THE EFFECTS OF LOAD CARRIAGE AND FATIGUE ON FRONTAL-PLANE KNEE MECHANICS DURING WALKING

1 He Wang, 1Jeff Frame, 1Elicia Ozimek, 2Daniel Leib, and 2Eric Dugan, 1Ball State University, 2Boise State University email: hwang2@bsu.edu

INTRODUCTION

Military personnel are commonly afflicted by lower extremity overuse injuries [1, 2]. Overuse knee conditions are among the most common injuries during basic training [3]. Walking with heavy loads is an inevitable part of the military training, and during the twelve-weeks of basic training, the loaded running and walking distance could exceed 200 miles [1]. Therefore, military personnel have to face physical challenges comprised of load carriage and muscle fatigue.

During walking, the knee joint experiences an external adduction moment [4]. Large varus knee loading leads to cartilage degeneration and medial knee osteoarthritis (OA) [5,6,7]. Thus, the long-term effect of repetitive high varus knee loading could lead to medial knee OA; in the short term, walking with large varus knee loading could result in knee pain.

Load carriage increases vertical ground reaction force (GRF) during walking [8,9]. Walking in a fatigue state also results in increased vertical GRF [10]. It is possible that under the influences of load carriage and muscle fatigue, the knee joint may experience increased internal mechanical loading. However, it is unclear whether load carriage and fatigue result in an increase of varus knee loading during walking.

Analyzing frontal-plane knee mechanics during loaded and fatigued walking will broaden our knowledge on the potential causes of developing lower-extremity overuse injuries such as overuse knee conditions during military training.

The purpose of the study was to investigate the frontal-plane knee mechanics during loaded and fatigued walking. As the vertical GRF is increased during both the loaded and fatigued walking [8,9,10], it was hypothesized that there would be increased internal knee abductor moments during loaded and fatigued walking.

METHODS

Eighteen healthy male subjects (age: 21 ± 2 yr.; body mass: 77.6 ± 9.6 kg; body height: 181 ± 4 cm) participated in the study. Subjects wore military boots and participated in a fatiguing protocol which involved a series of metered step-ups and heel raises while wearing a 16 kg rucksack. Subjects performed the following tasks in sequence: 5-min unloaded walking; 5-min loaded walking with a 32 kg rucksack; Fatiguing protocol; 5-min loaded walking with a 32 kg rucksack under fatigue; 5-min unloaded walking under fatigue. All walking tasks were performed at 1.67 m/s on a force instrumented treadmill (AMTI). A 15-camera system (VICON) was used to track reflective markers placed on the human body at 120 Hz. Ground reaction forces were collected at 2400 Hz. Visual 3D (C-Motion) was used to calculate lower extremity joint mechanics. The following variables were analyzed: peak hip and knee adduction angles, peak hip and knee abductor moments during weight acceptance of walking. Two-way repeated measures ANOVAs were performed. Load carriage and fatigue were the independent factors. $\alpha = 0.05$.

RESULTS AND DISCUSSION

No interactions were found between load carriage and fatigue for all the dependent variables ($P > 0.05$). Load carriage led to significant increases of hip adduction ($P < 0.05$), hip and knee abductor moments ($P < 0.001$) (Table 1). Fatigue did not lead to changes in hip and knee adduction angles and abductor moments ($P > 0.05$) (Table 1).

Frontal-plane knee mechanics is altered during loaded walking. There is a large internal abductor
moment introduced at weight acceptance. The increased internal abductor moment may be related to the increased GRF passing through medial side of the knee. As the internal abductor moment increases, medial compartment of the knee is under large compression. Increased stress in medial knee results in cartilage degeneration and onset of medial knee OA [5,6,7]. During a 12-week military training, the accumulated loaded walking/running distance exceeds 200 miles [1], the repetitive large medial knee loading may inflict cartilage damage in medial knee and result in knee pain.

In this study, we also found that the load carriage results in alterations of frontal-plane hip mechanics. There is an increase of hip adduction during weight acceptance of loaded walking. Increasing hip adduction stretches gluteus medius and enhances the muscle’s ability to stabilize the pelvis. Indeed, large hip abductor moment is associated with loaded walking. However, increasing hip adduction also stretches tensor fasciae latae on the lateral side of the hip. As load carriage results in increased knee flexion at weight acceptance of walking [8], the friction between the lateral femoral condyle and the illio-tibial band (ITB) could be elevated. Thus, during loaded distance walking, it is possible that increased hip adduction combined with cyclic knee flexion may lead to ITB syndrome.

Interestingly, the effect of fatigue on frontal-plane knee mechanics is insignificant. Although it was reported that there is an increased GRF associated with fatigued walking [10], the increased GRF may be positioned close to the center of the knee. Thus, there is no alteration of the external adduction moment.

In summary, at weight acceptance, load carriage leads to alterations of frontal-plane hip and knee mechanics. The increases of hip adduction and knee abductor moment could be the causes of overuse knee conditions, which are common during military training.

REFERENCES


ACKNOWLEDGEMENTS

Funding source: US ARMY #W81XWH-08-1-0587

Table 1: Means and SDs of Peak hip and knee adduction angles and abductor moments during weight acceptance of walking.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Unloaded and Unfatigued</th>
<th>Loaded and Unfatigued</th>
<th>Loaded and Fatigued</th>
<th>Unloaded and Fatigued</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip adduction angle (deg)*</td>
<td>9.3 (3.2)</td>
<td>10.3 (3.6)</td>
<td>10.2 (3.1)</td>
<td>9.5 (3.2)</td>
</tr>
<tr>
<td>Knee adduction angle (deg)</td>
<td>-1.4 (2.9)</td>
<td>-1.1 (2.9)</td>
<td>-1.4 (2.6)</td>
<td>-1.9 (2.9)</td>
</tr>
<tr>
<td>Hip abductor moment (Nm/kg)*</td>
<td>1.60 (0.18)</td>
<td>2.18 (0.38)</td>
<td>2.22 (0.35)</td>
<td>1.66 (0.24)</td>
</tr>
<tr>
<td>Knee abductor moment (Nm/kg)*</td>
<td>0.84 (0.18)</td>
<td>1.15 (0.32)</td>
<td>1.10 (0.36)</td>
<td>0.83 (0.22)</td>
</tr>
</tbody>
</table>

Note. * indicates significant difference between loaded and unloaded walking conditions (P < 0.05).