MOMENTUM ANALYSIS DUE TO FOOT-TO-FLOOR CONTACT FORCES IN FORWARD GAIT INITIATION

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INTRODUCTION

Gait analysis is commonly used to describe the differences between a patient's performance and a non-disabled subject performance. It is also used to classify the severity of a disability or to determine the efficacy of surgical interventions. Breniere and Do define Gait initiation as the transient period between early modification of upright posture and stationary process of gait [1], measured from the initiation cue to toe-off of the original stance limb [2]. Inman [3] summarized the ability of the human body to optimize its energy consumption by asserting: "the body will integrate the motion of various segments of the body and control the activity of muscles so that the energy required by each step is minimal". Based on this statement, this study makes a comparison between the total momentums at gait initiation due to foot-to-floor contact forces for three different speeds: Slow, 1 step every 1.5 seconds; Normal, 1 step every 1 second; and Fast, 1 step every 0.5 seconds; so as to determine the optimal speed in terms of momentum.

METHOD

Subjects

A total of 20 subjects, including 13 males and 7 females were involved in the study for which anthropometrical data was collected as well as age and gender. The participants ranged in age from 18 to 34 years old with an average age of 24.9 (S.D. 4.27). The average height of subjects was 66.9 inches (S.D. 4.73). The average weight was 159.75 lb (S.D. 28.16). 85% of the subjects were right handed while 75% were right legged.

Equipment

A level platform served as walkway during data collection. The walkway was 4 feet wide and 32 feet long. Incorporated into the walkway was an Advanced Mechanical Technology Inc. (AMTI) OR6 force platform that simultaneously measured force components along three axes. The force plate was calibrated every time prior to data gathering. The reaction forces for each subject were obtained using Ariel Performance Analysis System (APAS) analog module, and a video using a JVC 1800 camcorder captured images that were used to synchronize the data previously obtained. These forces were then normalized and processed using Matlab in order to find the total momentum at each of the three different speeds for each individual.

Procedures

Each subject signed a statement of informed consent before participating in this study. Afterwards, each subject stood barefoot in an erected position with one foot on the platform. Measurements for each leg were taken independently in order to have their respectively contribution to the total momentum. The camera was placed facing the side of the leg to be studied. Each subject performed two recorded trials at each speed, which was in turn defined by a beep sequence to be followed by the subject. Data were collected for 1.5 seconds for each trial.

Data Analysis

Force plate data and video recordings were stored on a computer disc for later analysis. The normalization of measured forces was analog to that proposed by Kirtley (1996) which divided the values obtained by the weight (mass*gravity) of each subject [4], to be allowed to compare the results regardless of weight, which was the highest standard deviation parameter. Using the following equation, the calculated values were used to find the momentum of each force component:

$$M = \int F dt \tag{1}$$

Once the momentum was calculated for each force (component) the total momentum for each limb was calculated by adding the momentums in all three axes. Then the total momentum for each velocity was calculated by adding those resultant vectors.

Finally, Analysis of Variance (ANOVA) was used to analyze the data with three levels of independent variable, gait initiation speed: slow, normal and fast.

Results

Figure 1 and Figure 2 show the average force in foreaft, medial-lateral and vertical directions obtained for the swing limb and stance limb respectively. Time zero seconds corresponds to the cue or auditory signal to start walking forward. Analyzing the data obtained, the stance limb generates more momentum than the swing limb due to the fact that forces for the latter proved to be smaller.

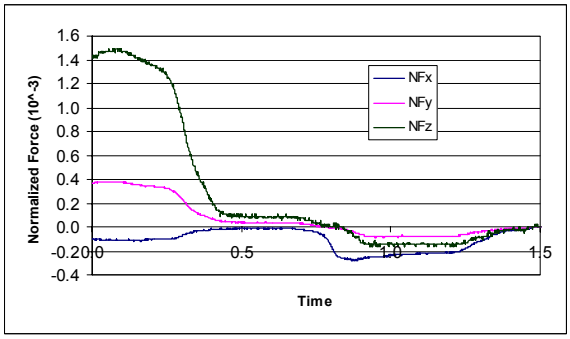

Figure 1. Average Normal Speed for Swing Limb
Normalized reaction forces of swing limb for forward gait initiation at a normal speed

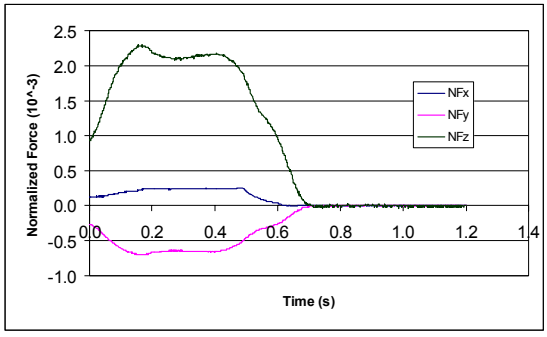

Figure 2. Average Normal Speed for Stance Limb
Normalized reaction forces of stance limb for forward gait initiation at a normal speed

The average total momentum for each speed is shown in the following table:

	x	y	z	Magnitude
SLOW	0.0086	-0.3196	1.8197	**1.848**
NORMAL	-0.0475	-0.2543	1.5987	**1.619**
FAST	0.1115	-0.2085	1.7029	**1.719**

Table 1. Average Total Momentum
Average magnitude of total momentum in forward gait initiation at three different speeds. Magnitude given in Ns.

Discussion and Conclusion

This study provides an analysis of the momentum in gait initiation for various speeds. Although Herman, *et al* [5], and Nissan and Whittle [6] among others obtained force plate data, they did not compare it at different speeds. Also studies made by Breniere and Do [1] or Cook and Cozzens [7] included different speeds, but did not analyze the momentum generated by those forces. On the other hand, studies made by Winter *et al* [8,9] about energy in normal gait calculated the contribution of each segment during the walking cycle but they did not compare them at various speeds. There has been a lack of comparison among different gait initiation speeds, and this was therefore the aim of our study.

From the results obtained, it was concluded that normal speed requires less momentum to achieve steady-state gait than the other two initial speeds. Besides, it was found that gait initiation with the right lower limb was more natural for individuals with right side dominance.

Further investigation on the roll that energy place in gait initiation and its relation to the center of pressure will be useful for practical applications.

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