Single-Leg Balance Impairments Persist in Fully Operational Military Special Forces Operators With a Previous History of Low Back Pain

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Background: Single-leg balance (SLB) can be chronically impaired after low back pain (LBP). Impaired SLB is a risk factor for recurrent LBP and lower extremity injury. In the United States military, the special forces operator (SFO) deploys on high-risk missions under extreme conditions, and impaired SLB can potentially threaten SFO safety and mission success.

Purpose: To compare SLB in fully operational SFOs with and without a history of LBP. The hypothesis was that SLB deficits would be present in SFOs with a history of LBP.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: A total of 226 SFOs were included in this analysis. Comparisons were made between SFOs with and without medical chart documented history of LBP (LBP group [n = 43]: mean age = 31.2 ± 10.3 years, mean height = 177.3 ± 7.2 cm, mean mass = 87.3 ± 11.8 kg; healthy group [n = 183]: mean age = 28.0 ± 6.0 years, mean height = 177.9 ± 6.0 cm, mean mass = 84.9 ± 8.8 kg). Bilateral SLB was tested (eyes open and eyes closed) in both groups using a force plate. The variability in the ground-reaction forces was averaged across 3 trials for each leg for both conditions. Comparisons were made between legs in the LBP and between the LBP and healthy group ($\alpha = .05$).

Results: There were significant between-group differences for each leg for both conditions, with the healthy group demonstrating better SLB compared with the LBP group. *P* values ranged from .01 to .03.

Conclusion: Impaired SLB persists in SFOs with previously reported LBP. Balance assessments of individuals who report LBP may assist with designing targeted interventions to address potential deficits that may increase the risk of future injury.

Clinical Relevance: SFOs with a known history of LBP would benefit from examination of SLB and may benefit from balance training to resolve any deficits that may be present to lower the potential risk for future injury.

Keywords: low back pain; postural stability; balance; military; special forces

Unintentional musculoskeletal injuries are a significant health concern for military personnel. These injuries trigger short- and long-term disability, lost duty time, hospitalization, and significant health care costs.[11,20-22,25,35,43,45] The effects of injury put military personnel at risk for recurrent or additional injuries[15,16,18,30,31] as they disrupt physical fitness, including aspects of muscle performance[7,9,16,26,31] and balance,[17,23,30,32] which are risk factors for reinjury[15,16,30,31] and the premature onset of osteoarthrosis.[4,18] Special forces operators (SFOs) in the US military may be at greater risk for such injuries as they execute frequent missions in extreme environments under physically demanding conditions and participate in rigorous predeployment preparation. Epidemiological data from large military populations indicate that low back pain (LBP) is the most frequent diagnosis for individuals deployed during Operation Iraqi Freedom[5] as well as individuals who

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were not deployed.[19] Although SFOs suffer a wide distribution of joint injuries,[10,24,34] epidemiological evidence, including our own data, have demonstrated that the lumbar spine is 1 of the 3 most common locations for musculoskeletal injuries.[34,42]

Low back pain has a significant impact on both the individual and force, as some military personnel are unable to return to their unit.[6] LBP can have a significant effect on musculoskeletal, physiological, and neuromuscular characteristics. Individuals with a history of LBP have deficits in trunk strength,[2] hamstring strength,[27] and reduced flexibility and range of motion of the trunk, hip, and knee.[27] Individuals with a history of LBP generally have a higher body mass index[2,3,14] and have lower anaerobic power and capacity.[47] Changes in postural stability and balance are frequently observed in populations with LBP, which may be one of the more significant consequences of this injury.[8,31,37]

Postural stability is the ability to maintain the body in equilibrium by maintaining the projected center of mass within the limits of the base of support.[41] It is a dynamic process that requires afferent information regarding body motion, integration of sensorimotor information within the central nervous system, and execution of appropriate musculoskeletal responses to establish an equilibrium between destabilizing and stabilizing forces.[36] The components of this dynamic process can be affected by injury and have been demonstrated to be a risk factor for ankle and knee injury.[28,33,44,46,49,50] The possibility that LBP may result in deficits in postural stability, which, in turn, could increase the operator's risk for other injury such as to the ankle and the knee, is a concern for SFOs and their medical and training personnel.

The SFO is tasked with physically demanding missions under extreme conditions that can result in musculoskeletal injury. They frequently suffer lumbar spine injuries and LBP, which can result in musculoskeletal and neuromuscular impairments, including balance deficits. These deficits may persist beyond return to duty, which can put the SFO at risk for recurrent injury to the lumbar spine or new injury to the lower extremity. The purpose of this research study was to compare the balance capabilities of a group of SFOs who have previously reported LBP with a group of SFOs who have never reported LBP. We hypothesized that the balance ability of the operators with reported LBP would be significantly less than those who have never reported LBP. The results of this study, if our hypothesis is true, may demonstrate the need to augment current physical training with balance training for those operators who report LBP to prevent future injury to the lumbar spine or to the lower extremity.

