Fitness

Impact of a Supervised Worksite Exercise Program on Back and Core Muscular Endurance in Firefighters

John M. Mayer, DC, PhD; William S. Quillen, DPT, PhD; Joe L. Verna, DC; Ren Chen, MD, PhD; Paul Lunseth, MD; Simon Dagenais, DC, PhD

Abstract

Purpose. *Low back pain is a leading cause of disability in firefighters and is related to poor muscular endurance. This study examined the impact of supervised worksite exercise on back and core muscular endurance in firefighters.*

Design. *A cluster randomized controlled trial was used for this study*

Setting. *The study occurred in fire stations of a municipal fire department (Tampa, Florida).*

Subjects. *Subjects were 96 full-duty career firefighters who were randomly assigned by fire station to exercise ($n = 54$) or control ($n = 42$) groups.*

Intervention. *Exercise group participants completed a supervised exercise targeting the back and core muscles while on duty, two times per week for 24 weeks, in addition to their usual fitness regimen. Control group participants continued their usual fitness regimen.*

Measures. *Back and core muscular endurance was assessed with the Biering-Sorensen test and plank test, respectively.*

Analysis. *Changes in back and core muscular endurance from baseline to 24 weeks were compared between groups using analysis of covariance and linear mixed effects models.*

Results. *After 24 weeks, the exercise group had 12% greater ($p = .021$) back muscular endurance and 21% greater ($p = .0006$) core muscular endurance than did the control group. The exercise intervention did not disrupt operations or job performance.*

Conclusion. *A supervised worksite exercise program was safe and effective in improving back and core muscular endurance in firefighters, which could protect against future low back pain. (Am J Health Promot 2015;29[3]:165–172.)*

Key Words: Firefighters, Low Back Pain, Physical Fitness, Prevention, Exercise Training, Prevention Research. Manuscript format: research; Research purpose: intervention testing/program evaluation; Study design: randomized trial; Outcome measure: biometric; Setting: workplace; Health focus: fitness/physical activity; Strategy: skill building/behavior change; Target population age: youth, adults; Target population circumstances: geographic location

PURPOSE

Firefighting is one of the most hazardous, physically demanding, and psychologically stressful occupations.[1] As a consequence, firefighters are at high risk of musculoskeletal injuries, particularly of the low back, and low back injury is the most common injury leading to early retirement for firefighters.[1,2] Firefighters perform numerous occupational activities that expose them to physical overexertion, which increases the possibility of back injury.[3] These activities require adequate levels of back and core muscular support in order to stabilize the spine and counteract the physical demands placed on them.

Deconditioned back and core muscles have been associated with low back pain in firefighters and the general population. A preliminary study observed that firefighters with a history of low back pain have lower levels of back muscular endurance compared with those without a history of low back pain.[4] In the general population, reduced strength and endurance, atro-

John M. Mayer, DC, PhD; William S. Quillen, DPT, PhD; and Paul Lunseth, MD, are with the School of Physical Therapy and Rehabilitation Sciences, and Ren Chen, MD, PhD, is with the Clinical and Translational Science Institute, College of Medicine, University of South Florida, Tampa, Florida. Joe L. Verna, DC, is with the Vert Mooney Research Foundation, San Diego, California. Simon Dagenais, DC, PhD, is with Spine Research LLC, Winchester, Massachusetts.

Send reprint requests to John M. Mayer, DC, PhD, University of South Florida, 12901 Bruce B. Downs Blvd MDC77, Tampa, FL 33612; jmayer2@health.usf.edu.

This manuscript was submitted February 28, 2013; revisions were requested July 1, 2013; the manuscript was accepted for publication September 18, 2013.

0890-1171/15/$5.00 + 0
DOI: 10.4278/ajhp.130228-QUAN-89

phy, fatty infiltration, and abnormal myoelectrical activity in the back and core muscles have been reported in individuals with low back pain.[5–7] Moreover, decreased back muscular endurance has been associated with an increased risk of future low back pain and is predictive of an increased incidence of work disability.[6,8]

Given the importance of the back and core muscles, the Fire Service Joint Labor Management Wellness Fitness Initiative recommends that all firefighters undergo physical fitness testing and exercise training for these muscles.[1] However, this initiative does not offer specific suggestions about strategies to improve and maintain the functional capacity of the back and core muscles, making it unclear how these recommendations could be implemented within the fire service.

While no known randomized controlled studies have assessed the effectiveness of exercise interventions on improving muscular endurance and reducing back injuries in firefighters, several previous studies provide preliminary insight about the relationship of physical fitness and worksite interventions on back injuries in firefighters. For example, in a cross-sectional study, Cady et al.[9] demonstrated that a significant relationship existed between physical fitness parameters, such as back strength, and subsequent risk of back injury in firefighters. In a one-arm cohort study, Peate et al.[10] reported that a core exercise program for firefighters resulted in a reduction of lost work time related to back injuries. In a one-arm cohort study, Kim et al.[11] found that a back education program resulted in reduction of lost work time and costs related to low back injuries. In a two-arm cluster randomized trial, Hilyer et al.[12] reported that a general flexibility exercise program resulted in a reduction of loss time costs related to unspecified musculoskeletal injuries in firefighters.

