Correlations and gender-related differences in dynamic postural stability and landing kinematics in U.S. Marines

[1] Heather Bansbach, [1]Erin Pletcher, [1]Mita Lovalekar, [1]Megan Frame, [1]Yosuke Kido, [2]Timothy Sell, and [1]Katelyn Allison

[1] University of Pittsburgh, Pittsburgh, PA, USA
[2]Duke University, Durham, NC, USA
email: hmb47@pitt.edu, web: nmrl.pitt.edu

INTRODUCTION

Unintentional musculoskeletal injury is a significant health concern for the United States military. Unintentional injuries result in lost duty time, high healthcare costs, and impact military readiness [1]. The majority of nonbattle injuries occur during physical training [2] with lower extremity (LE) injuries making up a large percentage of injury locations. Several factors have been shown to be predictive of LE musculoskeletal injuries including strength imbalances, flexibility, landing position, and postural stability. Dynamic postural stability tasks are often used in military and athletic populations as they are more challenging tasks and may better differentiate between risk factors in healthy, physically active individuals [3]. Dynamic postural stability has been shown to differ between genders [4]. It is unknown if certain LE landing strategies are related to dynamic postural stability. Landing positions that allow for more efficient postural control may be important to incorporate Marines physical training. The purpose of this study was to determine the relationship between landing position and dynamic postural stability in U.S. The secondary purpose was to determine there were any gender-related differences in landing strategy and dynamic postural stability in United States Marines.

METHODS

A total of 269 United States Marines were recruited and tested at a Warrior Human Performance Research Laboratory, an onsite laboratory operated by University of Pittsburgh personnel (Table 1).

Three-dimensional LE kinematics and ground reaction forces (GRF) were collected during a single-leg landing task (Vicon Motion Systems, Centennial, CO, USA and Kistler Corp, Amherst, New York, USA). Participants were asked to take off from two feet, jump over a 30cm hurdle and land on their test-leg (single-leg) in the center of the force plate. Participants initiated the jump at a distance equal to 40 percent of his or her height measured from the edge of the force platform nearest to the participant. Once balance was recovered, participants held position for 5 seconds after landing.

LE kinematics were calculated using the Plug-In-Gait biomechanical model. GRF were used to identify initial contact of participants with the force platforms. Initial contact was identified when the vertical GRF exceeded 5% body weight. Knee and hip kinematic data in the sagittal plane were calculated at initial contact, and peak knee kinematics in the sagittal plane were calculated during the landing phase of the maneuver. GRF during the first 3 seconds following initial contact were used to calculate a dynamic postural stability index (DPSI) representing dynamic postural control. DPSI is a composite of the mean square deviations in the anterior-posterior, medial-lateral, and vertical GRF, and is normalized to body weight.

There were no significant differences between limbs, thus we averaged the data across limbs for all variables. Data were not normally distributed,

Table 1. Group Demographics

Measures	Males	Females	*P* Value
n	199	70	
Age (years)	22.5 ± 2.7	22.7 ± 2.7	0.730
Height (m)*	1.77 ± 0.07	1.64 ± 0.6	< 0.001
Weight (kg)*	80.2 ± 10.8	64.7 ± 7.3	< 0.001

*Significant difference ($p < 0.05$)

therefore a Spearman's correlation coefficient was used to identify significant correlations between DPSI and landing kinematic variables (hip and knee flexion angles at initial contact and peak knee flexion angle during landing). A Mann-Whitney U test was used to identify any significant differences in DPSI and landing mechanic variables between male and female Marines. All statistical analyses were performed using SPSS (Version 23, IBMM, Armonk, NY, USA). Alpha was set at 0.05 *a priori* for all analyses with Bonferroni correction.

RESULTS AND DISCUSSION

DPSI was significantly correlated with hip flexion angle at initial contact ($p < 0.001$) and peak knee flexion angle ($p = 0.003$) during landing (Table 2). Both showed a negative correlation suggesting that as hip and peak knee flexion angles decreased, the DPSI increased. A higher DPSI score is representative of greater variability in GRFs during landing, which may suggest diminished dynamic postural control. Participants that landed with greater hip flexion and showed greater peak knee flexion during landing, are likely better able to absorb ground reaction forces during landing and may be more stable during a single-leg landing task. After Bonferroni correction, no significant correlation was found between DPSI and knee flexion angle at initial contact ($p = 0.040$).

Female Marines had significantly different DPSI ($p < 0.001$) and hip flexion angles ($p < 0.001$) at initial contact compared to males Marines (Table 3). On average, female Marines had a lower DPSI and greater hip flexion angles at initial contact. This may suggest that female Marines who display lower DPSI have better dynamic postural control and are better able to dissipate forces through LE musculature. No significant differences were found in peak knee flexion angle between males and females (p = 182).

Table 2. Pairwise correlation between DPSI and landing kinematics

	DPSI	
Joint Angles (deg)	r-coefficient	*P* Value
Hip flexion at IC*	-0.22	<0.001
Knee flexion at IC	-0.13	0.040
Peak knee flexion*	-0.18	0.003

*Significant correlation ($p < 0.05$)

These results identified that landing with greater hip flexion and ending in greater knee flexion is related to greater stability during landing. Human performance personnel with the Marines can use these results to assist in training of both male and female Marines for their tactical demands.

Future research should consider if DPSI and LE kinematics are related to LE strength. Also, we should consider if DPSI is predictive of LE injury in the Marines and what training modifications can lead to improved dynamic postural control.

CONCLUSIONS

Landing with greater hip flexion and greater peak knee flexion is related to dynamic postural stability. Female Marines display better landing patterns and postural control during a single-leg landing compared to male Marines.

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Table 3. Gender-related differences

Dependent Variables	Males	Females	*P* Value
DPSI	0.364 ± 0.034	0.348 ± 0.027	<0.001
Hip flexion at IC (deg)	28.2 ± 6.4	32.5 ± 7.1	<0.001
Peak knee flexion (deg)	52.6 ± 6.5	53.6 ± 6.9	0.182

*Significant difference ($p < 0.05$)