KINETIC FACTORS INFLUENCING THE GAIT TRANSITION SPEED DURING HUMAN LOCOMOTION

Alan Hreljac, Rodney Imamura, Rafael F. Escamilla, W. Brent Edwards, and Toran Furch
Department of Kinesiology & Health Science, California State University, Sacramento
email: ahreljac@csus.edu

INTRODUCTION

Several researchers [1,2,3,4] have hypothesized that the gait transitions of quadrupeds are triggered by kinetic factors, such as musculoskeletal stresses, particularly at joints. Utilizing invasive techniques, it has been shown [1,2,4] that small horses, dogs, and goats reduced bone and joint strain when changing gait from a trot to a gallop. Non-invasive techniques (ground reaction forces-GRFs), have also been used [3] to make similar conclusions regarding a group of large horses.

Two studies [5,6] which have applied the non-invasive technique [3] to humans, found little evidence to suggest that external kinetic variables (GRFs) were related to the gait transition of humans. No human studies have examined the relationship of joint kinetic variables to the gait transition speed. The primary purpose of this project was to examine whether lower extremity joint kinetic factors are related to the gait transition during human locomotion.

METHODS

Following the determination of the preferred transition speed (PTS) of each of the 16 subjects using methodology described in previous studies [5,6,7], subjects walked down a 25 meter runway, and over a floor mounted force platform at five speeds (70, 80, 90, 100, and 110% of the PTS), and ran over the force platform at three different speeds (80, 100, and 120% of the PTS). Speed was monitored by three sets of infrared photocell timing lights. Reflective markers, placed on the greater trochanter, knee joint center, lateral malleolus, and head of the fifth metatarsal were recorded by a single digital video camera (240 Hz), in the right sagittal plane. A trial was considered successful only if the speed fell within ± 5% of the target speed, the landing foot completely contacted the force platform, and if there was no visible change in stride length.

Two-dimensional (2-D) kinematic data were synchronized with GRF data (960 Hz). The raw 2-D coordinate data were smoothed using a 4th order, zero lag, Butterworth filter. Joint moments were determined by inverse dynamics calculations. Joint powers were calculated as the product of the respective joint moment and angular velocity. Prior to analysis, all variables were normalized by dividing by body mass. Dependent variables (DVs) included maximum ankle dorsi- and plantar flexor moments, maximum knee extensor moment, and maximum power absorption and generation at the ankle and knee. A repeated measures MANOVA compared average values of all DVs between speed conditions. If the hypothesis tested was to be accepted for a DV, the value of the DV would increase as walking speed increased, then decrease when gait changed to a run (at the PTS). For all comparisons, $\alpha = 0.05$.

RESULTS AND DISCUSSION

The maximum dorsiflexor moment was the only DV which increased as walking speed increased, and decreased when gait changed to a run (Table 1). At the low running speeds tested during this study, many subjects exhibited a mid- or forefoot striking pattern, producing an initial dorsiflexion velocity. This movement is controlled eccentrically by the plantar flexors, just as the initial plantar flexion velocity during walking is controlled eccentrically by the dorsiflexors. Changing landing strategy in this way would transfer stress from the dorsiflexors to the plantar flexors at the PTS.

CONCLUSIONS

The dorsiflexor moment which occurs soon after foot contact is the only variable tested which appears to be related to the gait transition during human locomotion. This supports the results of previous studies [7,8] which have concluded that an important factor in changing gaits at the PTS is the prevention of stress in the dorsiflexor muscles.

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Table 1: Value of DVs at all conditions (M in N·m/kg, P in W/kg, Abs=Absorption, Gen=Generation, *=sig. decrease from W100).

Condition	Ankle-PFM	Ankle-DFM	Knee-ExtM	Ankle-P-Abs	Ankle-P-Gen	Knee-P-Abs	Knee-P-Gen
W70	1.49 ± 0.16	0.25 ± 0.07	1.17 ± 0.44	0.70 ± 0.26	5.02 ± 0.96	3.87 ± 2.01	1.04 ± 0.46
W80	1.52 ± 0.20	0.30 ± 0.13	1.09 ± 0.42	0.74 ± 0.32	5.87 ± 0.97	2.97 ± 2.33	1.59 ± 0.52
W90	1.60 ± 0.17	0.32 ± 0.13	1.24 ± 0.60	0.91 ± 0.38	6.53 ± 1.26	4.74 ± 2.50	1.85 ± 1.02
W100	1.64 ± 0.20	0.37 ± 0.11	1.46 ± 0.46	0.78 ± 0.36	7.49 ± 0.97	4.92 ± 2.89	2.23 ± 0.84
W110	1.67 ± 0.17	0.43 ± 0.19	1.45 ± 0.63	0.45 ± 0.17	7.91 ± 1.13	3.77 ± 2.03	2.49 ± 0.84
R80	1.94 ± 0.28	0.11 ± 0.06*	2.24 ± 0.58	3.51 ± 1.68	6.48 ± 2.30	5.68 ± 1.57	4.49 ± 2.04
R100	2.04 ± 0.29	0.18 ± 0.09*	2.49 ± 0.63	3.58 ± 1.20	7.92 ± 2.49	7.38 ± 2.01	5.43 ± 2.40
R120	2.22 ± 0.37	0.22 ± 0.10*	2.73 ± 0.59	4.12 ± 1.78	9.92 ± 2.45	8.17 ± 2.17	7.21 ± 2.29