Research Report

Effects of Traditional Sit-up Training Versus Core Stabilization Exercises on Short-Term Musculoskeletal Injuries in US Army Soldiers: A Cluster Randomized Trial

John D. Childs, Deydre S. Teyhen, Patrick R. Casey, Kimberly A. McCoy-Singh, Angela W. Feldtmann, Alison C. Wright, Jessica L. Dugan, Samuel S. Wu, Steven Z. George

Background. The US Army has traditionally utilized bent-knee sit-ups as part of physical training and testing. It is unknown whether the short-term effects of a core stabilization exercise program without sit-up training may result in decreased musculoskeletal injury incidence and work restriction compared with traditional training.

Objective. The objective of this study was to explore the short-term effects of a core stabilization exercise program (CSEP) without sit-up training and a traditional exercise program (TEP) on musculoskeletal injury incidence and work restriction.

Design. The study was designed as a cluster randomized trial.

Setting. The setting was a 16-week training program at Fort Sam Houston (San Antonio, Texas).

Participants. The study participants were soldiers with a mean age of 22.9 years (SD=4,7, range=18–35) for whom complete injury data were available for analysis (n=1,141).

Intervention. Twenty companies of soldiers were cluster randomized to complete the CSEP (10 companies of 542 soldiers) or the TEP (10 companies of 599 soldiers). The CSEP included exercises targeting the transversus abdominus and multifidus musculature. The TEP comprised exercises targeting the rectus abdominus, oblique abdominal, and hip flexor musculature.

Measurements. Research staff recorded all injuries resulting in the inability to complete full duty responsibilities. Differences in the percentages of musculoskeletal injuries were examined with chi-square analysis; independent sample t tests were used to examine differences in the numbers of days of work restriction.

Results. Of the 1,141 soldiers for whom complete injury data were available for analysis, 511 (44.8%) experienced musculoskeletal injuries during training that resulted in work restrictions. There were no differences in the percentages of soldiers with musculoskeletal injuries. There also were no differences in the numbers of days of work restriction for musculoskeletal injuries overall or specific to the upper extremity. However, soldiers who completed the TEP and experienced a low back injury had more days of work restriction: 8.3 days (SD=14.5) for the TEP group and 4.2 days (SD=8.0) for the CSEP group.

Limitations. A limitation of this study was the inconsistent reporting of injuries during training. However, the rates of reporting were similar between the groups.

Conclusions. The incidence of musculoskeletal injuries was similar between the groups. There was marginal evidence that the CSEP resulted in fewer days of work restriction for low back injuries.

J.D. Childs, PT, PhD, MBA, is Associate Professor and Director of Research, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School, 3151 Scott Rd, Room 2307, Fort Sam Houston, San Antonio, TX 78234 (USA). Address all correspondence to Dr Childs at: childsjd@gmail.com.

D.S. Teyhen, PT, PhD, is Associate Professor, Center for Physical Therapy Research, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

P.R. Casey, PT, is a graduate student, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

K.A. McCoy-Singh, PT, is a graduate student, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

A.W. Feldtmann, PT, is a graduate student, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

A.C. Wright, PT, is Study Coordinator, Prevention of Low Back Pain in the Military Trial, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

Author information continues on next page.

J.L. Dugan, PT, is Study Coordinator, Prevention of Low Back Pain in the Military Trial, US Army-Baylor University Doctoral Program in Physical Therapy (MCCS-HMT), Army Medical Department Center and School.

S.S. Wu, PhD, is Associate Professor and Program Director, Department of Epidemiology and Health Policy Research, University of Florida, Gainesville, Florida.

S.Z. George, PT, PhD, is Associate Professor and Assistant Department Chair, Department of Physical Therapy, Center for Pain Research and Behavioral Treatment, University of Florida.

[Childs JD, Teyhen DS, Casey PR, et al. Effects of traditional sit-up training versus core stabilization exercises on short-term musculoskeletal injuries in US Army soldiers: a cluster randomized trial. *Phys Ther.* 2010;90:1404–1412.]

The US Army has incorporated traditional bent-knee sit-ups (with the hands interlocked behind the head) during physical fitness training for many years.[1] Sit-ups test muscular endurance for the abdominal and hip flexor muscles and have validated normative standards based on sex and age.[1] This exercise has been adopted as part of the military's physical training doctrine because of its ease of testing groups of people and the notion that poorer performance of sit-ups on the Army Physical Fitness Test (APFT) has been associated with a higher incidence of musculoskeletal injuries.[2] Sit-ups also are commonly incorporated in general public training routines for the purpose of improving abdominal and hip flexor muscular endurance.