In non-firefighters, back muscular endurance gains have been observed following a supervised exercise training program using specific progressive resistance exercise protocols,[13] but the efficacy of this program has not been studied in firefighters. Although high-intensity, general physical fitness programs such as cross training have gained support among various fire service organizations,[14,15] such programs are time-consuming, physically intense, and difficult to implement, which may negatively affect compliance and short-term job performance in firefighters.[14,15] Moreover, general physical exercise programs may result in substantial proportion of worksite injuries in firefighters.[16]

Given the unclear effectiveness of general physical fitness programs to improve the functional capacity of the back and core muscles and the importance of these muscles to low back injuries in firefighters, exercises focused on improving the endurance of back and core muscles seem warranted. Such targeted exercise programs appear to be a more efficient and direct approach to reduce the burden of low back injuries among firefighters and could be more widely implemented if deemed successful. However, the effectiveness and safety of these programs have not been assessed in firefighters through a randomized controlled trial. The primary objective of this study was to assess the effectiveness of a supervised worksite exercise program targeting the back and core muscles on the development of back and core muscular endurance in firefighters. A secondary objective was to assess the safety of this program by examining the harms reported by study participants.

METHODS

Design

This study was a two-arm, cluster randomized controlled trial in which the unit of randomization was the worksite (i.e., fire station). Participants were randomized to one of two groups for a period of 24 weeks: (1) exercise (supervised exercise training targeting the back and core muscles, plus usual physical fitness program) or (2) control (usual physical fitness program alone). Primary outcome measures were collected at a university-based human functional performance laboratory, and exercise training sessions were carried out at the fire station.

Sample

Participants ($n = 96$; 9 female, 87 male) (Table 1) were career firefighters taken from regular service firefighters ($n = 573$) at Tampa Fire Rescue (Tampa, Florida) who were recruited through presentations, e-mail notices, flyers, and word-of-mouth. To determine eligibility, candidates underwent a telephone and on-site screening with self-reported health questionnaires, urine pregnancy testing for females, and a physical examination by a medical physician. The university's institutional review board approved the experimental protocol, and all participants provided informed consent prior to screening.

Inclusion criteria for participation were that subjects be (1) 18 years of age or older and (2) a full-duty, career firefighter of Tampa Fire Rescue. Exclusion criteria were as follows: (1) cardiovascular or orthopedic contraindications to resistance exercise[17] as identified by history and physical examination; (2) history of systemic inflammatory disease or spinal surgery; (3) clinically significant current low back pain or disability;[18,19] (4) currently diagnosed with or receiving treatment for a psychological or psychiatric disorder; (5) currently performing progressive resistance back extension exercises using a variable angle Roman chair or weight machine-based protocols; (6) active workers' compensation or personal injury case; (7) pregnant; (8) drug or alcohol abuse within the past year.

Measures

Safety. Adverse event data, including specific symptoms, as well as their severity, duration, and health care utilization, were gathered by study personnel at each study visit and exercise training session, and they could be reported by participants at any time. Data were tabulated and categorized by the investigators according to severity, type, and relatedness to the study procedures.

Isometric Back and Core Muscular Endurance. The primary outcomes for this study were isometric back muscular endurance time and isometric core muscular endurance time, which were assessed at baseline and after 12 weeks and 24 weeks of the intervention. A modified version of the Biering-Sorensen test was used to assess isometric back muscular endurance[20] because of

Table 1
Baseline Characteristics of Participants*

	Exercise (n = 54) Mean ± SD	Control (n = 42) Mean ± SD	Total (n = 96) Mean ± SD	Exercise (n = 54) No. (%)	Control (n = 42) No. (%)	Total (n = 96) No. (%)
Continuous variable						
Age (y)	37.6 ± 9.8	31.3 ± 8.0	34.8 ± 9.5			
Career as firefighter (y)	11.3 ± 9.3	5.7 ± 7.1	8.9 ± 8.8			
Height (cm)	177.3 ± 7.5	176.7 ± 9.0	177.1 ± 8.2			
Weight (kg)	88.7 ± 12.8	85.6 ± 18.7	87.3 ± 15.7			
Body fat (%)	23.4 ± 8.9	21.3 ± 7.0	22.5 ± 8.1			
Physical activity (d/wk)	3.2 ± 1.2	3.3 ± 1.4	3.2 ± 1.3			
Categorical variable						
Sex						
Female				7 (16.7)	2 (3.7)	9 (9.4)
Male				35 (82.3)	52 (96.3)	87 (90.6)
History of low back pain						
No				29 (53.7)	38 (90.5)	67 (69.8)
Yes				23 (46.3)	4 (9.5)	29 (30.2)
BMI classification (kg/m^2)						
Normal (18.5–24.9)				11 (21.6)	13 (31.7)	24 (26.1)
Overweight (25.0–29.9)				24 (47.1)	20 (48.8)	44 (47.8)
Obese (≥30)				16 (31.4)	8 (19.5)	24 (26.1)

*BMI indicates body mass index; and SD, standard deviation.

its ability to activate the low back muscles,[6] its relationship with future incidence of low back pain,[6] and its reliability as a measure of isometric back extension muscular endurance.[20] For the test, the participant was positioned on a variable angle Roman chair with the anterior superior iliac spines aligned to the superior edge of the pelvic restraint pad of the machine. The hands were placed behind the head, the ankles were positioned under the ankle pad, and the legs were held as straight as possible. The participant was instructed to elevate the torso to a horizontal position and was verbally encouraged by the examiner to hold the position as long as possible. If the participant was unable to maintain the test position (e.g., if the torso dropped 10° below the horizontal position) after two warnings, the examiner stopped the test, and time was recorded in seconds.

