DIFFERENCES IN STRIDE INTERVAL VARIABILITY DURING STAIR-CLIMBING AND TREADMILL WALKING

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INTRODUCTION

Stair climbing is an activity of daily living that is common yet challenging and exhausting. Many times multiple steps have to be covered and previous studies have investigated the kinematics and kinetics at various joints during stair-climbing [1,2]. Previous research has also shown that long-range correlations of stride intervals exist during overground walking, treadmill walking and running [3,4]. Particularly, the fluctuations that occur during the stride intervals of human walking have been shown to be persistent and self-similar. Thus, it has been suggested that human locomotion is fractal-like during overground walking, treadmill walking, and running [3,4]. However, it is unknown if this is also true for other types of locomotion like a stair-climbing task. Hence, the objective of the current study was to compare variability of stride time intervals during treadmill walking and stair-climbing and to determine if long-range correlations exist during stair-climbing.

METHODS

Nine healthy participants (5 females; 25.2±4.9 years; 1.71±0.10 m; 69.1±13.8 kg) were recruited to participate in the study. Spatial-temporal data were collected using 12 high-speed cameras (Motion Analysis, Santa Rosa, CA) at 60 Hz as the subjects performed continuous stair-climbing on the SC916 stairmill (StairMaster, Fitness Direct, San Diego, CA) without using the handrails. Subjects were asked to find the stepping rate that they were most comfortable at, and this was used as their preferred stepping rate. We confirmed the subject’s preferred stepping rate by increasing the stepping rate until the subject reported discomfort with further increase in stepping rate. Once the preferred stepping rate was determined, spatial-temporal data was collected for three minutes at that rate.

As all the subjects demonstrated right leg dominance, right leg stride time was calculated using Matlab (Mathworks, Inc., Natick, MA). Right stride time was defined as the time between two consecutive toe-off events with the right leg and was calculated using the position of the marker placed on the head of the second meta-tarsal.

After walking on the stairmill, each subject rested for three minutes. Then the subjects were asked to walk on a treadmill (BodyGuard Fitness, Georges, QC, Canada) for five minutes at their preferred walking speed. Their preferred walking speed was determined similar to the procedure used to find the preferred stepping rate on the stairmill.

The mean, standard deviation (SD), and coefficient of variation (CV) of the right stride time were computed for each subject from the entire stairmill and treadmill walking trials. The SD and CV indicate the amount of variability in the stride time series. Additionally, long-range correlations of the right stride time were calculated using the Detrended Fluctuation Analysis (DFA) technique [5]. The DFA forms a sum of the time series from the minimum and maximum values of N provided, where N is the total number of data points in a time series. In the present study, N = 65 was used as that was the minimum number of strides across all the subjects. The range of the window size used was from $n_1=4$ to $n_m=16$ [4]. The DFA was used to determine the strength of the long-range correlations and provide a measure of temporal structure of the variability ($\alpha$-value). If the outcome value of $\alpha$ is greater than 0.5 then the correlations are said to be positive persistent, meaning a long stride interval is followed by a long stride interval whereas a short stride interval is followed by another short stride interval. If the value of $\alpha$ is less than 0.5 the correlations are said to be anti-
persistent, meaning long stride intervals are followed by short stride intervals whereas short stride intervals are followed by long stride intervals. If the $\alpha$-value is equal to 0.5 then long-range correlations are said to be absent. A paired sample $t$-test comparing stairmill and treadmill walking was performed on all the dependent measures. The statistical significance was set at 0.05.

**RESULTS AND DISCUSSION**

Results are shown in Table 1. The preferred stepping rate for stairmill walking was 52.44 (11.58) steps/min and the preferred walking speed for treadmill walking was 2.67 (0.53) m/s. From DFA, the mean $\alpha$-value for right stride time was obtained as 0.50 for stairmill walking and 0.64 for treadmill walking. An $\alpha$-value of 0.50 for the stairmill walking indicates the presence of white noise and an absence of scaling and fractal behavior and that long-range correlations are absent [3]. This was confirmed by surrogation analysis where most subjects exhibited alpha-values that were not significantly different than the randomly shuffled surrogates of the same stride interval time series [6]. On the treadmill, an $\alpha$-value of 0.64 shows that there are long-range correlations present and that these correlations are positively persistent, similar to results of previous studies [3,4]. The mean stride time, SD and CV for treadmill walking were significantly less than stairmill walking (all $P < 0.001$). However, the mean alpha values were not significantly different ($P = 0.208$).

These significant differences could have been due to the difficulty associated with stairmill walking. Participants were more comfortable to walk on the treadmill at a greater stepping rate (lesser stride interval). Stairmill walking is a more strenuous and difficult task than treadmill walking and probably requires more involvement from central nervous system resources. It is possible that during stairmill walking, the brain considers each step as a new problem to solve and depends minimally on the feedback from the previous step(s). Mechanically, stairmill walking places constraints on the individual to produce sufficient vertical and forward motion of the foot to successfully accomplish the task. Perhaps, the individual must solve this problem at each step there by producing greater amount of variability and absence of long-range correlations during stairmill walking. We also speculate that the results could have been affected by the small length of stride interval data series (N = 65). Presently, we explore this issue by collecting longer time series during stairmill walking.

**CONCLUSION**

The results show that continuous stair-climbing differs from treadmill walking primarily in terms of the amount of variability.

**REFERENCES**


**ACKNOWLEDGEMENTS**

Funding provided by the National Institute on Disability and Rehabilitation research (Grant No. H133G080023), National Institute of Health (Grant No. 1R011AG034995-01A1), the NASA Nebraska Space Grant & EPScoR (Grant No. NNX11AM06A) and the Nebraska Research Initiative.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Stairmill</th>
<th>Treadmill</th>
<th>t-statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean*</td>
<td>2.29 (0.42)</td>
<td>1.07 (0.10)</td>
<td>8.24</td>
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<td>Standard Deviation</td>
<td>0.08 (0.03)</td>
<td>0.02 (0.01)</td>
<td>6.77</td>
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<td>Coefficient of Variation (%)</td>
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<td>1.34 (0.64)</td>
<td>9.54</td>
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<tr>
<td>Alpha value from DFA</td>
<td>0.50 (0.26)</td>
<td>0.64 (0.29)</td>
<td>-1.37</td>
<td>0.21</td>
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