Despite longstanding tradition and the widespread popularity of sit-ups, it has been postulated that this exercise results in increased lumbar spine loading, potentially increasing the risks of injury and low back pain (LBP). Specifically, sit-ups produce large shear and compressive forces on intervertebral disks and across the lumbar spine.[3–5] Increased muscle activation anteriorly results in both initial hyperextension and subsequent hyperflexion of the lumbar spine, contributing to large compressive forces during sit-ups.[6,7]

To address these potential concerns, health and fitness professionals commonly recommend alternative "core stabilization" exercises (also commonly known as "lumbar stabilization" or "motor control" exercises), which comprise abdominal and trunk muscle strengthening exercises, in lieu of sit-ups to improve abdominal muscular fitness.[8] These recommendations are based on the accumulated evidence demonstrating that these exercises selectively activate the key abdominal and trunk musculature (ie, the transversus abdominus, multifidus, erector spinae, and quadratus lumborum muscles) involved in controlling forces across the lumbar spine.[9–13] This literature has demonstrated that these exercises should be prescribed because they are based on controlled-activation, low-load principles, which require minimal trunk movements that better match the function of the muscles and contribute to improved trunk neuromuscular control.[4,7] Advocates of these approaches also cite research indicating that abdominal crunch and trunk stabilization exercises optimize the challenge to the abdominal muscles while minimizing potentially deleterious lumbar spine forces.[3,14]

Core stabilization exercises have been supported by the US Army and advocated for inclusion in US Army physical fitness training programs[15]; however, US Army personnel are still required to take an APFT that incorporates a 2-minute maximal sit-up test. Failure to pass the APFT can have negative consequences on a soldier's career and decrease the chance for promotion; this may be one reason why a core stabilization exercise program (CSEP) has not been widely adopted in the US Army. However, Childs et al[16] recently found that a CSEP did not have a detrimental effect on sit-up performance or overall fitness scores or pass rates. There was a small but significantly greater increase in sit-up pass rates in a group receiving a CSEP (5.6%) than in a group receiving a traditional exercise program (TEP) (3.9%).[16]

Despite recent evidence that incorporating a CSEP into US Army physical training does not increase the risk of suboptimal performance on the APFT,[16] it is important to establish that any newly proposed training programs do not pose unintended consequences, such as an increased risk of musculoskeletal injuries dur-

Figure 1.
Horizontal side support exercise, part of the core stabilization exercise program.

ing training. As an example, there have been anecdotal concerns that the horizontal side support exercise (Fig. 1) might contribute to an increase in upper-extremity (UE) injuries because of the prolonged weight bearing through the shoulders that is associated with this exercise. Despite the hypothesized concerns, there are no empirical data indicating whether this exercise actually poses a real injury risk. From a broader health policy perspective, previous studies of soldiers in US Army basic training showed that the incidences of injuries during training varied from 23% to 28% for men and 42% to 67% for women.[17–21] Musculoskeletal injuries during training delay the successful completion of training or result in soldiers having to drop out of training; the end result is substantial lost productivity associated with costs estimated to be in the millions of dollars per year.[2,22–24] An adequate understanding of the potential injury risks associated with any newly proposed training programs is essential to inform policy decision making.

Therefore, the purpose of this study was to explore the short-term effects of a CSEP and a TEP on musculoskeletal injury incidence and work restriction. We hypothesized that there would be no differences between the groups in short-term injury incidence or work restriction. Advancing the understanding of the implications of newly proposed training regimens for short- and long-term injury rates will aid in policy decision making related to the design and implementation of optimal physical training guidelines in the military.

Method

Design Overview

Consecutive soldiers entering a 16-week training program at Fort Sam Houston, San Antonio, Texas, to become combat medics in the US Army were considered for study participation. This study is a report of a planned analysis of the proximal outcome of a clinical trial concerning the prevention of LBP in the military (NCT00373009),[25] which has been registered at http://clinicaltrials.gov.

The Bottom Line

What do we already know about this topic?

Low back pain (LBP) is a leading cause of disability in the US military. Traditional bent-knee sit-ups, which are widely used in military physical fitness training, have been proposed to be a potential risk factor for developing LBP due to increased lumbar spine loading. Recent evidence suggests that performing core stabilization exercise in lieu of traditional bent-knee sit-ups during training actually results in small improvements in passing rates on the sit-up component of the US Army's physical fitness test.

What new information does this study offer?

Overall, musculoskeletal injury incidence during training was similar between soldiers performing core stabilization and traditional sit-up training programs, suggesting that at least in the short term, core stabilization exercise did not result in increased injuries compared with traditional training. There was some evidence that soldiers who performed core stabilization exercise experienced fewer days of work restrictions due to low back injuries.

If you're a patient, what might these findings mean for you?

Although evidence is needed to determine whether core stabilization exercise reduces the incidence or severity of low back injuries over a longer period of time, core stabilization exercise appears to be a safe alternative to traditional sit-up training.