Following the Biering-Sorensen test and a 4-minute rest, the plank test was performed to assess isometric core muscular endurance[1] because of its ability to activate the core muscles,[21] its inclusion in the Fire Service Joint Labor Management Wellness Fitness Initiative as a recommended fitness test for firefighters,[1] and its reliability as a measure of isometric core muscular endurance.[22] For the test, the participant assumed the following position while prone on a floor mat: upper body, hips, and legs evaluated off the floor so the neck, trunk, and lower extremities aligned in the sagittal plane; body supported on forearms and toes; elbows directly under the shoulders; ankles maintained at 90°; scapulae stabilized with elbows at 90°; and spine in a neutral position. The participant was verbally encouraged by the examiner to hold this position as long as possible. If the participant was unable to maintain this position after two warnings, the examiner stopped the test, and time was recorded in seconds.

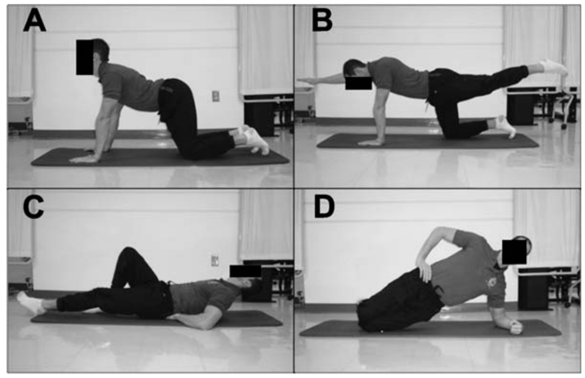
Sample Size Calculation. The unit of randomization was the fire station to which participants were normally assigned. We assumed that the intracluster correlation coefficient (ICC) for the primary outcome measures would be .1, with an average of five participants per fire station. Based on a previous exercise training study in healthy non-firefighter adults,[13] we hypothesized that participants in the exercise group would increase isometric back muscular endurance by 40% compared with controls at 24-week follow-up. Along with the mean ± standard deviation (SD) of 111 ± 47 seconds reported for isometric back muscular endurance times in untrained firefighters,[4] we estimated that 60 participants in two groups of 30 would be adequate to establish statistical significance with a two-tailed test at the .05 alpha level and a power of .80.

Randomization. Participants were randomized by cluster (fire station) instead of by individual to protect against the potential of exposure bias and contamination. Firefighters within the same station live in the same facility, eat together, train and practice together, and are otherwise in each other's company for 24 hours during each shift. If randomization were carried out by individual, firefighters within a station would have many opportunities to discuss the study with firefighters from the other study group and would observe the other group's intervention, thereby increasing the risk of exposure bias and contamination.

Prior to enrollment, the statistician (who was blinded to group assignment and did not determine eligibility) stratified the 21 fire stations of Tampa Fire Rescue by pertinent characteristics—size (i.e., number of firefighters), age of firefighters, and number of emergency responses. Each fire station was paired with another station with similar characteristics. The statistician generated the randomization sequence for each pair of fire stations using SAS (Statistical Analysis System, version 9.2, Cary, North Carolina), assigning one station to the exercise group and the other station to the control group. Of the 21 fire stations, 11 were randomized to the exercise training group and 10 were randomized to the control group. Participants were informed of their group assignment by phone. The study statistician, physician, and examiner for the back and core endurance tests were blinded to group assignment. The study participants were blinded to group assignment during baseline assessments.

Figure 1

Core Exercises (A) Cat camel, (B) Birddog, (C) Curl-up, and (D) Side bridge



Intervention

Exercise. Participants in the exercise group completed a supervised exercise training program while on duty at the fire stations, two times per week for 24 weeks. Each exercise session consisted of one set of five exercises (four core exercises on a floor mat and one back extension exercise on a variable angle Roman chair), which took approximately 10 minutes to complete. This exercise protocol was based on prior literature suggesting its effectiveness in activating the back and core muscles and improving back and core muscle endurance.[13,23,24]

Each exercise session was supervised by a certified exercise trainer who was either an exercise specialist from the research team or a peer fitness trainer[1] from the fire department. The exercise trainer traveled to each fire station assigned to the exercise group at least one time per day, 7 days per week to administer exercises for the participants. Given the shift schedule of the firefighter participants (1 day on duty followed by 2 days off duty, with an extra "R" day off every 3 weeks), the participants had a maximum opportunity to exercise 2 days per week. The participants were not relieved of their usual fire service activities (e.g., emergency responses) in order to perform the exercises, which were therefore occasionally interrupted.

To begin each exercise session, the participant completed four mat-based core exercises (cat camel, birddog, curl-up, and side bridge) (Figure 1).[24] The core exercises were performed in an isometric manner, with the isometric contraction lasting 6 to 8 seconds. One set of five repetitions was completed for each exercise, with no rest between exercises. The core exercises were performed in the same manner at each session, with the volume and intensity remaining constant throughout the training period.

Following the core exercises, the participant completed one set of dynamic progressive resistance exercise for back extension on a variable angle Roman chair (Conner Athletic Products, Jefferson, Iowa) using an exercise training protocol that was adapted from a protocol previously assessed in healthy non-firefighter adults.[13] The participant started each repetition of exercise in the terminal extension position and was instructed to lower the torso in a smooth, controlled fashion, completing the eccentric phase at terminal flexion in 4 seconds. Next, the participant raised the torso during the concentric phase of exercise, ending at terminal extension in 4 seconds. The participant held the terminal extension position for 4 seconds prior to the start of the eccentric phase of the next repetition. This set of exercise was performed until volitional fatigue or 30 repetitions was attained. The exercise resistance level was progressed at subsequent exercise sessions by altering the variable angle Roman chair angle setting (six settings) and manipulating the participant's hand positions (three hand positions) using a standardized progression protocol (Figure 2).[23,25]

Control. Participants in the control group did not receive the supervised back and core exercise intervention. Participants in both groups were instructed to continue performing their usual physical fitness routines throughout the 24-week study period and to not start any new exercises for the back and core muscles other than those administered as part of the study. Compliance to these instructions was monitored by general questioning at the follow-up study visits. The usual physical fitness routine of firefighters of the target population varies widely and was not monitored in this study.

