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Gender Differences in Static and Dynamic Postural Stability of Soldiers in the Army's 101st Airborne Division (Air Assault)

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Context: Postural stability is essential for injury prevention and performance. Differences between genders may affect training focus. ***Objective:*** To examine static and dynamic postural stability in male and female soldiers. ***Design:*** Descriptive laboratory study. ***Setting:*** Biomechanics laboratory. ***Participants:*** 25 healthy female soldiers (26.4 ± 5.3 y) and 25 healthy male soldiers (26.4 ± 4.9 y) matched on physical demand rating and years of service from the Army's 101st Airborne Division (Air Assault). ***Interventions:*** Each person underwent static and dynamic postural stability testing. ***Main Outcome Measures:*** Standard deviation of the ground reaction forces during static postural stability and the dynamic stability index for dynamic postural stability. ***Results:*** Female soldiers had significantly better static postural stability than males but no differences were observed in dynamic postural stability. ***Conclusions:*** Postural stability is important for injury prevention, performance optimization, and tactical training. The differences observed in the current study may indicate the need for gender-specific training emphasis on postural stability.

Keywords: balance, injury prevention, military

On January 24, 2013, the Department of Defense rescinded the direct ground combat exclusion rule for female service members based on the unanimous recommendation of the Joint Chiefs of Staff.[1] This rule previously excluded women from serving in ground combat positions and created opportunities for women to serve in different military occupational specialties (MOS). Women who are assigned to these MOS may require additional or different physical training and they may be at greater risk for injury or different injury types. Ideally, physical training will match the individual's performance capabilities to the task requirements of the position and should also match injury prevention strategies to the potential injuries that can occur during physical training and the execution of the occupational requirements of the MOS.

Gender differences in physical capabilities and injury risk may also require gender-specific physical training. For example, in civilian athletic populations, such as basketball and soccer, females are at greater risk for knee injuries[2] and also demonstrate gender-specific differences in musculoskeletal, biomechanical, and neuromuscular characteristics that are associated with this increased risk of injury.[3–5] Gender differences for injury risk are also present in military populations[6,7] and, similar to civilian populations, there are examples of gender-specific differences in musculoskeletal, biomechanical, and neuromuscular characteristics that may predispose females for greater risk of injury or may require additional or different training to meet the gender-neutral requirements of the newly opened MOS.[8,9]

Postural stability is a dynamic process that requires sensory detection of body motions, integration of sensorimotor information within the central nervous system, and execution of appropriate musculoskeletal responses in order to establish an equilibrium between destabilizing and stabilizing forces.[10] Measurement of postural stability is critical for performance,[11] injury evaluation,[12,13] and examining risk factors for injury, including lower extremity injuries.[4,11,14–18] The examination of gender differences in postural stability in military servicemen and women may provide evidence for gender-specific training given the frequency of lower extremity injuries.[19–21]

Postural stability assessments with comparisons between genders have not provided consistent results. Postural stability comparisons between genders have been examined multiple times in healthy, active adult populations using force plates.[3,4,22] Lephart et al[3] examined time to stability during a landing task in healthy, active adults and demonstrated no differences between genders, while Wikstrom et al[22] found that females had worse dynamic postural stability utilizing a similar landing task. Rozzi et al[4] demonstrated that college-aged female athletes had significantly better balance than male athletes during single-leg standing. Both Teyhen et al[8] and Gorman et al[23] have demonstrated that female high school athletes have significantly lower dynamic balance scores on the Lower Quarter Y Balance Test, but Gribble et al[24] demonstrated that the opposite was true on the Star Excursion Balance Test. The results are mixed regarding the gender differences in postural stability which may be due to differences in test protocols previously used and outlined above. None of the previously cited research studies have examined both static and dynamic postural stability in the same population.

The critical physical tasks required of military occupational specialties are not based on gender, but the shift in policy allowing female military personnel to occupy a wider range of military occupational specialties may require changes in physical training to be gender-specific relative to risk of injury and physical capabilities and requirements. The examination of postural stability is

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necessary for injury prevention and performance optimization research due to the frequent occurrence of lower extremity injuries in the military and the dynamic activities that military personnel perform. The purpose of the current study was to examine and compare the single-leg static and dynamic postural stability of male and female soldiers who currently occupy MOS with similar physical demand ratings. Based on the previous literature, we hypothesized that females would have better static postural stability and that males would have better dynamic postural stability. The results of this study will provide population- and gender-specific guidance on injury prevention and physical training programs in military populations. The results of this study may also be applicable to other physically active populations such as student-athletes and recreational athletes.

