INFLUENCES OF LOAD CARRIAGE AND FATIGUE ON LOWER EXTREMITY KINETICS DURING WALKING

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INTRODUCTION

Military personnel are commonly afflicted by lower extremity overuse injuries such as knee pain and stress fractures [1, 2]. Walking with heavy loads is an inevitable part of the military training and during the twelve-weeks of basic training, the combined running and walking distance could exceed 200 miles [1]. Therefore, military personnel commonly face physical challenges comprised of load carriage and muscle fatigue.

Load carriage has been found to alter gait kinematics [3]. Specifically, there are increases of pelvic anterior tilt, hip flexion, and knee flexion angles at heel strike [3, 4]. Ground reaction forces and ground reaction loading rates are also increased during loaded walking [3, 5]. Muscle fatigue has also been found to alter running kinematics with increases of hip and knee angles at heel strike [6, 7]. During fatigued walking, vertical ground reaction force and loading rate are found to increase [8]. Further, fatigued muscles’ ability to attenuate impact loading is decreased [9].

Thus, under the influences of load carriage and muscle fatigue, the lower extremities are exposed to increased ground reaction impact forces with increased loading rate during walking. The risk of lower extremity injury may be increased. However, it is yet to be determined if the lower extremity joint kinetics are altered as a result of load carriage and muscle fatigue. Analyzing lower extremity joint kinetics during loaded and fatigued walking will broaden our knowledge on the potential causes for development of lower limb injuries during military training.

The purpose of the study was to investigate the lower extremity joint kinetics during loaded and fatigued walking. As the vertical ground reaction force and loading rate are increased during weight acceptance, it is expected that the lower extremity joint kinetics will be altered to accommodate the increased external impact loading.

METHODS

Eighteen healthy male subjects (age: 21 ± 2 yr.; body mass: 79 ± 11 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 kinetics. The following variables were analyzed: peak knee and hip extensor moments and peak knee and hip joint powers during weight acceptance of walking. Two-way repeated measures ANOVAs were performed. Load carriage and fatigue were the independent factors. α = 0.05.

RESULTS AND DISCUSSION

No interactions were found between load carriage and fatigue (P > 0.05). Load carriage led to significant increases of knee and hip extensor moments, knee and hip joint powers (P < 0.001) (Table 1). Fatigue did not lead to changes in knee extensor moment and knee joint power (P > 0.05) but resulted in significant increases of hip extensor moment and hip joint power (P < 0.01) (Table 1).
In this study, we found the knee extensor moment increases as a partial mechanism to absorb the increased ground impact forces during loaded walking. Therefore, during long-distance loaded walking, it is possible that the increased knee power absorption along with high magnitudes of impact forces could expose the military recruits to increases of overuse knee injuries. We also found the hip joint exhibited increased extensor moment and joint power magnitude during weight acceptance. As increased pelvic anterior tilt is associated with load carriage [4], the increased hip extensor moment may be used to decelerate the increased pelvic anterior tilt at heel strike.

During fatigued walking, the hip extensor moment and power increase during weight acceptance. The increased hip extensor moment may be used to stabilize the pelvis and elevate the center of mass. Also, the increased hip extensor moment can help stabilize the femur and prevent knee flexion during weight acceptance. Interestingly, Fatigue does not lead to alteration of knee extensor moment and knee power absorption during weight acceptance. Thus, the increased vertical ground reaction force during fatigued walking may be attenuated by lower leg bone structures such as the tibia.

In summary, during weight acceptance, load carriage leads to alterations of knee and hip joint kinetics; Fatigue leads to alterations of hip kinetics. The altered lower extremity joint kinetics associated with load carriage and fatigue may be related to the high incidence of lower extremity overuse injuries in the military.

REFERENCES

ACKNOWLEDGEMENTS
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Table 1: Means and SDs of Peak knee and hip extensor moments and peak knee and hip joint powers 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>Knee extensor moment (Nm/kg)*</td>
<td>0.88 (0.20)</td>
<td>1.61 (0.37)</td>
<td>1.63 (0.42)</td>
<td>0.90 (0.25)</td>
</tr>
<tr>
<td>Hip extensor moment (Nm/kg)* #</td>
<td>1.54 (0.41)</td>
<td>2.26 (0.42)</td>
<td>2.38 (0.42)</td>
<td>1.85 (0.48)</td>
</tr>
<tr>
<td>Knee joint power (W/kg)*</td>
<td>-1.34 (0.37)</td>
<td>-2.65 (1.40)</td>
<td>-2.76 (1.06)</td>
<td>-1.39 (0.54)</td>
</tr>
<tr>
<td>Hip joint power (W/kg)* #</td>
<td>1.03 (0.36)</td>
<td>1.69 (0.61)</td>
<td>1.97 (0.64)</td>
<td>1.47 (0.49)</td>
</tr>
</tbody>
</table>

Note. * indicates significant difference between loaded and unloaded walking conditions (P < 0.00); # indicates significant difference between fatigued and unfatigued walking conditions (P < 0.01).