Analysis

Analysis of covariance (ANCOVA), which controlled for baseline muscular endurance time,[26] was used to determine if a difference in back and core muscular endurance existed between the exercise and control groups at the 24-week time point. A linear mixed effects model was used to assess the effect of group on change in muscular endurance over the 24 weeks of the study. A linear mixed effects model was selected because the sphericity assumption required for a repeated measures analysis of variance was violated, data were missing from the follow-up time points, and it accounted for the hierarchical structure and correlated measurements.[27]

For the linear mixed effects model, the fixed factors were group (exercise,

Figure 2
Progressive Resistance Exercise Protocol Used for Back Extension Exercise Training

Machine Angle	Hand Position	Resistance
 75°	1. Hands on Sternum 2. Genie Arm Cross 3. Behind the Head	LEAST *(easiest)*
 60°	4. Hands on Sternum 5. Genie Arm Cross 6. Behind the Head	↓
 45°	7. Hands on Sternum 8. Genie Arm Cross 9. Behind the Head	↓
 30°	10. Hands on Sternum 11. Genie Arm Cross 12. Behind the Head	↓
 15°	13. Hands on Sternum 14. Genie Arm Cross 15. Behind the Head	↓
 0°	16. Hands on Sternum 17. Genie Arm Cross 18. Behind the Head	MOST *(hardest)*

control), time point (baseline, 12 weeks, 24 weeks), interaction between group and time, age of participant (years), body mass index (BMI) (kg/m^2), and physical activity level (d/wk). The random factor was the individual within the fire station. The ICC was estimated to measure the clustering effect and the proportion of variance owing to clustering. Factors related to improvements in muscular endurance were assessed for the exercise group participants by calculating Spearman rank and Pearson product moment correlation coefficients. Spearman rank correlation coefficients were used to assess the relationship between the number of exercise sessions completed over 24 weeks and the improvement in muscular endurance observed at 24 weeks. Pearson product moment correlation coefficients were used to assess the relationship between baseline muscular endurance and the improvement in muscular endurance observed at 24 weeks. Intention to treat analyses were used, and statistical significance was accepted with alpha set at .05. Data are reported as mean ± SD unless otherwise noted. All analyses were conducted using SAS version 9.2 and SPSS version 20 (IBM, Armonk, New York).

Results

Disposition of Participants Through Study. (See Figure 3.) Of the 153 firefighters assessed for eligibility, 96 were deemed eligible to participate and were randomized (exercise n = 54, control n = 42). Reasons for ineligibility were that they (1) did not meet inclusion/exclusion criteria at phone screen (n = 18); (2) were unable or unwilling to participate at phone screen (n = 6); (3) were eligible at phone screen but did not attend screening visit (n = 23); and (4) did not meet inclusion/exclusion criteria at screening visit (n = 10). Of the 96 participants who were randomized, 86 completed the end-of-trial (24-week) assessments. Reasons for missed end-of-trial assessments were (1) voluntary withdrawal (n = 4); (2) not meeting inclusion/exclusion criteria required to continue participation (n = 3); and (3) not showing up for end-of-trial assessment (n = 3). Baseline physical activity level, weight, BMI, body fat percentage, back muscular endurance, and core muscular endurance were not significantly different between randomized participants who completed the end-of-trial assessments and those who did not complete the end-of-trial assessments.

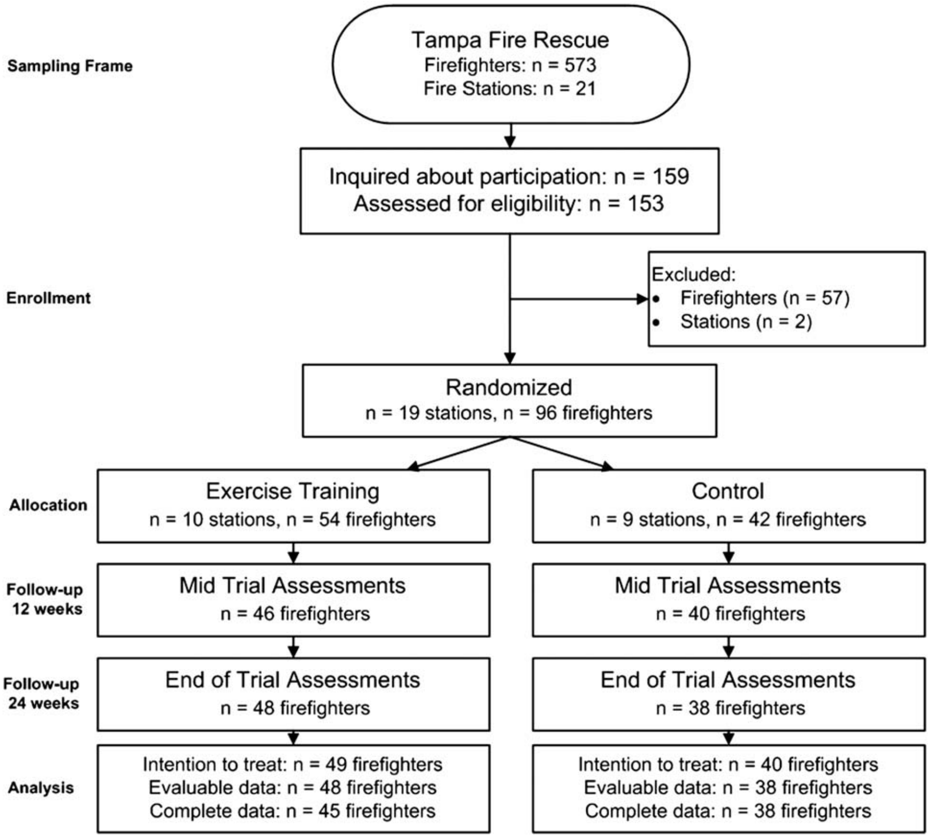
Exercise Training Characteristics. Exercise interventions were completed for all participants over a 228-day period, requiring 218 days of supervised exercise training, 1105 visits to the fire stations, and 1745 individual supervised exercise sessions administered by the exercise trainers. The mean ± SD number of exercise training sessions completed over the 24-week training period by each participant in the exercise group was 32.3 ± 10.1, which was approximately 67% of the target of 48 exercise sessions.