Methods

Participants

Fifty soldiers (25 males and 25 females) from the Army's 101st Airborne Division (Air Assault) voluntarily participated in the study. This Army Division is a light infantry division that primarily uses helicopters to deliver troops into combat. The 2 groups were matched on age (±2.0 y), physical demand rating (exact), and years of service (±2.0 y). The physical demand rating of occupations in the military describes the job demands from "Light" to "Very Heavy" with a value of "1" representing "Light" and a value of "5" representing "Very Heavy".[25] Demographic information of the participants is included in Table 1. There were no significant differences in years of service ($P = 0.82$), age ($P = 1.00$) or physical demand rating ($P = 1.00$). All participants were clear of any history of concussion or mild head injury in the previous year; had no history of upper extremity, lower extremity, or back injury in the previous 3 months that could affect the ability to perform the required tests; and had no history of neurologic or balance disorders. All participants were clear for active duty without any recent prescribed duty restrictions and provided informed consent before participation. Human subjects protection approvals were obtained from civilian and military institutional review boards. Testing was conducted at the Human Performance Research Laboratory in Fort Campbell, KY, a remote research facility operated by the Neuromuscular Research Laboratory at the University of Pittsburgh.

Instrumentation

A single force plate (Kistler 9286A, Amherst, NY) was used to collect the ground reaction force data (1200 Hz) during the static and dynamic postural stability tasks. Force plate data were passed through an amplifier and an analog to digital board (DT3010, Digital Translation, Marlboro, MA) to a personal computer for additional signal and data processing.

Procedures

Participants reported to the Human Performance Research Laboratory for a single-test session. Dynamic and static postural stability were both assessed due to the lack of correlation observed in performance of these measures.[26–29] Static postural stability was assessed under eyes open (EO) and an eyes closed (EC) conditions. The protocol employed in the current study was based on Goldie et al[30,31] and there is evidence to support the validity and reliability of this protocol.[11,30,31] Both static postural stability conditions began with participants assuming a single-leg stance on their dominant leg (preferred kicking foot); hands placed on hips; and with the nonstance leg flexed at the knee and hip in order to bring the foot to the height of the stance leg ankle. Participants focused on a marker located approximately 20 feet directly in front of the force plate for the EO condition. Participants began the EC condition identical to the EO condition and were directed to close their eyes once they were ready for data collection to begin. The protocol and data processing procedures employed for static postural stability allows for touchdowns of the nonstance leg but participants were instructed to immediately return their nonstance leg back to the starting position if a touchdown occurred. A trial was discarded if the nonstance touched the stance leg or touched down on the ground around the force plate. Three 10-second trials were collected for data analysis following the practice trials which consisted of a minimum of 3 repetitions but no more than 5 repetitions.

Dynamic postural stability was assessed during a single-leg landing. The protocol was based on Wikstrom et al[32] and Ross et al[33] and has been demonstrated to be reliable in a previous study.[26] The jump began with participants standing on 2 legs at a distance of 40% of their body height from the force plate. Participants were instructed to jump forward to the force plate, clear a 30.5 cm hurdle, land on the force plate with their test leg only, stabilize as quickly as possible, and maintain balance with their hands on their hips for 10 seconds. Participants wore their own shoes. Upper extremity movement was allowed without instructions other than to place their hands on their hips as quickly as possible after landing. Trials were discarded and recollected if the nontest leg touched the test leg or the ground. Individuals were allowed to practice the jump and landing prior to actual data collection. A total of 3 trials were processed for the dynamic postural stability assessment following the same procedures for the practice trials outlined for static postural stability testing.

