

Effect of Walking Speed on Plantar Loading and Foot Kinematics in subjects with Stage II Posterior Tibial Tendon Dysfunction

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INTRODUCTION

Large forces are transmitted through the foot during walking.¹ The muscles and ligaments that cross the foot and ankle joints are responsible for producing and controlling these forces. In the presence of stage II Posterior Tibial Tendon Dysfunction (PTTD) weakness of the posterior tibialis muscle and failure of supporting ligaments (spring ligament) may alter the production and control of force.^{2,3} Walking speed may effect force production and control, leading to changes in plantar loading patterns and foot kinematics.⁴ Compensations for weakness may be possible at slower speeds but fail when walking faster. It remains unclear what effect walking speed may have on foot loading patterns and foot kinematics. It is hypothesized that, when walking fast, total loading in the foot and the distribution of loading under the foot will change as a sign of altered force production and control. Additionally, it is hypothesized that, when walking fast, altered medial longitudinal arch (MLA) kinematics will accompany changes in the loading patterns due to muscle weakness and failing support ligaments.

METHODS

Fourteen individuals with PTTD (6 male, 8 female; age=57.9 ± 12.4; body mass index = 31.6 ± 3.9) volunteered for this study. The arch height index, used to document the height of the MLA, was 0.311 ± .02 indicating a lower MLA and acquired flatfoot deformity.

An Optotrak Movement Analysis System (Northern Digital, Inc, Waterloo, CANADA) integrated with The Motion Monitor software (Innsport, Inc, Chicago, IL, USA) was used to measure movement from a multi-segment foot model during walking. The Pedar insole pressure system (Novel Inc, Germany) was used to collect plantar loading data

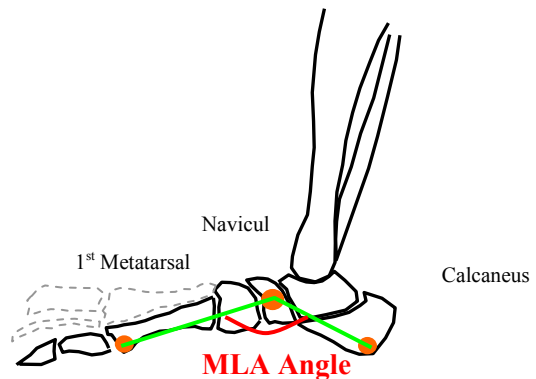


Figure 1: The medial longitudinal arch (MLA) angle was calculated using the dot product between two vectors created with the navicular tuberosity as the apex.

during separate walking trials. Subjects were asked to walk at two speeds (1.0 m/s and 1.5 m/s) and speed was controlled using timing gaits. Plantar loading data was collected at 90 Hz and kinematic data at 60 Hz.

The multi-segment foot model was used to calculate a MLA angle (**Figure 1**). A minimum of five steps were averaged and the MLA angle was compared across stance with larger values indicating a lower MLA. The sub-talar neutral position was used as a zero reference position. The plantar loading data were also averaged from five steps and compared across the stance phase. Total loading under the foot as well as loading from two masks defined to correlate to loading posterior to the apex of the MLA and anterior to the apex of the MLA were examined. The heel segment consisted of pressure under the foot posterior to the navicular tuberosity (apex of the MLA in the kinematic model) while the forefoot mask was defined as an area of pressure anterior to the navicular tuberosity. A two-way repeated measure ANOVA model was used to compare walking speeds (1.0 m/s and 1.5 m/s) across three points in the stance phase of gait (heel rocker – 10%, ankle rocker – 50%, and toe rocker – 90%). The model was repeated for each dependent

variable (total loading, heel loading, forefoot loading, MLA angle)

