Estimating ground reaction forces from accelerations during prolonged load carriage

Liam Pettus
Mentored by Jennifer Neugebauer, PhD

Introduction

Ground reaction forces (GRFs) are the forces exerted onto the ground, in the vertical (GRFvert) and horizontal (GRFbrake) directions, by the body’s center of mass. Activity monitors (AM) measure accelerations related to ground contact in the vertical (ACCvert) and horizontal (ACCbrake) directions. Accelerations have been related to GRFbrake while walking and running (Neugebauer, Collins, & Hawkins, 2014) and GRFvert while walking and carrying load (Neugebauer & LaFiandra, 2018). Greater GRFs can take a significant toll on one’s body and this research informs people on the risks of undergoing rapid accelerations while carrying heavy loads and how these factors affect the forces exerted onto oneself. If applied correctly, physicians could adapt the results of this research, identifying possible causation of an injury as a result of increased GRFs. Prior to this study, no one has examined the relationship between accelerations and prolonged load carriage on GRFs. Therefore, the purpose of this experiment was to determine an equation identifying the relationship between GRFs and accelerations, during prolonged load carriage.

Materials and Methods

The materials implemented in this experiment were a force plate treadmill, loaded combat vests and rucksacks (figures 1 and 2), and an accelerometer contained within a tri-axial ACTi-Graph GT3X+ activity monitor (figure 3). The force plate treadmill was utilized to measure each subject’s vertical and braking GRFs, which were collected through the data processing program, Cortex®. Variable loads were implemented to investigate how carried mass affects vertical and braking GRFs.

Twelve active duty, male soldiers participated in data collection at the SPEAR cross country (XC) course and rifle range (RR) on Aberdeen Proving Ground.

The subjects walked the following course, going over the force plate treadmill (figure 4) at each distance increment: starting at the force plate (mile 0), completing the XC course (figure 5, mile 2.7), walking to a rifle range (mile 3.7), resting, then walking the XC course a second time (total 6.3 mi). Each subject walked two days. On day one, the subject carried the 26.1 kg load; on day two, the subject carried the 48.5 kg load.

The subjects walked the following course, going over the force plate treadmill (figure 4) at each distance increment: starting at the force plate (mile 0), completing the XC course (figure 5, mile 2.7), walking to a rifle range (mile 3.7), resting, then walking the XC course a second time (total 6.3 mi). Each subject walked two days. On day one, the subject carried the 26.1 kg load; on day two, the subject carried the 48.5 kg load.

The data predicted using the previously published GRFbrake equation versus the actual data was associated with a percent error of 39.3% (Graph 2). An accurate model is characterized by a Bland-Altman plot bias closer to zero and a smaller distance between the limits of agreement (LoA).

Results

The data predicted using the previously published GRFbrake equation versus the actual data was associated with a percent error of 39.3% (Graph 2). An accurate model is characterized by a Bland-Altman plot bias closer to zero and a smaller distance between the limits of agreement (LoA). The subjects walked the following course, going over the force plate treadmill (figure 4) at each distance increment: starting at the force plate (mile 0), completing the XC course (figure 5, mile 2.7), walking to a rifle range (mile 3.7), resting, then walking the XC course a second time (total 6.3 mi). Each subject walked two days. On day one, the subject carried the 26.1 kg load; on day two, the subject carried the 48.5 kg load.

A mixed linear model in R was implemented to verify that distance was insignificant in predicting both GRFvert (p = 0.12) and GRFbrake (p = 0.39). Generally, GRFvert increased as ACCvert increased. The data predicted using the previously published GRFvert equation versus the actual data was associated with a percent error of 6.1% (Graph 1).

Conclusion

Distance was not supported as a significant variable in predicting GRFvert or GRFbrake. The previously published GRFvert equation (Neugebauer & LaFiandra, 2018) was adequate to predict GRFvert whereas the previously published GRFbrake equation (Neugebauer, Collins, & Hawkins, 2014) did not accurately predict GRFbrake for this dataset, over a 6.33 mile distance rucksack march. A probable reason for this is the lack of running trials during this study, which the 2014 research included. A new equation is required to predict GRFbrake.

References