STEP LENGTH PERTURBATIONS ALTER VARIATIONS IN CENTER OF MASS HORIZONTAL VELOCITY

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INTRODUCTION
Speed of transport has previously been identified as an important factor in gait selection, with attention to transitions from walking to running [5]. Preferred gait speed has been attributed to optimization of mechanical efficiency and metabolic cost [2,4]. Previous investigations have explored steady-state gait speed, modeling the trajectory of the system center of mass (COM) as an inverted pendulum [2]. Speed adjustments are associated with alterations in step frequency and step length (SL), with the latter implicated in gait instability [1,5]. Specifically, longer SLs, exceeding preferred, have demonstrated greater vertical oscillation of the system COM, increasing the cost of transport [2]. From this, examining gait speed via system COM forward velocity (COMv_x) under contrasting stride conditions is considered valuable in gaining insight into selection of SL during locomotion.

The purpose of this research was to investigate the effects of SL perturbations on system COM forward velocity (v_x) during walking gait. Comparisons were made among step length perturbations and preferred stride walking (PW) and preferred stride running (PR) conditions.

METHODS

Eight participants (5 male, 3 female; age 23.5±3.6 yrs, height 1.72±0.18 m, mass 73.11±15.29 kg) free from previous lower extremity injury were included in this investigation. Informed consent was obtained prior to participation, as approved by the Research Ethics Board at the affiliated institution.

Kinematic data were acquired using a 12-camera system (Vicon MX T40-S; 200Hz), and 35-point spatial model (Vicon Plug-in Gait Fullbody). Data filtering and interpolation included a low pass, 4th order (zero lag) Butterworth filter (cutoff frequency 15Hz) and cubic 3rd order cubic spline.

PW, PR, and SL manipulations calculated as a percentage of leg length (LL; mean distance from anterior superior iliac spine to medial malleolus on each leg) were completed in a series of five trial blocks. SL perturbations used lengths of 60%, 80%, 100%, 120%, and 140% of LL. Participants were instructed to match their SL with cones spaced on the floor at corresponding distances. Gait speed and step frequency were not controlled in the current protocol. Kinematic analysis was carried out over two steps (one stride) during each gait trial.

Maximum and minimum system COMv_x comparisons were made independently among stride conditions using one-way repeated measures ANOVA and Bonferroni post-hoc contrasts. Change in system COMv_x (ΔCOMv_x; maximum v_x – minimum v_x) across the gait stride was also evaluated among stride conditions using one-way repeated measures ANOVA and Bonferroni post-hoc contrasts, via SPSS 20.0 (α=0.05). Degrees of freedom were adjusted using the Huynh-Feldt correction method where appropriate.

RESULTS AND DISCUSSION

Differences in maximum COMv_x were detected among stride conditions (F[1.847,59.105]=339.458, p<.001, η²=.914). Post-hoc comparisons showed significant increases (p<.001) in maximum COMv_x at each successive SL from 60%LL to 140%LL (Figure 1). Due to the large number of significant differences among stride conditions, Figure 1 identifies non-significant differences (p>0.05), displaying stride conditions where COMv_x values were similar. All non-flagged comparisons were
significant \((p \leq 0.02)\). From Figure 1, PW COM\(_{v_x}\) appeared to occur between SLs of 80\%LL and 100\%LL, but significantly differs from either of these two conditions \((p < 0.001)\). PR predictably demonstrated significantly greater COM\(_{v_x}\) than PW and perturbed walking conditions \((p < 0.001)\).

Similar to maximum COM\(_{v_x}\), differences in minimum COM\(_{v_x}\) were detected among stride conditions \((F[2.118, 65.666] = 130.951, p < 0.001, \eta^2 = 0.809)\). In contrast to maximum COM\(_{v_x}\), minimum COM\(_{v_x}\) did not differ between PW and SLs at, and in excess of 100\%LL. Minimum COM\(_{v_x}\) appeared to plateau above the 60\%LL stride condition, demonstrating a trend dissimilar to that observed for maximum COM\(_{v_x}\). As a result, \(\Delta\text{COM}_{v_x}\) across the gait stride was explored at each stride condition.

Differences in \(\Delta\text{COM}_{v_x}\) were identified among stride conditions \((F[2.387, 74.000] = 40.364, p < 0.001, \eta^2 = 0.566)\). Pairwise comparisons detected significantly greater \(\Delta\text{COM}_{v_x}\) at 140\%LL, and significantly lesser \(\Delta\text{COM}_{v_x}\) at 60\%LL \((p \leq 0.005; \text{Figure 2})\). Greater \(\Delta\text{COM}_{v_x}\) was considered representative of larger fluctuations in gait speed as a result of braking during the gait stride [3]. Similar to Figure 1, Figure 2 depicts non-significant differences \((p > 0.05)\), highlighting stride conditions of similar \(\Delta\text{COM}_{v_x}\). All non-flagged comparisons were significant \((p \leq 0.005)\). Figure 2 suggests that \(\Delta\text{COM}_{v_x}\) was similar among PW, 80\%LL, 100\%LL, and PR, while 60\%LL and 140\%LL exhibited significant differences in \(\Delta\text{COM}_{v_x}\). From this, it appears as though increased SLs may become inefficient for locomotion, requiring large variations in forward velocity as a result of greater braking during gait.

**Figure 1**: Step condition vs. horizontal COM velocity (* is a non-significant difference; \(p > 0.05\))

**Figure 2**: Step condition vs. horizontal COM velocity difference \((\text{max } v_x - \text{min } v_x); * \text{ is a non-significant difference; } p > 0.05\)

**CONCLUSIONS**

The current research supports previous investigations relating preferred SL to metabolic and mechanical cost of transport [4]. Stride lengths greater than 100\%LL demonstrate greater deviations in forward COM velocity, as a result of braking and subsequent loss of forward velocity. This outcome may provide insight into mechanisms responsible for transitions to running gait due to the increased energy expenditure needed to maintain steady-state speed during transport.

**REFERENCES**


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