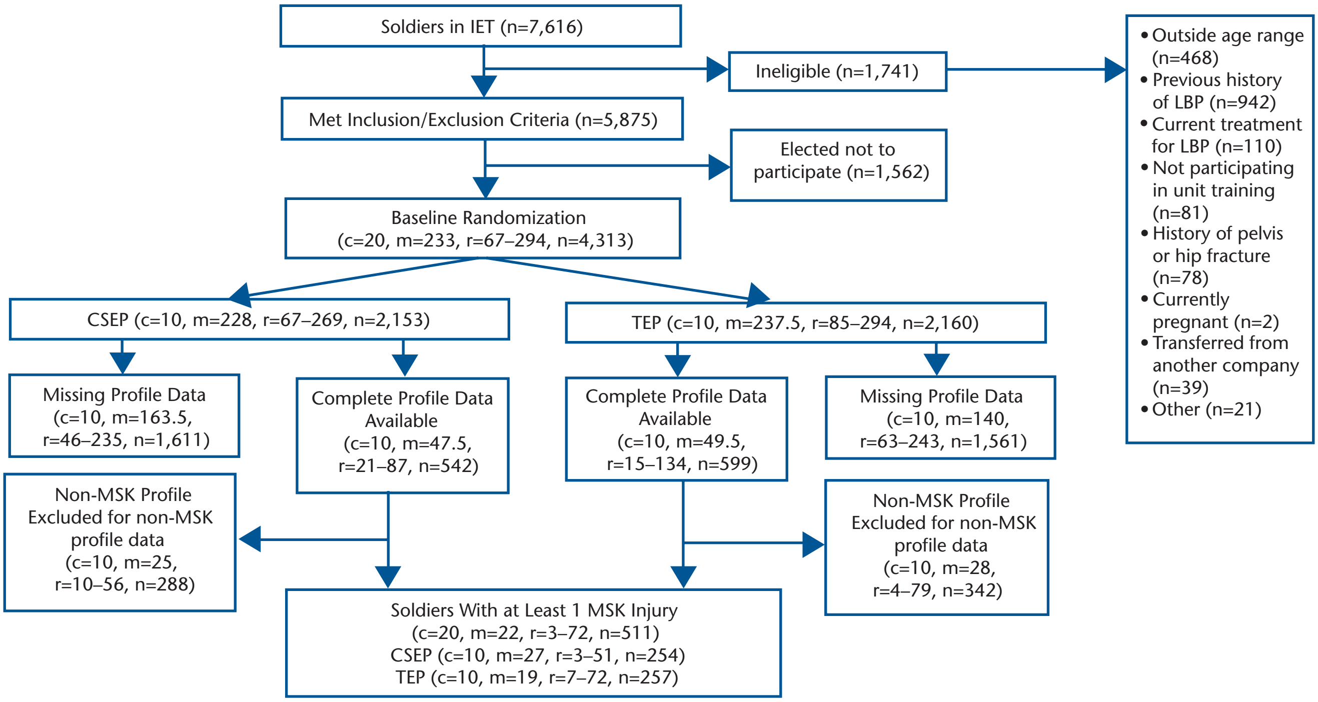

Figure 2.
Flow diagram for participant recruitment and randomization. c=number of companies, CSEP=core stabilization exercise program, IET=initial entry training, LBP=low back pain, m=median company size (number of soldiers), MSK=musculoskeletal, n=total number of soldiers, r=range of company size (number of soldiers), TEP=traditional exercise program.

In the primary trial, soldiers were randomized in clusters to receive a CSEP alone, a CSEP with a psychosocial education program, a TEP, or a TEP with a psychosocial education program. Soldiers are currently being monitored monthly for 2 years after the completion of training to assess the long-term outcomes regarding LBP occurrence and severity. However, the results of the primary trial are not yet available. Because the educational program was not designed to affect injury rates, we collapsed the study population into 2 groups (TEP group and CSEP group) for the purpose of this analysis.

Setting and Participants

Research staff at Fort Sam Houston introduced the study to individual companies of soldiers and obtained written informed consent. Soldiers were recruited during a training orientation session attended by all soldiers as part of their preparation for medic training. For 8 consecutive months, soldiers were screened for eligibility according to the inclusion and exclusion criteria. Soldiers were required to be 18 to 35 years of age (or 17-year-old emancipated minors), participating in training to become combat medics, and able to speak and read English. Soldiers with a prior history of LBP were excluded. A prior history of LBP was operationally defined as LBP that limited work or physical activity, lasted longer than 48 hours, and caused the soldier to seek health care. Soldiers also were excluded if they were currently seeking medical care for LBP; were unable to participate in unit exercise because of an injury in the foot, ankle, knee, hip, neck, shoulder, elbow, wrist, or hand; had a history of fracture (stress or traumatic) in the proximal femur, hip, or pelvis; were pregnant; or had been transferred from another training group. Other possible reasons for exclusion included acceleration into a company that had already been randomized and recruited for participation in the clinical trial concerning the prevention of LBP in the military or reassignment to an occupational specialty other than combat medic.