Data Reduction

A MATLAB (v7.0.4, Natick, MA) script file was written to process the data. All force plate data were processed with a dual pass 4th order low pass Butterworth filter with the cutoff frequency set at 20 Hz. The standard deviation[30,31] of each of the ground reaction

Table 1 Subject Demographics

	Males (n = 25)		Females (n = 25)		Total (n = 50)	
	Mean	±SD	Mean	±SD	Mean	±SD
Age (y)	26.4	4.9	26.4	5.3	26.4	5.0
Height (inches)	69.3	3.1	63.8	2.7	66.6	4.0
Mass (pounds)	190.3	24.8	139.0	22.8	164.7	35.0
Service (y)	6.3	4.4	6.0	4.5	6.1	4.4
Physical demand rating	4	1	4	1	4	1

force components (anterior-posterior, medial-lateral, and vertical) was calculated during the ten-second trial to derive the variables for statistical analysis (anterior-posterior standard deviation (AP stdev), medial-lateral standard deviation (ML stdev), and vertical standard deviation (V stdev), respectively). The AP stdev, ML stdev, and V stdev were then averaged across 3 trials used for the statistical analysis. The data processing for the dynamic postural stability assessment included calculation of the dynamic postural stability index for each of the ground reaction force components and for a single variable incorporating all the ground reaction force components.[34] These calculations are based on mean square deviations around a zero point.[32] Lower values for all variables indicate better scores.

Statistical Analysis

The means, minima, maxima, standard deviations, and 95% confidence intervals for the mean were calculated for all of the postural stability variables. Normality (Shapiro-Wilk test) was checked for each of the postural stability variables. Independent t-tests were employed to examine potential differences between genders if the normality assumption was met and Wilcoxon matched-pairs signed-ranks test was employed when the normality assumption was not met. All statistical analysis procedures were performed using Stata (Version 12.1, StataCorp, College Station, TX).

Results

The means, minima, maxima, standard deviations, and 95% confidence intervals for all of the postural stability variables are listed in Table 2. Table 2 also contains all of the gender comparisons. Figures 1 and 2 represent the static postural stability scores and dynamic postural stability scores with statistical comparisons respectively. Higher scores on all variables represent lower postural stability capability. The assumption of normality was checked for all data and revealed that the static postural stability variables were not normally distributed; therefore, Wilcoxon matched-pairs signed-ranks tests were performed for all of the static postural stability variables and independent *t*-tests were employed to compare genders for the dynamic postural stability variables. The statistical analysis revealed that females had significantly better static postural stability scores than males across 5 of the 6 variables analyzed (see Table 2). The independent *t*-tests demonstrated no

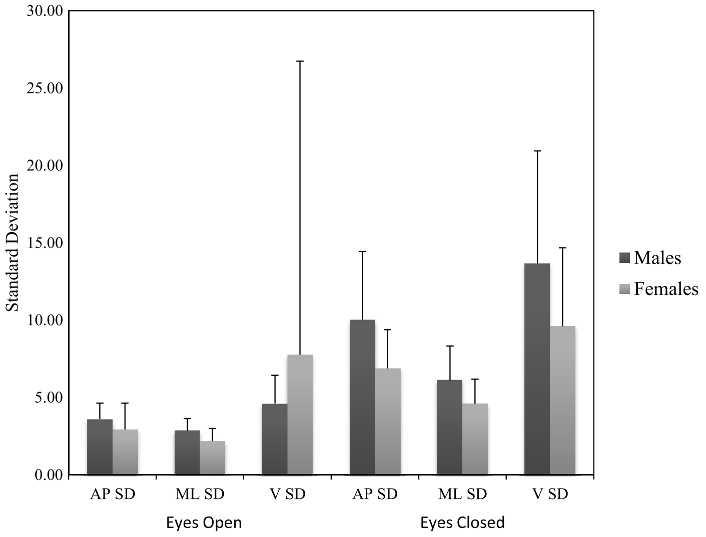

Figure 1 — Static postural stability comparisons between genders.

Table 2 Descriptive Statistics and Gender Comparisons for Static and Dynamic Postural Stability

