with other studies that used similar tasks.

The demands and expectations of firefighters to be able to operate under fatiguing, variable, and extreme time constraints requires an effort of how to improve their movement efficiency. From the results of this study, it can be encouraged that firefighters participate in a training program that emphasizes core stabilization including exercises that involve anti-rotation, anti-lateral flexion, and anti-extension. Subjects anecdotally reported their current exercise routines, and it can be summarized that participants lacked exposure to exercises involving core stabilization in their current routine. Participation in these exercises may help increase movement efficiency across their daily tasks, decrease the chance of injury through improving their ability to withstand the external loads of gear, tools, and victims, and decrease their time to completion

of a rescue task. For firefighters, these factors can be the difference between life or death not only for the victims but also for themselves.

The delimitation of this study was set to involve a population of individuals within a tactical career field due to their ability to recognize the need to perform under time with heavy demands. Limitations that were present during this study encourage further research on this topic. Environmental conditions may have influenced completion times due to the difference in weather associated with winter between the pre and post session. Also, the time of day the performance tests were completed was maintained as consistent as possible; however, there were variations in order to fit subject availability. The ability to recruit subjects, including subjects with prior CPAT testing experience due a lack of exposure in the recruited local fire departments, resulted in a small sample size. This small sample size was also affected by subject mortality with the nature of it being volunteer recruitment, injury, shift schedule, and treatment compliance. Subjects were asked to complete a self-directed warm-up prior to testing (under the assumption those who warmed up the first time would do so the second session as well); however, this assumption was not held and it may have acted as a limitation of which to be controlled for across all subjects in future studies. The role of testing familiarization as a threat to internal validity during the second testing session is arguable because the exercises that were chosen for testing are tasks that each subject should already be proficient in as an active firefighter.

Overall, it is recommended that this study be performed on a larger population size with more ability to control for the limitations set forth in this study. This study proposed the question of whether the addition of core stabilization exercises during a workout could serve as a positive corrective action to employ in the daily exercise routine of firefighters. Tactical populations often concentrate on the development of large muscle groups through exercise such as powerlifting or CrossFit and as a result, the small stabilizing muscles, such as those of the hips, trunk, and core, are often neglected. Future implications of this study are for fitness professionals such as personal trainers, athletic trainers, physical therapists, etc., as well as for firefighters and the health and safety captains of the department who are responsible for the standards of physical fitness. Emphasis from fitness professionals needs to be drawn to the small stabilizing muscles of the core involving the hips and trunk, and should be an active component of any workout or rehabilitation program. Although future research is recommended, the results of this study support the role of core stabilization training providing the added benefit of increasing the performance of firefighters in functional tasks under a time constraint.

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