VERTICAL GROUND REACTION FORCE ASYMMETRY DURING UPHILL, LEVEL AND DOWNHILL RUNNING.

1Bhushan Thakkar, 1D. S. Blaise Williams III, 1Kathryn Harrison, 1Jacqueline Morgan, 2Robin Queen

1 VCU RUN LAB Virginia Commonwealth University, Richmond, VA, USA
2 Kevin Granata Biomechanics Lab, Department of Biomedical Engineering and Mechanics, Virginia Tech University, Blacksburg, VA, USA
email:thakkarbs2@vcu.edu

INTRODUCTION

Running-related injuries are most often single-sided and are partially attributed to lower limb movement and loading asymmetries.[6,9] For example, runners with tibial stress fractures demonstrate asymmetry in loading rate.[3-5] In fact, clinical intervention often focuses on the restoration of symmetry by attempting to restore function to the non-injured limb following injury.[5,6] Healthy runners have demonstrated varying levels of symmetry across different kinematic, spatiotemporal and kinetic parameters. [2,5,7,8] Running is a dynamic athletic event in which runners often engage in both inclined and declined running with the goal of improving conditioning.[1] While human gait is not perfectly symmetrical even on level ground, the introduction of a more challenging task such as uphill or downhill running is likely to exaggerate side-to-side differences.[2,4-7]

Symmetry Angle (SA) is a commonly used, robust measure of determining symmetry.[7,8] SA is calculated by the angle formed by the vector of two values (left and right) when plotted in a Cartesian coordinate system where values of the right leg are plotted on the x-axis and values of the left leg on the y-axis. The deviation from the vector of perfect symmetry is a measure of asymmetry between the two values. When this deviation is normalized to the maximum deviation which is 90°, a SA value of 0% indicates perfect symmetry, while 100% indicates that two values are equal and opposite. [4, 6, 8]

SA = (45° - arctan (X_{left}/X_{right}))/90°×100% [8]

The purpose of this study was to compare peak vertical ground reaction force (VGRF) symmetry using the SA during uphill, level and downhill running on an instrumented treadmill. We hypothesized that SA would be different across the three running conditions and runners would be highly asymmetric with downhill running which is associated with high peak VGRF values. [1,2,10]

METHODS

Eleven healthy adults (five males, six females, age: 27.6 yrs. (8.3), height: 1.71 m (0.11), mass: 68.4 kg (12.3)) volunteered to participate in this study. Demographic information was collected prior to testing. For gait analysis, participants wore tight-fitting athletic clothing, and were provided with footwear (New Balance 680, New Balance, Boston, MA). Gait analysis was performed on an instrumented treadmill. (Treadmetrix, Park City, UT) Each participant performed a total of eleven trials of 20 seconds of running, each with a unique incline. For the current study, running at 2.7 m/s at grades of 0°, 5.74° incline and 5.74° decline were analyzed. Visual3D software (C-Motion, Germantown, MD) was used to compute peak GRF data and a threshold of 60-N was set to detect heel strike and toe-off gait characteristics. Treadmill GRF data was filtered using low-pass Butterworth filter with a cut-off frequency of 50Hz.

SA was computed using the peak VGRF values from both the limbs. To calculate SA for running uphill condition, X_{left} was the peak VGRF of the left lower limb and X_{right} was the peak VGRF of the right lower limb during that running trial. Similarly, SA was computed for level running and downhill running. Analysis of variance was used to compare SA across uphill, level and downhill running and to evaluate changes in peak VGRF for both the right and the left lower limb of all the runners using Microsoft Excel data analysis tools. An alpha level of 0.05 was used.
RESULTS AND DISCUSSION

Downhill running resulted in the highest peak VGRF values bilaterally and the most asymmetry (Table 1). Uphill running produced the lowest peak VGRF values bilaterally and was the least asymmetric. No statistically significant differences in symmetry angle were observed between level running, uphill running and downhill running. (p=0.61)

The unexpected uniformity in vertical GRF across uphill, level, and downhill running is consistent with the absence of changes in the peak magnitudes of the GRF observed previously. [1] This suggests that neither moderate uphill or downhill running result in increases in peak GRF that may be considered injurious. Although some speculate that higher impact forces contribute to musculoskeletal injury, the evidence supporting this theory is disputed. [3,5] Increasing the amount of incline or decline may further exacerbate the observed changes.

It is likely that with this group of runners bilateral imbalances in strength, structure or kinematic gait mechanics could contribute to their gait symmetries during uphill and downhill running than kinetic alterations measured using peak VGRF. Another possible explanation for not seeing differences could be the level of inclination or decline that was used in this study, previous studies on sloped running have looked at 6.98% grade of incline and decline.[10] Studies that have looked at running uphill and downhill have used faster speeds (3-3.7m/s) to evaluate changes in GRF kinetics [1,4,10] and the inherent intra-limb variability between strides has been shown to increase with speed.[6] Among runners, gait asymmetries and alterations in lower extremity kinetics may become more apparent with fatigue[11] and all runners in this study were tested in a non-fatigued state.

Table 1: Mean and standard deviations of peak VGRF and SA within three running conditions.

<table>
<thead>
<tr>
<th></th>
<th>UPHILL</th>
<th>LEVEL</th>
<th>DOWNHILL</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGHT LEG (PEAK VGRF)</td>
<td>2.24(0.17)</td>
<td>2.35(0.15)</td>
<td>2.41(0.18)</td>
<td>0.06</td>
</tr>
<tr>
<td>LEFT LEG (PEAK VGRF)</td>
<td>2.25(0.15)</td>
<td>2.37(0.15)</td>
<td>2.40(0.180)</td>
<td>0.07</td>
</tr>
<tr>
<td>SYMMETRY ANGLE (%)</td>
<td>0.56(0.55)</td>
<td>0.61(0.36)</td>
<td>0.83(0.66)</td>
<td>0.61</td>
</tr>
</tbody>
</table>

CONCLUSIONS

This was the first study that looked at kinetic symmetry using peak GRF in healthy recreational runners during uphill level and downhill running. This study suggested that uphill and downhill running does not contribute to potential alterations in interlimb symmetry and could be considered as a safe alternative to level running on a treadmill. Asymmetry which is usually a consequence of excessively high strains on the musculoskeletal structures on a particular side or due to large relative imbalances between sides is an important contributor to injury. Future studies should look at runners in a fatigued state and incorporate kinematic and spatiotemporal gait parameters to compute lower limb symmetry.

REFERENCES