There were no reports from study staff, peer fitness trainers, fire department administrators, or study participants that participants assigned to the control group completed the back and core muscle exercises assigned to the exercise group, indicating that contamination was not a major issue. None of the study participants in either group reported that they started any new exercises for the back and core muscles other than those administered as part of the study during these 24 weeks.

Safety. A total of 22 adverse events that were related or possibly related to the exercise tests and interventions were reported throughout the study, all of which occurred in the exercise training group (Table 2). When expressed relative to the total number of 1893 exposures (i.e., sum of the 1745 individual exercise sessions and 148 individual testing sessions for the exercise training group), the incidence of related or possibly related adverse events was 1.2 adverse events per 100 exposures. None of the related or possibly related adverse events affected work status, and all participants continued to work as full active-duty firefighters. The vast majority of related or possibly related adverse events were minor, temporary, self-limiting, and consistent with responses to progressive resistance exercise (e.g., muscle soreness). There were no reports that the exercise intervention negatively affected job performance or fire service operations.

Figure 3

Flow Diagram of Participants Through the Phases of the Study



Back and Core Muscular Endurance. Raw isometric back and core muscular endurance times at baseline, 12 weeks, and 24 weeks are found in Table 3. The ICC values for back and core muscular endurance were .062 and .068, respectively. Based on the ANCOVA results, the adjusted isometric back muscular endurance time (mean ± standard error [SE]) at 24 weeks was 12% greater for the exercise group compared with the control group (exercise: 99.7 ± 3.3 seconds; control: 89.0 ± 3.0 seconds; $p = .021$). Linear mixed effects model results found a significant group by time interaction ($p = .0089$), indicating that on average, isometric back muscular endurance time increased by 1.1 seconds per month in the exercise group and decreased by 1.1 seconds per month in the control group. No significant association was found between the improvement in back muscular endurance at 24 weeks and baseline value or number of exercise sessions completed over 24 weeks.

Based on the ANCOVA results, the adjusted isometric core muscular endurance time (mean ± SE) at 24 weeks was 21% greater for the exercise group compared with the control group (exercise: 145.9 ± 4.7 seconds; control: 120.6 ± 5.3 seconds; $p = .0006$). Linear mixed effects model results found a significant group by time interaction ($p = .0166$), indicating that on average, isometric core muscular endurance time increased by .9 seconds per month in the exercise group and decreased by 2.5 seconds per month in the control group. A significant association was found between the improvement in core muscular endurance at 24 weeks with baseline value (Pearson coefficient = –0.484; $p = .0005$) and number of exercise sessions completed over 24 weeks (Spearman coefficient = 0.39; $p = .006$).

DISCUSSION

The main finding of this study was that a two-time per week, 24-week supervised exercise program targeting the back and core muscles was safe and effective. When compared to usual physical fitness programs performed by firefighters in the control group, the supervised exercise program resulted in 12% and 21% greater gains in back and core muscular endurance, respectively.

Although the impact of increased muscular endurance on preventing back injuries in firefighters is currently unclear, previous studies provide some insight regarding the clinical significance of the observed gains. For example, higher levels of endurance from various muscle groups, including the lower trunk, have been shown to be positively related to better performance on simulated firefighting tasks,[28,29] which suggests that improvements in back and core muscular endurance may coincide with improvements in job performance. In addition, a higher level of back muscular endurance has been shown to be related to improved movement quality and functional movement.[30]

Previous studies have also reported that relatively small differences in back muscular endurance were useful to identify subgroups of participants with previous, current, or future low back pain. Only 5.0 seconds separated those who reported low back pain less than a week ago from those who had low back pain more than a week ago, whereas 11.8 seconds separated those with current versus previous low back pain; 16.0 seconds distinguished those with intermittent low back pain versus no low back pain; and 17.3 seconds divided those who would experience their first episode of low back pain in the next 12 months from those who would remain symptom free.[31–33] Viewed in this context, the observed improvement of 10.7 seconds in back muscular endurance may be clinically meaningful, although the long-term impact of increased back muscle endurance on low back pain and work injuries remains unknown and requires future research.

