INTERNAL KINETIC FACTORS AND THE PREFERRED TRANSITION SPEED IN HUMANS

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INTRODUCTION

Previous authors (Biewener, et al., 1983, Biewener, et al., 1986, Farley, et al., 1991, Rubin, et al., 1982) have suggested that the preferred gait transition (PTS) of quadrupeds are triggered by internal kinetic factors within the musculoskeletal system. Invasive research on horses, dogs, and goats has demonstrated that musculoskeletal strain decreases when changing gait from a trot to a gallop (Biewener, et al., 1983, Biewener, et al., 1986, & Rubin, et al., 1982). In addition, non-invasive ground reaction force (GRF) data from large horses (Farley, et al., 1991) supported similar conclusions.

Two experiments (Hreljac, 1993, Raynor, et al., 2002) have been conducted on humans, using a non-invasive GRF data collection technique previously used on animals (Farley et al., 1991), to determine if external kinetic variables may have a relationship with the human gait transition. These studies did not support the hypothesis that external kinetic variables have a relationship to gait transitions in humans.

The walk-run PTS has been shown to be triggered by dorsiflexor stress (Hreljac, 1995). Peak dorsiflexor activity occurs just after toeoff. Dorsiflexor muscles during the swing phase were focused on within this study to follow up on previous findings (Hreljac, 1995). The purpose of this investigation was to determine if ankle joint kinematic and kinetic factors, particularly dorsiflexor power during the swing phase are related to the gait transition speed in humans.

METHODS

The PTS was determined on 24 male subjects, using a method similar to previous studies (Hreljac, 1993, Raynor, et al., 2002, Hreljac, 1995), under two loading conditions. An unloaded condition did not include an external load, and a loaded condition included a 2 kg load attached to each shoe of the subject about the center of mass of the foot. Each condition was completed twice in a random order for each subject.

After determination of the PTS, subjects walked on a treadmill at three speeds (60, 80, and 100% of the PTS), and ran at one speed (100% of the PTS) for both loading conditions, in random order. Speed for all trials was calculated from the elapsed time of ten belt rotations. Reflective markers were placed on the right greater trochanter, knee joint center, lateral malleolus, calcaneus, and base of the 5th metatarsal while a digital video camera (240 Hz) recorded subjects in the right sagittal plane. Ten stride lengths were recorded for each trial.

Raw kinematic data were smoothed using a 4th order, zero lag, Butterworth filter. Ankle joint kinetic factors during the swing phase were determined using inverse dynamics. Ankle joint power was calculated as the product of ankle joint moment and ankle angular velocity. All variables were
normalized to body mass before comparisons were made. Dependent variables (DVs) included maximum ankle angular velocity, ankle angular acceleration, and ankle joint power. The PTS under the two loading conditions were also compared in order to assure that the loaded condition affected the PTS. A repeated measures MANOVA compared average values of all DVs between speed and loading 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**

PTS data are included (Table 1) to demonstrate that the unloaded PTS was significantly faster than the loaded PTS condition. All of the DVs, under both loading conditions, increased as walking speed increased, and decreased with the change to a run (Table 2). Ankle angular velocity and acceleration results support previous findings (Hreljac, 1995). The results of the current study, along with previous findings, indicate dorsiflexor muscle stress has a role in determining the PTS. The ankle joint moments produced by the dorsiflexors may also have a relationship with the PTS. Further study may demonstrate that other internal kinetic factors are determinants of the PTS. Kinetic factors are ultimately responsible for kinematics, so finding an ankle joint moment as a determinant makes sense.

**Table 1:** Gait speed (m/s) at all conditions (*=significant difference between the loading conditions while walking at the PTS)

<table>
<thead>
<tr>
<th>Condition</th>
<th>w60</th>
<th>w80</th>
<th>w100</th>
<th>w100 (PTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unloaded</td>
<td>1.24</td>
<td>1.62</td>
<td>2.03</td>
<td></td>
</tr>
<tr>
<td>Loaded</td>
<td>1.16</td>
<td>1.55</td>
<td>1.94</td>
<td></td>
</tr>
</tbody>
</table>

**SUMMARY/CONCLUSIONS**

Ankle angular velocity, angular acceleration, and joint power appear to have a relationship to the PTS. Dorsiflexion appears to be important to the PTS in humans based on the results of this study and others (Hreljac, 1995, Hreljac, et al., 2001). Further study should be conducted on internal kinetic factors in relationship to the PTS in humans.

**REFERENCES**


**Table 2:** Value of DVs at all conditions (*=sig. difference from previous speed under respective loading condition).

<table>
<thead>
<tr>
<th>Condition</th>
<th></th>
<th>w60u</th>
<th>w80u</th>
<th>w100u</th>
<th>r100u</th>
<th>w60l</th>
<th>w80l</th>
<th>w100l</th>
<th>r100l</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \omega ) (rad/s)</td>
<td></td>
<td>2.69</td>
<td>3.17*</td>
<td>3.83*</td>
<td>2.75*</td>
<td>3.31</td>
<td>3.54*</td>
<td>4.09*</td>
<td>3.42*</td>
</tr>
<tr>
<td>( \alpha ) (rad/s/s)</td>
<td></td>
<td>100.33</td>
<td>115.05*</td>
<td>125.51*</td>
<td>62.30*</td>
<td>116.25</td>
<td>130.04*</td>
<td>140.95*</td>
<td>68.10*</td>
</tr>
<tr>
<td>P (W/kg)</td>
<td></td>
<td>0.03</td>
<td>0.05*</td>
<td>0.07*</td>
<td>0.05*</td>
<td>0.06</td>
<td>0.09*</td>
<td>0.13*</td>
<td>0.08*</td>
</tr>
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