Figure 2 shows a flow diagram describing the numbers of companies and soldiers who were considered for the clinical trial, who were eventually enrolled in the trial, and who completed the follow-up assessment, in accordance with the guidelines of the Consolidated Standards of Reporting Trials (CONSORT) statement.[26,27]

Randomization and Interventions

Military training environments require living in close quarters with other members of the unit, making individual randomization not feasible for this trial because of concerns related to the disruption of the normal training schedule and treatment contamination. Therefore, a cluster randomization strategy was used for assigning companies to receive a TEP or a CSEP. This meant that for a given company, every soldier who consented to the study received the same study condition. Cluster randomization is a viable methodological choice that has been effectively used in other large samples of primary prevention.[28–30] The randomization schedule was prepared by computer before recruitment began and was balanced to ensure equal allocation to both conditions after 20 companies were recruited.

Soldiers in both groups performed the assigned exercise programs in a group setting under the direct supervision of their drill instructors as part of daily unit physical training. The exercise regimens for both groups consisted of 5 or 6 exercises, each of which was performed for 1 minute. Exercise programs were performed daily, for a total dosage time of approximately 5 minutes per day, 4 days per week, over a period of 12 weeks. Performing the exercise programs under the supervision of drill instructors and in a group setting helped to ensure compliance with the assigned program and dosage. Other aspects of standard physical training (ie, warm-up, aerobic training, strength and conditioning drills, and cool-down) were performed to US Army standards by both groups. Additional details regarding each exercise program are given elsewhere.[16]

The soldiers' drill instructors were given comprehensive training in the study procedures by the research staff before the initiation of the study. The drill instructors were given detailed training cards specific to each program. This information also was provided to the drill instructors on the Web site for the primary trial (http://polm.ufl.edu) for reference purposes. This training ensured that both the drill instructors and the soldiers were proficient in their assigned exercise programs and enhanced their ability to accomplish the exercise programs in a standardized manner. Study personnel supervised physical training for an average of 2 days per week over the 12-week training period to answer questions and monitor adherence to the assigned exercise programs.

Outcomes and Follow-up

Study-related measures were collected before training and 12 weeks later, when training was completed, by study personnel who were unaware of the randomization assignments. All measures were scored in a masked manner by computer algorithm. Soldiers provided standard demographic information, such as age, sex, and past medical history, and completed a variety of health outcome measures. It was not possible to prevent soldiers from being aware of their group assignments because they actively participated in their randomly assigned training programs. However, APFT scores were collected by drill instructors according to the standard testing procedures outlined below.[1] The drill instructors were not formally involved with the study other than within the context of the usual training environment.

As part of the primary trial, research staff aggregated the data on all injuries (musculoskeletal and nonmusculoskeletal) resulting in work restrictions on the basis of information provided by the administrative clerks within the soldiers' units. A *work restriction* was defined as any restriction that resulted in a soldier's inability to complete full duty responsibilities. The administrative clerks recorded injuries resulting in work restrictions on Department of the Army Form 3349 (Physical Profile) according to the US Army's standard reporting procedures. Physical profiling is a system of classifying people according to functional abilities.[31] A profile identifies a soldier's medical condition and functional activity limitations and makes suggestions for accommodative work environments and necessary work restrictions for a specified period of time. Physical profiles are issued by health care providers upon evaluation of a soldier's physical status immediately after an injury is reported. Profiles were collected on a weekly basis by study personnel.

Injuries were first classified as being musculoskeletal or nonmusculoskeletal in origin. Musculoskeletal injuries were injuries that affected the musculoskeletal system and that might have been associated with exercise and military training. Traumatic injuries (eg, a femur fracture) that could not possibly be related to the training regimen were excluded. An example of a nonmusculoskeletal injury would be a condition such as the common cold. Musculoskeletal injuries were further classified according to key body regions of interest (low back, UE, and lower extremity [LE]). We did not report separately the number of neck-related injuries because there was no hypothesis about the potential of a TEP or a CSEP to adversely affect the cervical spine. Low back injuries were defined as those affecting the lumbopelvic region. Upper-extremity injuries were defined as injuries affecting the shoulder, elbow, wrist, or hand. Lower-extremity injuries were defined as injuries affecting the hip, knee, ankle, or foot. In the event an injury crossed over regions (such as low back and hip pain), the injury was classified according to the location of the primary pain. The incidence of injury was determined by counting the number of profiles for each type of injury during training. The duration of injury was recorded as the number of days of work restriction, as annotated on the Physical Profile form.

Data Analysis

Descriptive statistics, including measures of central tendency and dispersion for continuous variables, were calculated to summarize the data. The demographic and baseline levels of variables were compared between the groups (ignoring clusters) by use of *t* tests for comparison of means and chi-square tests for comparison of proportions.

