RESPONSE OF THE KNEE ADDUCTION MOMENT TO CHANGES IN GAIT SPEED: PEAK VERSUS IMPULSE

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INTRODUCTION

The external knee adduction moment during gait is a proxy for the distribution of load between the medial and lateral compartments of the knee. Peak values from this moment have been implicated in the initiation of chronic knee pain [1] and radiographic progression of knee osteoarthritis (OA) [2]. Factors that influence the knee adduction moment include mechanical alignment of the lower limb and overall body weight. Some studies have also demonstrated a relationship between gait speed and the peak knee adduction moment [3], though this relationship has not been consistently reported [4]. Understanding the effect of gait speed on the knee adduction moment is important because gait speed is easily modified and therefore could be a treatment strategy to modify joint loading [5].

Despite previous emphasis on the peak, researchers have found that the knee adduction moment impulse, which reflects both the duration and magnitude of medial loading during a stride, is also important in radiographic and symptomatic knee OA [4]. However, the knee adduction moment impulse has not been examined with the participants ambulating at different speeds. It is unclear how the impulse would change with increasing gait speed. Any increase in amplitude might be negated by the anticipated decrease in the stance time with a faster gait speed. Thus, the purpose of this study was to examine changes in the knee adduction moment, including the peak and impulse, in response to controlled changes in gait speed, in healthy participants during over ground ambulation.

METHODS

A convenience sample of 32 healthy adults participated (age 32 ± 8 years, body mass index 25 ± 4 kg/m^2, 18 women).

The knee adduction moment was calculated using 8 cameras (Motion Analysis Corp., Santa Rosa, USA) with a sample rate of 60 Hz and a synchronized floor-mounted force plate (AMTI, Watertown, USA) with a sample rate of 1200 Hz. A Helen-Hayes marker configuration was used, with 21 reflective markers. Participants stood on the force plate to determine body mass and provide a reference frame. Participants actively flexed, extended, abducted and adducted the hip to calculate functional hip joint centres.

Three gait speed conditions were examined in the following order: self-selected, slow and fast. For the self-selected condition, participants ambulated barefoot across a 6 metre capture area. The time required for each participant to ambulate the 6 metres was recorded using a stopwatch (Sportline 220, Sportline Inc., New York, USA). For the slow condition, participants completed the six metres in a 15% longer time period than the self-selected speed. For the fast condition, participants ambulated 15% faster compared to the self-selected speed. For all conditions, a successful trial was defined as completing the six metres within ±5% of the target time. Then, kinematic and kinetic variables were calculated with commercial software using a fixed tibial coordinate system (Orthotrak 6.2.4, Motion Analysis Corp., Santa Rosa, USA). Data were not normalized to stride.

To ensure appropriate gait speeds were achieved, forward progression speed of the sacral marker was reviewed. Trials were excluded if gait speed was not within 2.5% of the target. Five trials were averaged for the self-selected condition and 3 trials were averaged for the slow and fast conditions.

A one-way repeated measures analysis of variance (ANOVA) was used to identify differences in gait speed and between conditions in the stance peak and impulse of the knee adduction moment waveform, ($p < 0.05$). Adjusted p values, using Greenhouse-Geisser values, were examined if the assumption of sphericity was not tenable as demonstrated by Mauchly's Test of Sphericity (p <

0.05). The sphericity assumption maintains that the pair-wise comparisons have equivalent variances. Tukey's Honestly Significance Difference test was used to make pair-wise comparisons between the condition means.

RESULTS

Gait speed data violated the sphericity assumption. Thus, an adjusted repeated measures ANOVA was analyzed and revealed that mean gait speeds during self-selected (1.39 ± 0.15 m/s), slow (1.19 ± 0.13 m/s) and fast (1.60 ± 0.17 m/s) conditions were different ($p<0.05$).

Data for the mean peak knee adduction moment in each condition violated the sphericity assumption. An adjusted repeated measures ANOVA revealed differences in the peak between the conditions ($p<0.05$). There was a greater peak during the fast condition compared to the slow condition. The peak for the self-selected condition was not different than the slow or fast conditions (Table 1).

Data for the mean knee adduction moment impulse met the sphericity assumption. A difference existed between conditions for impulse ($p<0.05$). The impulse for the slow condition was greater than both the self-selected and fast conditions. There was no difference in the impulse between the self-selected and fast conditions (Table 1).

Table 1: The knee adduction moment impulse and peak mean values during self-selected, slow and fast gait speeds among 32 healthy adults.

Variable	Self-selected Speed Mean (SD)	Slow Speed Mean (SD)	Fast Speed Mean (SD)
Impulse (Nm*s)	8.97 (3.93)	10.14 (4.72)	8.83 (4.00)
Peak (Nm)	30.05 (10.97)	27.63 (10.08)	32.28 (13.18)

By examining data non-normalized to stride, differences between speeds in the peak and impulse revealed information important to understanding the medial loading environment (Figure 1).

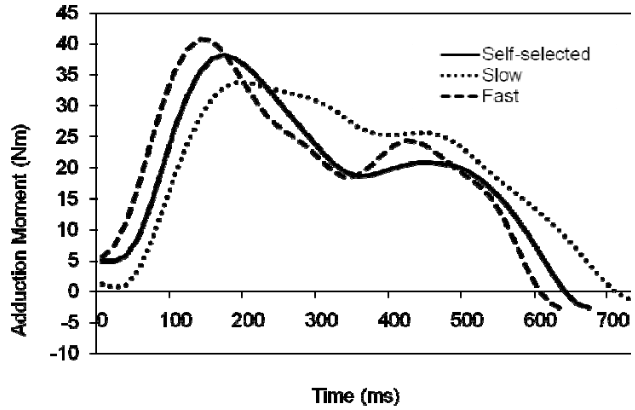

Figure 1: External knee adduction moment for the self-selected, slow and fast gait speeds in one participant.

DISCUSSION AND CONCLUSIONS

Gait speed altered the knee adduction moment and therefore the distribution of loading across the medial and lateral knee compartments. Speed-related changes in the peak and impulse occurred in opposite directions, suggesting these variables represent different aspects of medial loading. The impulse was more sensitive than the peak to changes in gait speed. The impulse was time-dependent and reflected total loading of the medial compartment during one stride. An increase in gait speed by 15% from the self-selected to fast condition did not alter the impulse. Thus, slowing gait speed below self-selected speed had a greater influence on the impulse than increasing gait speed. Meanwhile, the peak reflected the maximum medial load. A 30% increase in gait speed (from slow to fast condition) was required to increase the peak.

Slowed gait speed has been recommended as a potential intervention for knee OA [5]. These findings highlight that while slowed gait speed results in a lower peak load, a concurrent increase in impulse may result in a greater total load exposure.

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