		Mean	±SD	Min	Max	95% CI	*P*-value
Static postural stability–eyes open (AP standard deviation)	Males	3.594	1.038	2.290	6.280	3.166–4.023	0.01
	Females	2.929	1.702	1.740	10.040	2.226–3.632	
Static postural stability–eyes open (ML standard deviation)	Males	2.827	0.807	1.770	5.090	2.494–3.160	0.001
	Females	2.170	0.824	1.270	4.920	1.830–2.510	
Static postural stability–eyes open (V standard deviation)	Males	4.599	1.836	2.100	10.580	3.841–5.357	0.20
	Females	7.754	18.977	2.300	98.300	−0.080–15.587	
Static postural stability–eyes closed (AP standard deviation)	Males	10.022	4.415	4.560	21.090	8.199–11.844	0.01
	Females	6.878	2.502	2.670	14.180	5.846–7.911	
Static postural stability–eyes closed (ML standard deviation)	Males	6.094	2.230	2.590	11.330	5.174–7.014	0.01
	Females	4.586	1.590	1.940	9.780	3.930–5.243	
Static postural stability–eyes closed (V standard deviation)	Males	13.629	7.309	4.010	30.560	10.612–16.646	0.04
	Females	9.600	5.071	3.860	27.680	7.507–11.693	
Dynamic postural stability–AP component	Males	0.136	0.014	0.102	0.158	0.130–0.141	0.27
	Females	0.131	0.017	0.104	0.167	0.124–0.138	
Dynamic postural stability–ML component	Males	0.031	0.008	0.020	0.050	0.027–0.034	0.12
	Females	0.028	0.005	0.019	0.037	0.026–0.030	
Dynamic postural stability–V component	Males	0.347	0.049	0.267	0.434	0.237–0.367	0.95
	Females	0.346	0.067	0.232	0.492	0.318–0.374	
Dynamic postural stability–composite score	Males	0.374	0.048	0.289	0.462	0.355–0.394	0.88
	Females	0.372	0.065	0.255	0.509	0.345–0.399	

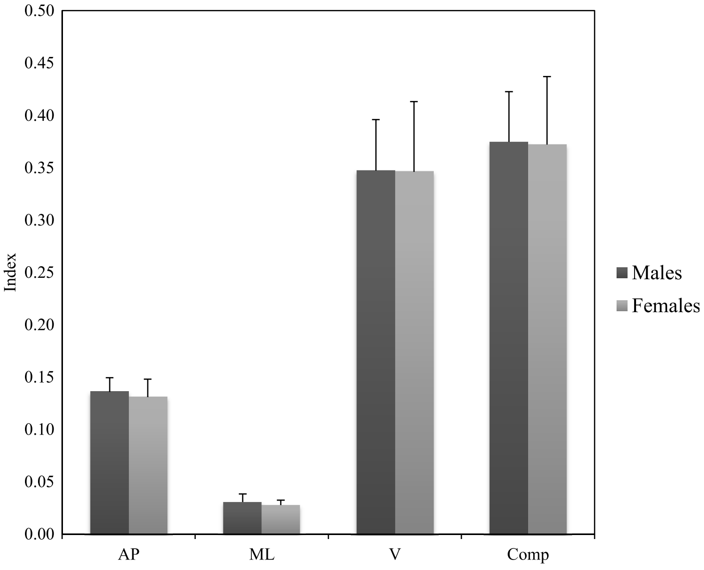

Figure 2 — Dynamic postural stability comparisons between genders.

significant differences between genders for any of the dynamic postural stability variables (see Table 2).

Discussion

Female soldiers had better static postural stability scores than male soldiers but the gender comparisons did not reveal significant differences in dynamic postural stability. These results partially supported our hypotheses as expected that females would have better static postural stability. Our hypothesis that males would have better dynamic stability was not supported. Overall, the analyses demonstrated that the significant differences between genders in postural stability under static conditions were reduced as the difficulty in condition increased. Postural stability training is central component of physical training for both performance and injury prevention. The gender differences observed in the current study may indicate that physical training should be adjusted based on gender relative to injury prevention, performance optimization, and to the occupational demands of each military occupational specialty.

The importance, emphasis, and specificity of injury prevention and performance optimization in military population have increased with the decision to rescind the direct ground combat exclusion rule for female service members. Individual military groups have already begun examining the effects of this policy change on physical testing, physical training, and occupational demands of different military occupational specialties. Military commands have a finite amount of time to prepare soldiers for their positions, deployment, and mission. Effective and efficient maintenance of postural stability, both static and dynamic, is important for performance of most tasks and becomes essential as the difficulty of the task increases. The postural stability differences observed in the current study may dictate differences relative to training these important capabilities for tactical readiness and injury prevention. The current data would suggest that physical training for males dictate additional emphasis on static postural stability since males demonstrated lower scores indicative of lower static postural stability aptitude. It is difficult to make a conclusion on gender-specific needs for dynamic postural stability training based on the current study, but consideration may be appropriate for additional dynamic postural stability training for females based on an equalization of capabilities as the postural stability conditions increased and the previously reported gender differences in injury risk[2,6,7] and neuromuscular control of dynamic joint stability.[3–5,8,9]