The exercise groups (CSEP and TEP) were compared for musculoskeletal injury incidence overall and according to body region (low back, UE, and LE) and for *work restriction*, defined as the number of days of work restriction. Differences in the percentages of musculoskeletal injuries were examined by use of hierarchical logistic regression; differences in the number of injuries and the number of days of work restriction were analyzed by use of hierarchical Poisson regression. The GLIMMIX procedure was used for the analyses, including a random company effect to model the correlations within clusters. The alpha level was set to .05 *a priori*. Soldiers with missing data were excluded because the purpose of this study was to determine the impact of a CSEP among soldiers who completed the full training period. All statistical analyses were performed with SAS version 9.1.*

Role of the Funding Source

This study was funded by the Congressionally Directed Peer-Reviewed Medical Research Program (W81XWH-06-1-0564). The funding agency played no role in the design, conduct, or reporting of the study or in the decision to submit the article for publication.

* SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513-2414.

Table 1.
Demographic and Other Baseline Variables[a]

Variable	All	CSEP Group	TEP Group	P
No. of companies	20	10	10	
No. of soldiers	1,141	542	599	
Age, y, $\overline{X}$ (SD)	22.7 (4.6)	22.5 (4.5)	22.7 (4.7)	.745
Sex (% men)	60.9	60.1	61.6	.615
Body mass index, kg/m^2, $\overline{X}$ (SD)	24.9 (3.6)	24.8 (3.2)	24.9 (3.9)	.538
Receiving PSEP (%)	51.6	50.0	53.1	.297
Complete profile data available (%)	26.4	25.2	27.7	.059
Currently smoke (%)	41.2	42.1	41.6	.776
Previous routine exercise (%)	42.7	47.2	44.9	.127
Education, some college (%)	56.3	56.6	55.9	.808
Previous profile (%)[b]	32.4	33.0	32.7	.818

[a] CSEP=core stabilization exercise program, TEP=traditional exercise program, PSEP=psychosocial education program that was part of the larger clinical trial.
[b] The percentage of individuals who were issued a physical profile for an injury or illness prior to arriving for the 16-week training program at Fort Sam Houston.

Results

Twenty companies with a total of 7,616 soldiers were screened for inclusion in the study. Of these soldiers, 5,875 were eligible to participate. Reasons for ineligibility included being outside the age range (n=468); having a history of LBP (n=942); currently seeking care for LBP (n=110); not participating in unit physical training (n=81); having a history of pelvis or hip fracture (n=78); currently being pregnant (n=2); transfer from another company (n=39); and other, unspecified reasons (n=21). Of the eligible soldiers, 4,313 (73.4%) consented to participate. Complete profile data were available for 1,141 (27.7%) of the randomized soldiers because of inconsistent reporting of profiles (Fig. 2); however, the rates of reporting were similar between the groups (Tab. 1).

The mean age of the soldiers was 22.7 years (SD=4.6 years), and 60.9% were men (Tab. 1). The demographic variables were similar between the exercise groups (Tab. 1). Of the 1,141 soldiers for whom complete profile data were available, 511 (44.8%) experienced at least 1 musculoskeletal injury (254 in the CSEP group and 257 in the TEP group). There were no statistically significant differences in the percentages of soldiers with musculoskeletal injuries overall (42.9% in the TEP group and 46.9% in the CSEP group; $P=.757$) or according to body region: 11.0% in the TEP group and 13.3% in the CSEP group ($P=.283$) for low back, 30.7% in the TEP group and 31.5% in the CSEP group ($P=.852$) for LE, and 4.5% in the TEP group and 6.1% in the CSEP group ($P=.513$) for UE (Tab. 2). Among soldiers with at least 1 musculoskeletal injury (n=511), there were no differences in the incidence of musculoskeletal injuries overall or according to body region ($P>.05$); the average soldier experienced 1.2 injuries during training, and the majority of these injuries were LE injuries (0.8 LE injury per soldier during training) (Tab. 3). Additionally, there were no statistically significant differences in the number of days of work restriction for musculoskeletal injuries overall or specific to the LE or UE. Means (SD) for musculoskeletal injuries overall were 21.4

Table 2.
Musculoskeletal Injuries That Resulted in Work Restrictions Among Soldiers (n=1,141)

Type of Injury	CSEP Group[a]			TEP Group[b]			P
	No. of Soldiers	% of Soldiers	Range of Cluster Percentages	No. of Soldiers	% of Soldiers	Range of Cluster Percentages	
Musculoskeletal (any)	254	46.9	14.3–63.8	257	42.9	16.7–73.3	.757
Low back	72	13.3	0–22.7	66	11.0	5.6–19.2	.283
Lower extremity	171	31.5	8.8–50	184	30.7	7.4–53.3	.851
Upper extremity	33	6.1	0–19.6	27	4.5	0–10.0	.513

[a] CSEP=core stabilization exercise program. The CSEP group comprised 10 companies and 542 soldiers.
[b] TEP=traditional exercise program. The TEP group comprised 10 companies and 599 soldiers.