The observation that back muscular endurance time declined in the control group at follow-up is difficult to explain. Because back muscular en-

Table 2
Adverse Events Reported by the Participants That Were Definitely or Possibly Related to the Exercise Intervention

Category and Severity	Definitely Related, No. (%)	Possibly Related, No. (%)	Total, No. (%)
Pain/soreness—low back			
Mild	5 (22.7)	6 (27.3)	11 (50.0)
Mild–Moderate	1 (4.5)	2 (9.1)	3 (13.6)
Unknown	1 (4.5)	2 (9.1)	3 (13.6)
Pain/soreness—rib			
Unknown	0 (0.0)	1 (4.5)	1 (4.5)
Pain/soreness—general			
Mild	0 (0.0)	1 (4.5)	1 (4.5)
Pain/soreness and stiffness—neck			
Mild	0 (0.0)	1 (4.5)	1 (4.5)
Stiffness—neck			
Mild	0 (0.0)	1 (4.5)	1 (4.5)
Stiffness—low back			
Mild	0 (0.0)	1 (4.5)	1 (4.5)

durance was assessed with a standardized physical fitness test requiring maximum voluntary effort, declines over time could be related to numerous factors, for example, loss of interest in repeating the study measurements for those in the control group, natural fluctuations in these measures over time, or actual decrements in physical performance and functional capacity related to natural history or other factors. In a recent study,[34] a similar reduction in back muscular endurance time was observed in healthy soldiers following 12 weeks of either core-specific or traditional trunk exercise programs.

Some potential limitations to this study must be acknowledged when interpreting its findings. All study participants were without current low back pain, without significant history of low back disorders, and from the same medium-sized municipal fire department in central Florida, which may limit its generalizability to firefighters with other health characteristics outside of this setting. The strict inclusion and exclusion criteria used to determine eligibility for participation in this initial study may have limited enrollment, thereby limited the generalizability of the study's findings. Also, potential differences were noted between groups at baseline regarding back muscular endurance, BMI, and history of low back pain, which may have complicated interpreting and comparing results. To minimize these potential confounders, we accounted for baseline scores and BMI in the statistical models. Another potential limitation of the study was that BMI and body fat percentage were not assessed at the midtrial and end-of-trial testing sessions. Since significant relationships between anthropometric measurements and back muscular endurance have been reported,[35] changes in anthropometric measurements may confound changes observed in muscular endurance over the course of an exercise program. Although statistically significant gains in muscular endurance were observed in this initial study, the impact of increased muscular endurance on preventing back injuries in firefighters is currently unclear. Many researchers and clinicians believe that improving muscular endurance through exercise is beneficial. However, the supporting evidence regarding specific details of the relationship between improving muscular endurance and reducing back injuries is unavailable. For example, no validated thresholds have been established to determine the acceptable or minimal level of endurance required to protect against back injuries in firefighters or other high-risk workers.

These findings suggest that additional randomized controlled trials with longer follow-up periods and additional outcomes are needed to determine if back and core exercise training can improve job performance and reduce the disability burden imposed by low back pain in firefighters. Such studies could also compare the effectiveness, cost effectiveness, and ease of implementation for supervised and unsupervised exercise programs, determine the clinical meaning of observed gains in back and core muscular endurance, and determine the long-term impact of this exercise program on firefighter health, disability, injuries, and absenteeism, which together influence preparedness and fitness for duty. Given that the exercise regimen was deemed to be safe and did not negatively impact job performance in the current study, future studies could use less-restrictive eligibility criteria to ensure that results are more easily generalized to the intended study populations.

The exercise program studied is of substantial practical value for health promotion professionals who design

Table 3
Unadjusted Back Muscular Endurance (Modified Biering-Sorensen Test) and Core Muscular Endurance (Plank Test) Scores at Baseline, Midtrial (12 Weeks), and End of Trial (24 Weeks)*

Variable	Exercise		Control	
	No.	Mean ± SD	No.	Mean ± SD
Back muscular endurance (s)				
Baseline	54	86.7 ± 27.0	42	99.6 ± 26.8
Midtrial (12 weeks)	46	88.0 ± 29.9	40	94.2 ± 22.8
End of trial (24 weeks)	48	95.7 ± 31.6	38	94.1 ± 20.6
Core muscular endurance (s)				
Baseline	54	138.4 ± 58.0	42	135.6 ± 51.8
Midtrial (12 weeks)	46	134.7 ± 53.6	40	121.9 ± 54.0
End of trial (24 weeks)	48	147.3 ± 52.3	38	118.7 ± 49.7

*SD indicates standard deviation.

and implement physical fitness programs for high-risk workers in physically demanding occupations, including firefighters. Current findings indicate that this exercise program is safe, effective, and practical, requiring relatively minimal time from its participants while on duty, minimal equipment and space, and minimal staff and firefighter training.

SO WHAT? Implications for Health Promotion Practitioners and Researchers

What is already known on this topic?

Firefighters are at high risk for low back pain and disability owing to their physically demanding work environment. Worksite exercise training for the back and core muscles is a potentially useful countermeasure to reduce risk of low back pain in firefighters.

What does this article add?

This study found that a supervised worksite exercise program targeting the back and core is safe and effective for improving back and core muscular endurance in firefighters, and it does not disrupt job performance or operations of the fire department. To our knowledge, no other published controlled study has demonstrated these effects.

What are the implications for health promotion practice or research?

The present study's findings support fire services' implementation of exercise programs designed to improve the functional capacity of the back and core muscles in firefighters. Researchers can build upon this study's findings to further assess the effectiveness of exercise programs to reduce the risk of low back pain and disability, reduce absenteeism, and enhance fitness for duty in firefighters.