MATERIALS AND METHODS

Participants

Special forces operators were recruited and tested at an onsite human performance research laboratory operated by personnel from the University of Pittsburgh. Since 2005, the University of Pittsburgh's Department of Sports Medicine and Nutrition has collaborated with the military to reduce the risk of injury and optimize performance of SFOs. As part of this effort, retrospective and prospective injury data were collected in parallel with musculoskeletal, neuromuscular, biomechanical, physiological, and nutritional data at an on-base human performance research laboratory. All operators had been cleared for full duty and voluntarily consented to participate in the study. A total of 226 SFOs were included in the study. Forty-three operators had a medical chart–documented history of LBP (mean age, 31.2 ± 10.3 years; mean height, 177.3 ± 7.2 cm; mean mass, 87.3 ± 11.8 kg); 183 operators did not have a medical chart–documented history of LBP (healthy; mean age, 28.0 ± 6.0 years; mean height, 177.9 ± 6.0 cm; mean mass, 84.9 ± 8.8 kg). Human subject protection approval was obtained, and participants provided written informed consent prior to participation.

Instrumentation

Force Plates. Ground-reaction force data during balance testing were collected utilizing 1 force plate (Kistler Corp, Amherst, New York, USA) that was located within a custom-built flooring system. The flooring system setup places the force plates flush with the surrounding surface. Ground-reaction force data were collected at 1200 Hz during testing using Vicon Nexus Software (Vicon, Centennial, Colorado, USA).

Procedures

Injury Survey. Injury data were manually extracted from the operators' medical charts and entered into the University of Pittsburgh's Military Epidemiology Database (UPITT-MED).[39] Medical charts were reviewed for musculoskeletal injury prior to the day of testing. The UPITT-MED is a relational database that serves as a central repository for deidentified data. Data include injury history; anthropometric, musculoskeletal, physiological, and biomechanical variables; and nutrition history. Customized structured query language (SQL) queries link data from multiple tables and extract data from the linked tables to allow for a multivariate analysis of the risk factors for injuries.[39] Injury data for this study were extracted from UPITT-MED using queries employing the operational definitions stated below.

Injury Operational Definitions. Previously injured operators were defined at the time of this study as those that had any chart-documented history of injury to the lumbosacral region and for which medical advice was sought. Healthy operators were defined at the time of this study as those without any chart-documented history of injury to the lumbosacral region. Injuries included those that could be clinically localized to the lumbosacral region (eg, facet joint syndrome, muscle strain). All injury types had standardized designations that were discussed and defined by experienced clinicians and researchers in our group to ensure validity and consistency of data.

TABLE 1
Single-Leg Balance Performance and Within-Group Comparisons[a]

	Right Side			Left Side			*P* Value	
Ground-Reaction Force, N	Mean	SD	Median	Mean	SD	Median	Paired *t* Test	Wilcoxon Signed-Rank Test
Healthy participants								
Eyes open								
Mediolateral (*x*-axis)	2.5	0.6	2.4	2.4	0.7	2.2	**.004**	NA
Anteroposterior (*y*-axis)	3.0	0.8	2.9	2.9	1.1	2.6	NA	**.000**
Vertical (*z*-axis)	4.1	1.4	4.0	4.1	1.8	3.6	NA	**.007**
Eyes closed								
Mediolateral (*x*-axis)	6.0	2.2	5.5	5.8	2.3	5.4	.156	NA
Anteroposterior (*y*-axis)	9.8	4.6	8.8	9.5	4.4	8.5	.278	NA
Vertical (*z*-axis)	11.6	5.8	10.4	11.5	6.8	10.0	.903	NA
Injured participants								
Eyes open								
Mediolateral (*x*-axis)	2.7	0.9	2.6	2.8	1.3	2.6	NA	.251
Anteroposterior (*y*-axis)	3.3	1.0	3.3	3.4	2.3	2.9	NA	**.015**
Vertical (*z*-axis)	4.7	1.9	4.3	4.8	3.0	4.2	NA	.121
Eyes closed								
Mediolateral (*x*-axis)	6.8	2.1	6.3	6.8	2.7	5.9	NA	.636
Anteroposterior (*y*-axis)	10.8	3.7	9.7	10.9	4.6	9.6	.897	NA
Vertical (*z*-axis)	14.3	5.5	13.2	14.5	7.8	12.5	.846	NA

[a]Boldfaced values represent statistically significant difference between right and left sides ($P < .05$). NA, not applicable; SD, standard deviation.