(24.7) days in the TEP group and 20.4 (16.9) days in the CSEP group (*P*=.919), those for musculoskeletal injuries specific to the LE were 20.0 (23.8) days in the TEP group and 19.5 (15.6) days in the CSEP group (*P*=.791), and those for musculoskeletal injuries specific to the UE were 19.5 (17.0) days in the TEP group and 24.0 (23.1) days in the CSEP group (*P*=.634). Soldiers who were in the TEP group and who experienced a low back injury did experience more days of work restriction; means (SD) were 8.3 (14.5) days in the TEP group and 4.2 (8.0) days in the CSEP group (*P*=.083) (Tab. 4).

Discussion

The results of the present study indicate that a CSEP does not result in increased incidence or duration of musculoskeletal injuries during training. Furthermore, the data refute anecdotal concerns that have been raised regarding the horizontal side support exercise (Fig. 1) in a CSEP increasing the potential to experience a UE injury. Approximately 5% of all injuries (musculoskeletal and nonmusculoskeletal) during training were UE injuries; however, there were no differences in UE injury rates between the groups (Tab. 2). The most common injuries were LE injuries, which accounted for more than 30% of all injuries, followed by low back injuries (12%) (Tab. 2). These data confirm those of previous studies demonstrating that low back and LE injuries are the most common injuries experienced during training.[2,24]

Soldiers with UE and LE injuries experienced similar numbers of days of work restriction regardless of exercise group (20–24 days) (*P*>.05) (Tab. 4); however, soldiers who experienced a low back injury did experience more days of work restriction with the TEP than with the CSEP: 8.3 (14.5) days and 4.2 (8.0) days, respectively (*P*=.083) (Tab. 4). Although this finding is not statistically significant, a potentially relevant effect may be emerging, as demonstrated by a between-group effect size of .37. Given the evidence from the biomechanical literature demonstrating that sit-ups produce large shear and compressive forces on intervertebral disks and across the lumbar spine,[3–5] perhaps the trend toward a short-term increase in the number of days of work restriction in association with the TEP is attributable to these suboptimal biomechanical effects. Another possibility is that the increase in the number of days of work restriction indicates an early protective benefit of the CSEP with respect to low back injuries. However, in light of the mar-

Table 3.
Number of Injuries That Resulted in Work Restrictions in Soldiers With at Least 1 Musculoskeletal Injury (n=511)

Type of Injury	CSEP Group[a]			TEP Group[b]			P
	No. of Injuries		Range of Cluster Averages	No. of Injuries		Range of Cluster Averages	
	$\overline{X}$	SD		$\overline{X}$	SD		
Musculoskeletal (any)	1.3	0.5	1.0–1.6	1.2	0.5	1.0–1.4	.699
Low back	0.3	0.6	0–0.5	0.3	0.5	0.2–0.5	.616
Lower extremity	0.8	0.6	0.5–1.1	0.8	0.6	0.4–1.0	.809
Upper extremity	0.1	0.3	0–0.3	0.1	0.3	0–0.2	.888

[a] CSEP=core stabilization exercise program. The CSEP group comprised 10 companies and 254 soldiers.
[b] TEP=traditional exercise program. The TEP group comprised 10 companies and 257 soldiers.

ginal *P* value, combined with the fact that we would not expect to detect a difference in work restriction in response to the CSEP over such a short period of time, this interpretation should be viewed with caution. Whether the CSEP is protective against the development of low back injuries will be established more definitively once the 2-year follow-up is complete.

One of the potential limitations of the present study was the inconsistent reporting of injuries during training; therefore, the absolute number of injuries reported during training likely was underestimated. However, the rates of reporting were equally represented across the groups (Tab. 1). Another potential limitation is that although we excluded soldiers with a current or a previous history of LBP or other injuries that would interfere with the successful completion of unit physical training, we did not control for previous non–low back musculoskeletal injuries, except those that would interfere with the completion of unit physical training. However, because we excluded soldiers with any previous low back injuries and soldiers with non–low back musculoskeletal injuries that would interfere with the successful completion of unit physical training, it is unlikely that a previous history of nonserious musculoskeletal injuries would have contributed to current injury complaints during training.

Despite evidence from the biomechanical literature supporting the potential benefits of a CSEP as well as current literature illustrating that a CSEP does not result in decreased performance on the APFT,[16] more definitive research on the potential long-term protective effects of a CSEP on injury rates is needed. We propose that future research consider the potential of a CSEP to prevent musculoskeletal injuries, such as LE and low back injuries, in the long term. We also propose conducting a similar study outside military training environments to determine whether the results can translate to the general population.