References

1. International Association of Fire Fighters (IAFF) and International Association of Fire Chiefs (IAFC). *The Fire Service Joint Labor Management Wellness-Fitness Initiative.* 3rd ed. Washington, DC: IAFF; 2008.
2. Karter M, Molis J. *US Firefighter Injuries-2007.* Quincy, Mass: National Fire Protection Association; 2008.
3. Nuwayhid I, Stewart W, Johnson J. Work activities and the onset of first-time low back pain among New York City fire fighters. *Am J Epidemiol.* 1993;137:539–548.
4. Verna J, Mooney V, Stowell C, et al. Back muscle strength, endurance, and flexibility characteristics of firefighters. *Proceedings of the 7th Interdisciplinary World Congress on Low Back & Pelvic Pain.* 2010: 390–394.
5. Hides JA, Stokes MJ, Saide M, et al. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. *Spine.* 1994;19:165–172.
6. Demoulin C, Vanderthommen M, Duysens C, Crielaard J. Spinal muscle evaluation using the Sorensen test: a critical appraisal of the literature. *Joint Bone Spine.* 2006;73: 43–50.
7. Mooney V, Gulick J, Perlman M, et al. Relationships between myoelectric activity, strength, and MRI of the lumbar extensor muscles in back pain patients and normal subjects. *J Spinal Disord.* 1997;10:348–356.
8. Rissanen A, Helivaara M, Alaranta H, et al. Does good trunk extensor performance protect against back-related work disability? *J Rehabil Med.* 2002;34:62–66.
9. Cady L, Bischoff D, O'Connell E, et al. Strength and fitness and subsequent back injuries in firefighters. *J Occup Med.* 1979; 21:269–272.
10. Peate WF, Bates G, Lunda K, et al. Core strength: a new model for injury prediction and prevention. *J Occup Med Toxicol.* 2007;2:3.
11. Kim P, Hayden JA, Mior SA. The cost-effectiveness of a back education program for firefighters: a case study. *J Can Chiropr Assoc.* 2004;48:13–19.
12. Hilyer JC, Brown KC, Sirles AT, Peoples L. A flexibility intervention to reduce the incidence and severity of joint injuries among municipal firefighters. *J Occup Med.* 1990;32:631–637.
13. Verna JL, Mayer JM, Mooney V, et al. Back extension endurance and strength: the effect of variable-angle roman chair exercise training. *Spine.* 2002;27:1772–1777.
14. Abel MG. Concerns and benefits of on-duty exercise training for firefighters. *NSCA, TSCR.* 2012;July (23):1–4.
15. Abel MG, Mortara AJ, Pettitt RW. Evaluation of circuit-training intensity for firefighters. *J Strength Cond Res.* 2011;25: 2895–2901.
16. Poplin GS, Harris RB, Pollack KM, et al. Beyond the fireground: injuries in the fire service. *Inj Prev.* 2012;18:228–233.
17. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription.* 8th ed. New York, NY: Lippincott Williams & Wilkins; 2010.
18. Mayer JM, Mooney V, Matheson LN, et al. Continuous low-level heat wrap therapy for the prevention and early phase treatment of delayed onset muscle soreness of the low back: a randomized controlled trial. *Arch Phys Med Rehabil.* 2006;87:1310–1317.
19. Roland M, Fairbank J. The Roland-Morris Disability Questionnaire and the Oswestry Disability Questionnaire. *Spine.* 2000;25: 3115–3124.
20. Udermann B, Mayer J, Ploutz-Snyder L, Graves J. Quantitative assessment of lumbar paraspinal muscular endurance. *J Athl Train.* 2003;38:259–262.
21. Ekstrom RA, Donatelli RA, Carp KC. Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises. *J Orthop Sports Phys Ther.* 2007;37:754–762.
22. Schellenberg KL, Lang JM, Ming Chan K, Burnham RS. A clinical tool for office assessment of lumbar spine stabilization endurance: prone and supine bridge maneuvers. *Am J Phys Med Rehabil.* 2007;86: 380–386.
23. Mayer JM, Graves JE, Verna JL, et al. Electromyographic activity of the lumbar extensor muscles: effect of angle and hand position during Roman chair exercise. *Arch Phys Med Rehabil.* 1999;80:751–755.
24. McGill SM. Low back exercises: evidence for improving exercise regimens. *Phys Ther.* 1998;78:754–765.
25. Mayer JM, Verna JL, Manini T, et al. Electromyographic activity of the trunk extensor muscles: effect of varying hip position and lumbar posture during Roman chair exercise. *Arch Phys Med Rehabil.* 2002;83:1543–1546.
26. Senn S. Testing for baseline balance in clinical trials. *Stat Med.* 1994;13:1715–1726.
27. Krueger C, Tian L. A comparison of the general linear mixed model and repeated measures anova using a dataset with multiple missing data points. *Biol Res Nurs.* 2004;6:151–157.
28. Michaelides MA, Parpa KM, Henry LJ, et al. Assessment of physical fitness aspects and their relationship to firefighters' job abilities. *J Strength Cond Res.* 2011;25:956–965.
29. Rhea M, Alvar B, Gray R. Physical fitness and job performance of firefighters. *J Strength Cond Res.* 2004;18:348–352.
30. McGill S, Frost D, Andersen J, et al. Movement quality and links to measures of fitness in firefighters. *Work.* 2013;45: 357–366.
31. Biering-Sorensen F. Physical measurements as risk indicators for low back trouble over a one-year period. *Spine.* 1984;9:106–119.
32. Hultman G, Nordin M, Saraste H, Ohlsen H. Body composition, endurance, strength, cross-sectional area, and density of mm erector spinae in men with and without low back pain. *J Spinal Disord Tech.* 1993;6:114–123.
33. Latimer J, Maher C, Refshauge K, Colaco I. The reliability and validity of the Biering-Sorensen test in asymptomatic subjects and subjects reporting current or previous nonspecific low back pain. *Spine.* 1999;24:2085–2090.
34. Teyhen DS, Childs JD, Dugan JL, et al. Effect of two different exercise regimens on trunk muscle morphometry and endurance in soldiers in training. *Phys Ther.* 2013;93:1211–1224.
35. Mbada C, Ayanniyi O, Adedoyin R, Johnson O. Static endurance of the back extensor muscles: association between performance and reported reasons for test termination. *J Musculoskelet Res.* 2010;13: 13–21.

