Gait Asymmetry during Uphill, Downhill and Level Walking while Outdoors

[1]HyeYoung Cho, [1]Nathaniel Romine, [2]Junyoung Kim, [1]Michel Heijnen, [2]Babak Ziaie, [1]Shirley Rietdyk

[1]Health and Kinesiology, Purdue University, West Lafayette, IN, USA
[2]Electrical and Computer Engineering, Purdue University, West Lafayette, IN, USA
email: cho273@purdue.edu

INTRODUCTION

In recent research of gait assessment, symmetricity of gait has been regarded as a fundamental assumption for comprehensive data analysis. However, this assumption overlooks the anatomical and kinematic differences of lower limbs, and it could be related to the different contributions of the lower limbs in implementing propulsion and control tasks [1]. Since challenge is associated with gait asymmetry [2], more challenging tasks, such as uphill and downhill walking, may demonstrate more asymmetric gait patterns. A new device, SmartGait, has made possible the assessments of step length and step time during unrestrained outdoor walking [3]. The purpose of this abstract is to determine the asymmetricity of gait parameters including step length and step time during uphill, downhill and level walking outdoors.

METHODS

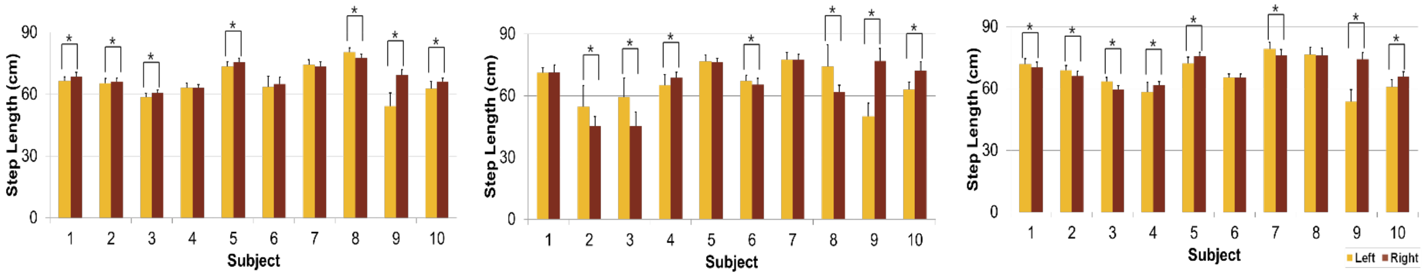
Ten young adults (age: 22.4±2.5 yrs.) walked outdoors at preferred speed for 91.4 m in three conditions: level surface, uphill slope of 5°, and downhill slope of 5°. Two trials of each condition were collected. All participants were right leg dominant as assessed with four questions [4]. SmartGait, a smartphone-enabled camera-based system for gait assessment [3], was used to assess gait parameters; this abstract will focus on step time (ST) and step length (SL). Variability of SL and ST was quantified as the standard deviation of each measure. A one-way ANOVA was conducted for comparing SL and ST in three different conditions. To assess asymmetry, left and right SL and ST were compared with a t-test for each subject in each condition. Due to multiple t-tests, a conservative p-value was set at 0.01.

RESULTS AND DISCUSSION

No significant differences were observed for ST ($p=0.53$) or SL ($p=0.68$) across the three walkway conditions. Similarly, no differences in gait parameters have been observed indoors for ST and SL during indoor walking with short distance (3.1 m) over a level surface, uphill and downhill slope [5]. Thus, adaptations to slopes are similar for indoor and outdoor walking.