These early data provide confidence that a long-term study of a CSEP in military training environments can be successfully carried out without increasing the risks of musculoskeletal injuries or decrements in fitness test scores, as previously reported.[16] These data, in addition to the long-term results of the primary trial, will assist health care professionals and policy makers in designing optimal military physical training programs that best maintain optimal physical fitness, maximize performance, and minimize potential injuries in both the short term and the long term. There also may be applications for clinicians, who could recommend these exercises as part of wellness or fitness routines.

Conclusions

The results of the present study demonstrated that the CSEP did not increase the incidence of musculoskeletal injuries or days of work restriction during training, regardless of the involved body region. In fact, the TEP resulted in approximately 4 more days of work restriction than the CSEP. These results may be explained by the increased shear and compressive forces across the lumbar spine during sit-ups[3–5] or may attest to an early protective effect of the CSEP. Future research should aim to determine whether the CSEP has long-term protective effects on common musculoskeletal injuries, such as LE and low back injuries.

Dr Childs, Dr Teyhen, and Dr George provided concept/idea/research design and fund procurement. Dr Childs, Dr Teyhen, Mr Casey, Ms McCoy, Ms Feldtmann, Dr Wu, and Dr George provided writing. Dr Childs, Dr Teyhen, Mr Casey, Ms McCoy, Ms Feldtmann, Ms Wright, and Ms Dugan provided data collection. Dr Childs, Dr Teyhen, Mr Casey, Ms McCoy, Ms Feldtmann, and Dr Wu provided data analysis. Dr Childs, Dr Teyhen, Ms Wright, and Ms Dugan provided project management. Dr Childs and Dr Teyhen provided participants. Dr Childs and Dr Teyhen provided facilities/equipment and institutional liaisons. Dr Childs, Dr Teyhen, Ms McCoy, Ms Feldtmann, Ms Wright, Ms Dugan, and Dr George provided consultation (including review of manuscript before submission). We thank Christopher Barnes, Yang Li, and Erik Henrickson for the creation and management of the Web site and database and Donna Cunningham for adminis-

Table 4.
Number of Limited-Duty Days That Resulted in Work Restrictions in Soldiers With at Least 1 Musculoskeletal Injury

Type of Injury	CSEP Group[a]			TEP Group[b]			P
	No. of Days		Range of Cluster Averages	No. of Days		Range of Cluster Averages	
	$\overline{X}$	SD		$\overline{X}$	SD		
Musculoskeletal (any)	20.4	16.9	14.1–28.8	21.4	24.7	10.6–28.5	.919
Low back	4.2	8.0	0–5.8	8.3	14.5	0–18.2	.083
Lower extremity	19.5	15.6	15.4–28.0	20.0	23.8	8.8–26.6	.791
Upper extremity	24.0	23.1	7.0–33.2	19.5	17.0	0–44.5	.634

[a] CSEP=core stabilization exercise program. The CSEP group comprised 10 companies and 254 soldiers.
[b] TEP=traditional exercise program. The TEP group comprised 10 companies and 257 soldiers.

trative assistance. We are grateful to various students within the physical therapy programs at the University of Texas Health Science Center at San Antonio, East Tennessee State University, University of Colorado at Denver and Health Sciences Center, Texas State University, and University of Puget Sound.

The institutional review boards at the Brooke Army Medical Center (San Antonio, Texas) and the University of Florida (Gainesville, Florida) granted approval for this project.

Some of the data from this study were presented at the Combined Sections Meeting of the American Physical Therapy Association; February 17–20, 2010; San Diego, California.

This study was funded by the Congressionally Directed Peer-Reviewed Medical Research Program (W81XWH-06-1-0564).

Trial registration: ClinicalTrials.gov: NCT0037 3009 http://clinicaltrials.gov/ct2/show/NCT 00373009).

This article was submitted November 23, 2009, and was accepted May 2, 2010.

DOI: 10.2522/ptj.20090389

References

1 *Physical Fitness Training: Field Manual 21-20 (Government Document)*. Headquarters, Department of the Army, Washington, DC; 1992:14.0–14.20.

2 Knapik J, Ang P, Reynolds K, Jones B. Physical fitness, age, and injury incidence in infantry soldiers. *J Occup Med*. 1993;35: 598–603.

3 Axler CT, McGill SM. Low back loads over a variety of abdominal exercises: searching for the safest abdominal challenge. *Med Sci Sports Exerc*. 1997;29:804–811.

4 McGill SM. The mechanics of torso flexion: situps and standing dynamic flexion maneuvers. *Clin Biomech (Bristol, Avon)*. 1995;10:184–192.

5 Nachemson A, Elfstrom G. Intravital dynamic pressure measurements in lumbar discs: a study of common movements, maneuvers and exercises. *Scand J Rehabil Med Suppl*. 1970;1:1–40.