AMERICAN JOURNAL *of* Health Promotion

The Wisdom of Practice and the Rigor of Research

AMERICAN JOURNAL *of* Health Promotion

Volume 28, Number 6
July/August 2014

THE SCIENCE OF LIFESTYLE CHANGE

Editor's Notes: What Is the ROI of Workplace Health Promotion? The Answer Just Got Simpler By Making the Question More Complicated Michael P. O'Donnell	iv
Recognition of Reviewers	vi
2015 Call for Conference Proposals	414
The Relationship Between Return on Investment and Quality of Study Methodology in Workplace Health Promotion Programs Siyan Baxter, Kristy Sanderson, Alison J. Venn, C. Leigh Blizzard, Andrew J. Palmer	347
Five-Year Medical and Pharmacy Costs After a Medically Supervised Intensive Treatment Program for Obesity Valerie H. Myers, Megan Apperson McVay, Meghan M. Brashear, William D. Johnson, Alok K. Gupta, Phillip J. Brantley, Donna H. Ryan	364
A Closer Examination of the Interaction Among Risk Factors for Low Back Pain Hui-Chuan Huan, Hsiu-Ju Chang, Kuan-Chia Lin, Hsiao-Yean Chiu, Jui-Hung Chung, Hong-Chieh Tsai	372
Eat for Life: A Work Site Feasibility Study of a Novel Mindfulness-Based Intuitive Eating Intervention Hannah E. Bush, Lynn Rossy, Laurie B. Mintz, Laura Schopp	380
Relationship Between Employment Characteristics and Obesity Among Employed U.S. Adults Sohyun Park, Liping Pan, Tina Lankford	389
Mobile Technology, Cancer Prevention, and Health Status Among Diverse, Low-Income Adults Jason Q. Purnell, Julia Griffith, Katherine S. Eddens, Matthew W. Kreuter	397
A Microgeographic Analysis of Physical Activity Behavior Within Elementary School Grounds Peter Anthamatten, Erin Fiene, Eve Kutchman, Melanie Mainar, Lois Brink, Ray Browning, Claudio R. Nigg	403
Associations Between Childhood Obesity and the Availability of Food Outlets in the Local Environment: A Retrospective Cross-Sectional Study Laura J. Miller, Sarah Joyce, Shannon Carter, Grace Yun	e137
Household Food Insecurity and Dietary Intake Among Mexican-American Women Participating in Federal Food Assistance Programs Angela Hilmers, Tzu-An Chen, Karen W. Cullen	e146
Abstracts	413

The Art of Health Promotion

Coaching and Accountability Paul E. Terry	TAHP-1

"*The American Journal of Health Promotion* provides a forum for that rare commodity — practical and intellectual exchange between researchers and practitioners."

Kenneth E. Warner, PhD
Dean and Avedis Donabedian Distinguished University Professor of Public Health
School of Public Health, University of Michigan

"The contents of the *American Journal of Health Promotion* are timely, relevant, and most important, written and reviewed by the most respected researchers in our field."

David R. Anderson, PhD, LP
Senior Vice President & Chief Health Officer, StayWell Health Management

Be the first to know.

onlineFirst

Available exclusively to ONLINE SUBSCRIBERS

The *American Journal of Health Promotion* is now publishing all articles online, ahead of print. Articles are available as a PDF document for download as soon as they have completed the review process. This means you can access the very latest papers in the field of health promotion – in some cases up to a year before they appear in print.

Subscribe Today.

6 Issues/Year

ISSN 0890-1171 (PRINT)
ISSN 2168-6602 (ONLINE)

Subscribe Online at www.HealthPromotionJournal.com
CUSTOMER SERVICE (US only) or 785-865-9402

ANNUAL SUBSCRIPTION RATES (Effective 1-1-2015 through 12-31-2015)

SUBSCRIPTION	USA	CANADA/ MEXICO	OTHER COUNTRIES
Individual Print & Online*	$145	$154	$163
Institutional Print Only**	$191	$200	$209
Tier 1: Institutional Print & Online	$373	$382	$391
Institutional Online Only	$373	$373	$373
Tier 2: Institutional Print & Online	$477	$486	$495
Institutional Online Only	$477	$477	$477
Tier 3: Institutional Print & Online	$581	$590	$599
Institutional Online Only	$581	$581	$581
University w/Archive Posting Privileges***	$895	$904	$913

*Individual Subscriptions must be set up in the name of a single individual and mailed to a residential address.
** Print subscriptions are one print copy per issue. For multi-site institutions wishing to have a copy sent to each location, additional subscriptions are required.
Tier 1 — Most Employers and Corporations except Health Organizations, Libraries and Schools
Tier 2 — Health Organizations including Hospitals, Clinics, Health Promotion Providers, Insurance Companies and Voluntary Health Agencies
Tier 3 — Libraries, Colleges and Universities
*****University w.Archive Posting Privileges** — Allows an unlimited number of faculty, students and staff to post an unlimited number of typeset accepted manuscripts on the school's internal archive website. Includes print and online.

*Kwame Owusu-Edusei, Jr. is serving in his personal capacity. The views expressed are his own and do not necessarily represent the views of the Centers for Disease Control and Prevention or the United States Government.