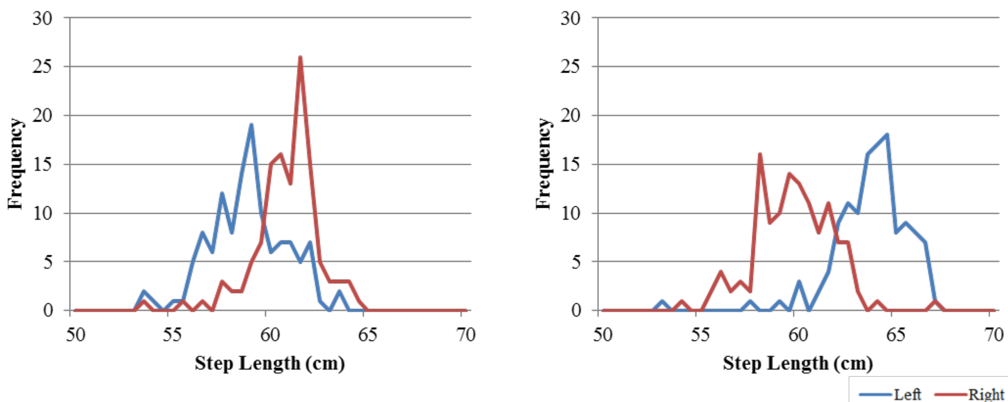
On level ground, four of the ten participants (40%) demonstrated asymmetry in both SL and ST on level ground, and nine (90%) showed asymmetry in at least one of the two measures (Fig. 1). SL distribution demonstrates that both limbs have similar range of SL, but the left limb has a higher frequency of steps at a shorter SL (Fig. 2A). When uphill walking, five subjects (50%) demonstrated asymmetry in both measures, and seven subjects (70%) demonstrated asymmetry in at least one of the two measures. When downhill walking, seven subjects (70%) demonstrated asymmetry in both measures, and eight (80%) demonstrated asymmetry in at least one of the two measures (Fig. 1). However, the dominant limb did not always demonstrate the longest SL or the longest ST. This result is consistent with the result that limb dominance cannot be related predictably to SL and ST [6].

Of particular interest, the limb with longest SL in level walking, which would be defined as the propulsive limb, became the limb with significantly smaller SL values in the uphill and/or downhill conditions in three participants (Fig. 2A; 2B). For example, the right limb SL was longer then the left for level walking, but shorter than the left for downhill walking (Fig. 2). Therefore, if the SL asymmetry is functional, that is, resulting from a propulsive limb and a stabilizing limb [1] it appears that the propulsion task can be shared across limbs;



(A) (B) (C)

Figure 1: Step time plotted as a function of limb (left (gold) vs right (brown)) and the three gait conditions. A) Level walking, B) uphill walking, and C) downhill walking. Asterisk (*) indicates p≤0.01.



(A) (B)

Figure 2: Distribution of step length as a function of limb (right vs left) for a single subject. A) Level walking and B) downhill walking. Red is right foot, blue is left foot.

each limb is not dedicated to a specific task. Future research should determine if this behavior is functional, that is, it provides benefit to the mobility. It is important to note that the measures reported here are kinematic, and it is known that kinetic measures provide a more accurate assessment of propulsion versus stability [2].

CONCLUSIONS

Gait asymmetry was observed while walking outdoors in uphill, downhill, and level walking conditions. However, the so-called propulsive limb (longer step length and/or step time) was not always the dominant limb. In fact, the propulsive limb was observed to switch between left and right limbs across the different gait conditions. Thus, it appears that young, able-bodied adults readily adapt the behavior of the limb based on the environmental context. Hill walking is critical for community mobility, and further exploring the propulsive limb adaptation may lead to improved interventions for people with asymmetrical gait due to disease and disorder.

REFERENCES

1. Sadeghi H, et al. *Gait Posture* **12(1)**, 34-45, 2000.
2. Patterson K, et al. *Arch Phys Med Rehab*, **89(2)**, 304-310, 2008.
3. Kim A, et al. *Gait Posture*, **42(2)**, 138-144, 2015.
4. Velotta J, et al. *Methods*, **11(2)**, 1035-1038, 2011.
5. Lay A, et al. *J Biomech*, **39(9)**, 1621-1628, 2006.
6. Gundersen L, et al. *Phys Ther*, **69(8)**, 640-650, 1989.

Conflict of Interest Statement: The SmartGait^{TM} device used in this research was developed by SmartGait LLC; two of the co-authors (BZ & SR) are co-founders of SmartGait LLC.