RESULTS

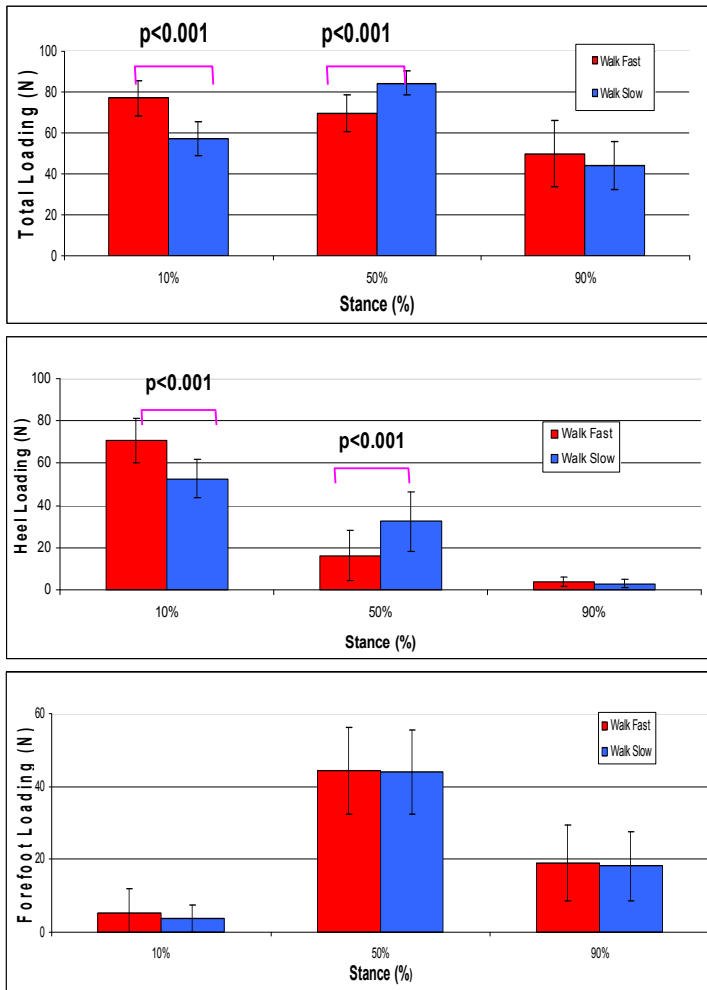


Figure 2. The total loading (top), heel loading (middle), and forefoot loading (bottom) for fast (red) and slow (blue) walking across three phases of stance. Significant differences are results of AVOVA pairwise comparisons between speeds.

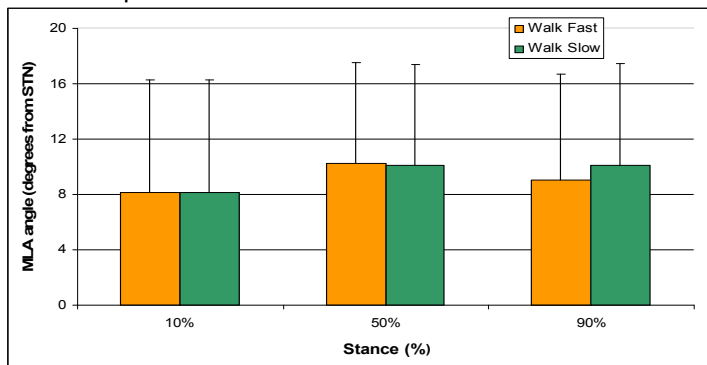


Figure 3. Kinematic measures of medial longitudinal arch angle comparing fast (orange) to slow (green) walking across three phases of stance. No differences were observed between walking speeds.

DISCUSSION

Despite altered plantar loading patterns in the foot suggesting a change in force transmission through the foot no change was observed in MLA angle. (Figure 2 and 3). The total plantar loading under the foot was larger at 10% of the stance and less at 50% of stance consistent with walking faster. Additionally, the heel loading was greater at 10% but less at 50% of stance suggesting an earlier heel rise and progression onto the forefoot when walking faster. However, no change in forefoot loading may imply the decrease in total load comes from unloading the heel without transferring load to the forefoot. This “lift off” pattern suggests a quicker transfer of weight to the opposite foot, possibly to unload the weaker, degenerative posterior tibialis tendon. These data suggests unloading when walking faster may serve as a compensatory mechanism as MLA kinematics were preserved when comparing walking speeds.

CONCLUSIONS

Walking faster alters the loading pattern in the foot in subjects with stage II PTTD. Evidence of unloading the foot when walking faster may serve to protect the midfoot as no change in MLA kinematics were observed.

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