Both static and dynamic postural stability were assessed in the current study due to the lack of correlation between these 2 measures.[26] These postural stability assessments also offer different and more challenging conditions.[26] For purposes of the current study, we defined static postural stability as maintaining steadiness on a fixed, firm, unmoving base of support.[35] As hypothesized, the female soldiers demonstrated better static postural stability than the male comparison group for both the eyes open and eyes closed conditions. Comparisons between the current study and previous studies are challenging due to differences in instrumentation, protocols, and populations studied, but the results of the current static postural stability gender comparisons are consistent with a similar study looking at college-aged, physically active individuals. Rozzi et al[4] tested single-leg balance utilizing the Biodex Stability System (Biodex, Inc, Shirley, NY) and revealed that females had better single-leg balance than males. Similar results have also been observed in high-school athletes (basketball players) utilizing a similar protocol to the one employed in the current study.[36] It could be argued that males should have better postural stability given that they typically have greater strength than females even normalized to body weight. These differences in strength[36,37] should provide an advantage since strength is an important component of maintaining postural stability. The relatively simple task of standing on 1 leg without perturbation or other challenge may negate this strength advantage and allow other components necessary for maintenance of postural stability to dominate such as visual/vestibular/somatosensory information or central processing components. It is possible that the strength advantage observed in male soldiers[37] plays a more significant role in the more difficult task of dynamic postural stability employed in the current study.

Dynamic postural stability has been defined by Goldie as the ability to transfer the vertical projection of the center of gravity around the supporting base.[30] There are multiple protocols for examining dynamic postural stability in physically active populations including perturbation of support surface, perturbation of the participant, or measuring ground reaction forces following a single-leg jump or landing.[32,33,35,38–40] We hypothesized that males would have better dynamic postural stability based on the gender differences observed in strength, neuromuscular control, components of joint stability, and landing biomechanics.[3,4,37,41] The results of the current study did not meet our hypothesis although gender differences observed in strength, neuromuscular control, and components of joint stability may have been responsible for equalizing the differences observed in static postural stability as the difficulty in condition increased (from static to dynamic postural stability). Comparisons to previous studies are also difficult for dynamic postural stability. The Star Excursion Balance Test (or variations of it) which does not require a landing have been employed to examine differences between genders in physically active populations under quasi-dynamic postural stability conditions.[8,23,24] The results have been equivocal as Teyhen et al[8] and Gorman et al[23] demonstrated females have worse postural stability while Gribble et al[24] demonstrated that females had better postural stability utilizing these measurements. The results of the current study are similar to the results of Lephart et al[3] who measured dynamic postural stability during a landing task. They demonstrated no differences between genders. In contrast, Wikstrom et al[22] employed a similar protocol to the one in the current study and demonstrated that females had worse dynamic postural stability.

There are a few limitations to the current study. First, trials during which participants failed to complete the task (stepped off of the force plate for example) were not counted. The number of failed trials per subject may provide additional insight regarding each participant's performance during the task. Second, the design of the testing was based on anticipatory control which does not account for the reactive component that may reflect real-life scenarios. A follow-up study that examines this aspect of postural stability would be warranted. Third, participants were matched on physical demand rating but were not matched on sport background. This lack of matching on sport background could have confounded the results. Finally, we chose a relatively short hurdle height for all participants to insure that each of the subjects had to jump a minimum height without inducing too much of a challenge. The height differences between genders may have made it a more difficult challenge for the females in the study. For comparison purposes, based on the demographic data of the participants the height of the hurdle was 17.3% of the height of female participants and 18.8% of the height for men. Finally, it is possible that the gender differences in static postural stability are based on differences in demographic data (weight and height). Our analysis does not account for these demographic data since comparisons were based exclusively on gender.

Conclusions

Female soldiers demonstrated significantly better static postural stability but not dynamic postural stability compared to male soldiers. These differences may demonstrate the need for gender-specific focus on static postural stability training given the importance of it for injury prediction,[4,11,14–18] performance optimization,[11] and mission preparation.[34] Although the current study only included United States Army soldiers the application of the results to other populations should not be excluded. The soldiers in the current study are similar to athletic populations such as student-athletes and recreational athletes as they participate in regular physical training. Individuals who train or treat similarly active populations may find the results applicable to their own practice settings.

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