6 Norris CM. Abdominal muscle training in sport. *Br J Sports Med*. 1993;27:19–27.

7 Richardson CA, Jull GA. Muscle control-pain control: what exercises would you prescribe? *Man Ther*. 1995;1:2–10.

8 Macedo LG, Maher CG, Latimer J, McAuley JH. Motor control exercise for persistent, nonspecific low back pain: a systematic review. *Phys Ther*. 2009;89:9–25.

9 Helewa A, Goldsmith CH, Lee P, et al. Does strengthening the abdominal muscles prevent low back pain: a randomized controlled trial. *J Rheumatol*. 1999;26: 1808–1815.

10 Hides JA, Jull GA, Richardson CA. Long-term effects of specific stabilizing exercises for first-episode low back pain. *Spine (Phila Pa 1976)*. 2001;26:E243–E248.

11 Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine (Phila Pa 1976)*. 1996; 21:2763–2769.

12 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 (Phila Pa 1976)*. 1994;19:165–172.

13 McGill SM. Low back exercises: evidence for improving exercise regimens. *Phys Ther*. 1998;78:754–765.

14 Halpern AA, Bleck EE. Sit-up exercises: an electromyographic study. *Clin Orthop Relat Res*. November–December 1979: 172–178.

15 *Army Physical Readiness Training: Field Manual 3-22.20 (Government Document)*. Headquarters, Department of the Army, Washington, DC; 2007:6.11–6.5.

16 Childs JD, Teyhen DS, Benedict TM, et al. Effects of sit-up training versus core stabilization exercises on sit-up performance. *Med Sci Sports Exerc*. 2009;41:2072–2083.

17 Bell NS, Mangione TW, Hemenway D, et al. High injury rates among female army trainees: a function of gender? *Am J Prev Med*. 2000;18:141–146.

18 Bensel CK, Kish RN. *Lower Extremity Disorders Among Men and Women in Army Basic Training and Effects of Two Types of Boots*. Natick, MA: US Army Natick Research & Development Laboratories; 1983. Technical Report Natick/TR-83/026. Available at http://handle.dtic.mil/100.2/ADA133002. Accessed May 21, 2010.

19 Jones BH, Bovee MW, Harris JM III, Cowan DN. Intrinsic risk factors for exercise-related injuries among male and female army trainees. *Am J Sports Med*. 1993;21: 705–710.

20 Kowal DM. Nature and causes of injuries in women resulting from an endurance training program. *Am J Sports Med*. 1980; 8:265–269.

21 Westphal KA, Friedl KE, Sharp MA, et al. *Health, Performance, and Nutritional Status of US Army Women During Basic Combat Training*. Natick, MA: Army Research Institute of Environmental Medicine; 1995. Technical Report A240203. Available at http://www.stormingmedia.us/24/2402/A240203.html. Accessed May 21, 2010.

22 Canham-Chervak M, Knapik JJ, Hauret K, et al. *Determining Physical Fitness Criteria for Entry Into Army Basic Combat Training: Can These Criteria Be Based on Injury Risk*? Aberdeen Proving Ground, MD: Army Center for Health Promotion and Preventive Medicine (Provisional); 2000. Final Report A717473. Available at http://www.stormingmedia.us/71/7174/A717473.html. Accessed May 21, 2010.

23 Jones BH, Knapik JJ. Physical training and exercise-related injuries: surveillance, research and injury prevention in military populations. *Sports Med*. 1999;27: 111–125.

24 Kaufman KR, Brodine S, Shaffer R. Military training-related injuries: surveillance, research, and prevention. *Am J Prev Med*. 2000;18:54–63.

25 George SZ, Childs JD, Teyhen DS, et al. Rationale, design, and protocol for the prevention of low back pain in the military (POLM) trial (NCT00373009). *BMC Musculoskelet Disord*. 2007;8:92.

26 Moher D, Schulz KF, Altman DG. The CONSORT Statement: revised recommendations for improving the quality of reports of parallel-group randomized trials. *J Am Podiatr Med Assoc*. 2001;91:437–442.

27 Campbell MK, Elbourne DR, Altman DG. CONSORT Statement: extension to cluster randomised trials. *BMJ*. 2004;328:702–708.

28 Olsen OE, Myklebust G, Engebretsen L, et al. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. *BMJ*. 2005;330:449.

29 Ornstein S, Jenkins RG, Nietert PJ, et al. A multimethod quality improvement intervention to improve preventive cardiovascular care: a cluster randomized trial. *Ann Intern Med*. 2004;141:523–532.

30 Watson L, Small R, Brown S, et al. Mounting a community-randomized trial: sample size, matching, selection, and randomization issues in PRISM. *Control Clin Trials*. 2004;25:235–250.

31 *Standards of Medical Fitness: Army Regulation 40-501 (Government Document)*. Headquarters, Department of the Army, Washington, DC; 2007:73–82.