INFLUENCE OF STEPPING RATE ON STRIDE INTERVAL VARIABILITY OF STAIR-CLIMBING

Srikant Vallabhajosula, Jessica J. Renz, Jung Hung Chien, Nathaniel Hunt and Nicholas Stergiou

Nebraska Biomechanics Core Facility, University of Nebraska at Omaha, Omaha, NE, USA
College of Public Health, University of Nebraska Medical Center, Omaha, NE, USA
email: svallabhajosula@unomaha.edu, web: nbcf.unomaha.edu

INTRODUCTION
The temporal structure of gait variability has been shown to exhibit long-range correlations in the stride interval during over-ground walking, treadmill walking and running [1-3]. In fact, it has been shown that these long-range correlations are speed-dependent [2,3]. Particularly, at the preferred walking and running speeds, the strength of these long-range correlations has been shown to be weaker compared to the strength at faster and slower speeds. While previous studies have examined the influence of walking speed on long-range correlations in walking and running, research is limited on other continuous locomotor tasks such as stair-climbing. Stair-climbing is a common activity of daily living that is more demanding. Research on stair-climbing is limited to examining the biomechanics using staircases with limited number of steps. The objective of the current study was to determine how stepping rate influences the stride interval variability during continuous stair-climbing. Based on the walking and running literature [1-3], we hypothesized that the amount of variability would decrease with increasing stepping rate. Also, we hypothesized that the temporal structure of variability would be affected by increasing the stepping rate.

METHODS
Nine healthy participants (5 females; 25.2±4.9 years; 1.71±0.10 m; 69.1±13.8 kg) performed continuous stair climbing on the SC916 Stairmill (StairMaster, Fitness Direct, San Diego, CA) without using the handrails under three randomly presented conditions: at preferred stepping rate (PSR), 110%PSR, and 120%PSR. Stride time intervals of the dominant leg were calculated using the position data of a marker placed on the head of the second metatarsal (60 Hz; 12 cameras; Motion Analysis, Santa Rosa, CA). Stride time was defined as the time between two consecutive toe-off events of the dominant leg. All the subjects were right leg dominant. The subjects walked for three minutes during each condition and rested for at least three minutes between each condition testing. A custom Matlab script (Mathworks, Inc., Natick, MA) was used to compute the mean, Standard Deviation (SD) and Coefficient of Variation (CV) of the stride time intervals for each subject under each condition. Additionally, long-range correlations of the stride time intervals were calculated using the Detrended Fluctuation Analysis (DFA) technique [4]. For the current study, the box size range used was n = 4 to N/4 (=16), where N = 65 is the minimum number of stride intervals among all the subjects across all the conditions [2]. This ensured that time series of similar data length were compared. These long-range correlations can be characterized by the slope or scaling factor (α) from DFA. Differences between the group means of the dependent measures (mean, SD, CV, α) for stairmill walking in each of the three conditions were evaluated using a repeated measures one-way ANOVA. Bonferroni post hoc tests were used if the ANOVA yielded a significant result.

RESULTS AND DISCUSSION
The mean stepping rate for the three conditions was: preferred, 52.44 (11.59) steps/min; 100%PSR, 56.67 (12.40) steps/min and 120%PSR, 62.89 (13.81) steps/min. There was a significant main effect of condition for the mean stride time (P < 0.001). The post hoc analysis showed that mean stride time significantly decreased as the stepping rate increased and all the conditions differed significantly with each other (P < 0.001; Fig. 1A). In contrast, there were no condition main effects for SD (P=0.182), CV (P=0.228) and alpha (P=0.345). Albeit non-significant, the amount of variability was greater during 110%PSR condition described by both SD and CV values (Fig. 1B & 1C). However, the temporal structure of variability showed the...
opposite trend with the lowest value at 110%PSR (Fig. 1D). The alpha values of stairmill walking at PSR indicated the presence of white noise and absence of long-range correlations [1]. 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 time series. However, as the stepping rate increases, persistent long-range anti-correlations exist during stairmill walking, implying that, a short stride interval is likely followed by a longer stride interval and vice-versa.

Compared to treadmill walking at different speeds [3], stairmill walking produced greater mean stride interval and CV, but lesser alpha values at all the speeds. However, the pattern of the variation of these variables remained consistent between treadmill and stairmill walking. These results could suggest that performing a more strenuous task like stairmill walking, particularly at a faster pace might place an additional demand on the cardio-vascular and neuro-muscular systems of the body. Perhaps compensation for this additional demand might occur with participants frequently slowing down before picking up the speed. It is also possible that during stairmill walking at PSR, the nervous system considers each step as a new problem to solve and depends minimally on the feedback from the previous step(s). However, as the stepping rate increases, reliance on this feedback probably increases as the problem has to be solved quickly to avoid a fall. We speculate that the range of box size and number of stride intervals used here might also influence the outcomes. Future work should evaluate stairmill walking for longer trials.

CONCLUSIONS

Long range correlations in stride interval were absent during stairmill walking at PSR. However, increase in stepping rate introduces persistent long-range anti-correlations in stride interval. Stepping rate seems to have minimal influence on the amount and structural variability of stride interval.

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).

![Figure 1](image-url) **Figure 1:** Mean (SE) of dependent variables for the three conditions; blue diamonds – stairmill walking; red squares – treadmill walking from [2] * Significant difference (P<0.05)