Balance Testing. Single-leg balance (SLB) testing was performed bilaterally by each participant under an eyes open and eyes closed condition. The protocol was based on reliable and valid methods established by Goldie et al.[12,13] The protocol employed in the current study has also been demonstrated as reliable in other studies.[38-40] A total of 3 trials (10 seconds each) for each leg were collected following practice trials for each condition (eyes open and eyes closed) and for each leg prior to actual testing. Participants were given specific directions for the testing, which included information regarding the number of practice trials, the number of test trials, the length of the trials, and the exact position to be maintained during testing. The testing position was single-leg stance with the untested leg flexed at the hip and the knee. The untested foot was lifted no more than 10 cm off the ground, with the ankle joint directly below the hip joint and located directly adjacent to the stance leg's shank. Participants were asked to maintain their hands on their iliac crests.

Trials began with the participant in a bilateral stance focusing on a target located in front of them at eye level. The participant was then asked to lift the untested lower extremity off the ground and into the test position. For the eyes open condition, data collection began after the participant had attained the test position and gave a cue that he or she was ready to begin. For the eyes closed condition, data collection began after the participant closed his or her eyes following the command, "Please close your eyes once you have gotten your balance." During testing, participants were instructed to remain as still as possible throughout each trial and to regain the test position as quickly as possible if there was a loss of balance. Touchdowns on the force plate were acceptable. Any trial that included touchdowns off the force plate was stopped, and a new trial collected.

Data Processing and Statistical Analysis

Force plate data were exported to MATLAB software (v 7.0.4; MATLAB, Natick, Massachusetts, USA) and filtered with a 0-lag, fourth-order, low-pass Butterworth filter with a 20-Hz cutoff frequency. Following data filtering, the standard deviation for each of the components of the resultant ground-reaction force (anterior-posterior, medial-lateral, and vertical) was calculated. For reference, based on data processing, lower scores represent better balance performance. A total of 3 trials were averaged for each condition for each leg. Means and standard deviations of all data were calculated. The normality of the data was assessed using a Shapiro-Wilk test. Side-to-side comparisons within each group were examined utilizing paired t tests when data were normally distributed or a Wilcoxon signed-rank test when data were not normally distributed. Between-group comparisons were examined utilizing unpaired t tests when data were normally distributed or a Mann-Whitney U test when data were not normally distributed. Statistical significance was set at $P < .05$ a priori.

RESULTS

Data were both normal and nonnormal in distribution, resulting in the use of both parametric and nonparametric tests. The means, standard deviations, medians, and side-to-side comparisons, including P values, for the balance testing in the healthy and injured participants are presented in Table 1.

TABLE 2
Single-Leg Balance Performance and Between-Group Comparisons[a]

Variable	*P* Value, Healthy vs LBP Groups	
	Right Leg	Left Leg
Eyes open		
Mediolateral ground-reaction force (*x*-axis)	**.005**	**.014**
Anteroposterior ground-reaction force (*y*-axis)	**.002**	.124
Vertical ground-reaction force (*z*-axis)	**.011**	.131
Eyes closed		
Mediolateral ground-reaction force (*x*-axis)	**.002**	**.025**
Anteroposterior ground-reaction force (*y*-axis)	**.011**	.060
Vertical ground-reaction force (*z*-axis)	**.000**	**.010**

[a]Boldfaced values represent statistically significant difference between groups ($P < .05$, Mann-Whitney *U* test). LBP, low back pain.

Significant differences were observed in the healthy participants between limbs for all 3 variables in the eyes open condition for SLB testing. No significant differences were observed in the healthy population between limbs for the eyes closed condition. Only 1 of the 6 comparisons across the 2 test conditions (eyes open and eyes closed) was significantly different between limbs in LBP participants. For the between-group comparisons, the left leg of the healthy group was used as a reference side since the left leg demonstrated significantly better performance than the right leg (Table 1). The between-group comparisons for SLB performance are presented in Table 2. For between-group comparisons, the injured group consistently demonstrated worse balance for both legs in both the eyes open and eyes closed conditions, and the majority of these comparisons were statistically significant. Four of the 6 comparisons for the eyes open condition were significant, and 5 of the 6 comparisons for the eyes closed condition were significant.

DISCUSSION

The purpose of this study was to examine the SLB ability of 2 groups of SFOs, 1 group of SFOs who had previously reported LBP and 1 group who had never reported LBP. The results indicated that operators who had previously reported LBP had significantly worse SLB under both the eyes open and eyes closed conditions compared with the healthy group. These results supported our hypothesis. Although the current study cannot definitively determine whether the SLB deficits caused the LBP or were the result of LBP, the presence of these deficits has implications for rehabilitation, physical training, and screening for risk of future injury.

Special forces operators, like all military personnel, are at risk for unintentional musculoskeletal injury. Injuries frequently occur during deployment but are more frequent during physical and tactical training based on our epidemiological analysis of data from this group of SFOs. These injuries can potentially impact physical and tactical readiness. In the current study, 43 of 226 operators surveyed had previously reported LBP. The large number of operators with LBP is consistent with epidemiological studies that have studied large cohorts of military personnel.[5,19] LBP can negatively affect strength, flexibility, and physical fitness.[26,30,32] LBP can have a negative impact on balance capability as well.[37]

The majority of previous studies that examined balance in cohorts who suffered LBP have demonstrated impaired balanced compared with healthy controls.[37] For example, della Volpe et al[8] examined postural stability in a cohort of 12 individuals with chronic LBP and compared them with an age-matched cohort while they were tested under a variety of double-leg stance conditions with varying levels of difficulty. Their cohort of individuals with chronic LBP demonstrated lower postural stability scores under the more difficult conditions, including conditions when the visual reference was removed. Mientjes and Frank[30] observed similar results in a cohort of 8 individuals with LBP. Participants with chronic LBP had worse postural stability when visual reference was removed. The results of the current study are consistent with these previous studies. In the current study, SFOs who reported LBP had significantly worse balance across both conditions of SLB testing.

It is difficult to compare the balance ability of the current population with previous studies of military personnel or civilian athletes because of differences in protocols, but there are 2 previous studies that have used a similar test protocol. Sell et al[40] examined SLB in highly proficient golfers using the identical protocol employed in the current study. Healthy operators in the current study had better SLB (eyes open and eyes closed) than the most skilled group of golfers.[40] Operators in the current study who had a previous history of LBP had similar scores to the same group of golfers for both conditions, demonstrating that despite the previous episode of LBP, they still had balance abilities similar to highly proficient golfers. Sell et al[39] also examined the SLB ability of 404 soldiers of the 101st Airborne Division (Air Assault) from Fort Campbell, Kentucky. The healthy group of operators in the current study demonstrated better SLB abilities under both conditions compared with male soldiers from the 101st Airborne Division, and the group of operators who reported LBP had similar or better scores as well.

The research design and nature of the data in the current study do not establish whether LBP was a result of the lower balance ability or if the lower balance ability was a result of the LBP. In fact, the reason for the differences in SLB may be other factors that are unknown or may not be reported in the medical chart. However, previous studies have demonstrated that balance deficits are predictive of new lower extremity injury.[28,33,44,46,49,50] McGuine et al,[28] Tropp et al,[46] and Watson[49] have all demonstrated prospectively that individuals who have lower postural stability or balance scores are more likely to suffer an ankle sprain. Soderman et al[44] prospectively examined postural sway scores in female soccer players and demonstrated that higher postural sway predicted traumatic lower leg injuries. Paterno et al[33] also demonstrated that lower postural stability scores predict lower extremity injury; although, in their study, they predicted a second anterior cruciate ligament injury.[33] In each of these studies, the individuals who demonstrated worse postural stability, regardless of the measure, were more likely to suffer a subsequent new injury. We cannot make the same claim for the operators with LBP in the current study, but the results and differences in balance ability may have clinical implications for physical training and the prevention of injuries not related to the reported LBP, as balance training has been demonstrated to reduce the incidence of new lower extremity injury.[1,29,48] It may be clinically judicious, therefore, to implement balance testing and training interventions for SFOs with a previous history of LBP. From a real-world clinical perspective, if an individual presents with measurable balance deficits, then it may be prudent to administer balance training interventions, regardless of whether the true cause of the balance deficits can be retrospectively and conclusively identified.

Special forces operators are tasked with demanding missions and deployment to extreme environments. Preparation for these missions and deployments requires a high level of fitness and focused physical and tactical training. Deficits such as those identified in the current study may affect preparation and predispose operators to risk for future injury. Considerations should be made for individualized training based on previous injury even though operators may be cleared for deployment. In this instance, operators who have previously reported LBP should include balance and postural stability training activities to augment current physical training to improve these abilities and prevent future injury.

CONCLUSION

The current study demonstrated decreased SLB ability in SFOs who had a documented history of LBP. These differences in balance ability may not be a result of the previous injury but they potentially put the operator at risk for future injury, including new injury to the lower extremity. Considerations for individualized training based on previous injuries should be made, including augmenting current protocols with balance and postural stability activities for those individuals who have reported LBP.

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