

AN EVALUATION OF FUNCTIONAL ASYMMETRY AT NON-PREFERRED WALKING SPEEDS

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INTRODUCTION

The idea of functional asymmetry has been used to explain documented bilateral asymmetries for various biomechanical measures during normal gait [1]. According to this idea, the non-dominant and dominant legs, considered as whole entities, contribute asymmetrically to support (upward center of mass acceleration) and propulsion (forward center of mass acceleration). It was believed that the non-dominant leg contributes more to support, while the dominant leg contributes more to propulsion [1]. We recently demonstrated, however, that the non-dominant and dominant legs contribute similarly to support and propulsion during preferred-speed walking, but the dominant leg contributes 7% more to propulsion than the non-dominant leg during walking at a speed that is 20% greater than preferred [2]. This indicates that functional asymmetry may not exist during preferred-speed gait, but it may occur while walking at a speed that is greater than preferred.

The purpose of this study was to further investigate the potential relationship between functional asymmetry and non-preferred walking speeds. We formulated three hypotheses that were based upon the idea that functional asymmetry may be influenced by walking speed: (1) As walking speed increases, contributions to propulsion (measured via impulse due to the forward-directed ground reaction force; GRF) would increase at a greater rate for the dominant leg than for the non-dominant leg; this was expected because propulsive requirements increase as walking speed increases. (2) Contributions to propulsion would be significantly

greater for the dominant leg, relative to the non-dominant leg for walking speeds that are greater than preferred. (3) Contributions to support (measured via impulse due to the vertical GRF) would be bilaterally symmetrical at various walking speeds, because support requirements are relatively constant across different walking speeds, due to the constancy of gravity.

METHODS

Bilateral GRFs were observed for 20 healthy subjects (age = 23 ± 2 yrs; height = 1.74 ± 0.09 m; mass = 71.4 ± 13.1 kg) who walked at nine different speeds (Table 1). Informed consent was obtained prior to data collection. Five trials were performed for both legs at each speed. Walking speed was measured with an optoelectronic timing device and reported immediately to subjects. If the speed was not within $\pm 2.5\%$ of the target speed, the trial was performed again. Impulse due to vertical GRF (support) was calculated as the time integral of the vertical GRF during stance. Propulsive impulse was calculated as the time integral of the anterior-posterior GRF, while this force was oriented in the forward direction (approximately the second half of stance). Impulses were normalized to the product of: 1) body weight and 2) the square root of limb length/gravity [3].

Two repeated measures ANOVA ($p = 0.05$) were used to evaluate the influence of leg and speed on both dependent variables: support and propulsive impulse. A potential leg \times speed interaction was tested for each dependent variable. If an interaction was detected, *post hoc* tests were used to compare

Table 1. Mean walking speeds (m/s) for the present study: the preferred speed (PS) and other speeds that were relatively slower (-) or faster (+). *P* values for bilateral comparisons of support and propulsive impulses are also indicated; there was no significant between-leg difference at any of the observed speeds.

Target Speed	-40%	-30%	-20%	-10%	PS	+10%	+20%	+30%	+40%
Actual Speed	0.94 ± 0.1	1.09 ± 0.1	1.25 ± 0.2	1.41 ± 0.3	1.56 ± 0.3	1.71 ± 0.3	1.88 ± 0.3	2.03 ± 0.4	2.20 ± 0.4
Support (<i>p</i>)	0.76	0.78	0.68	0.64	0.74	0.84	0.87	0.80	0.83
Propulsive (<i>p</i>)	0.89	0.89	0.73	0.56	0.20	0.20	0.07	0.34	0.42

the dependent variables at each speed. Alpha levels were adjusted using the false discovery rate procedure for multiple comparisons [4].

RESULTS AND DISCUSSION

A significant leg \times speed interaction was detected for support ($p = 0.01$) and propulsive ($p = 0.04$) impulse (Figure 1). *Post hoc* comparisons revealed no significant bilateral differences for any of the dependent variables at any walking speed (Table 1).

Overall, the data were inconclusive regarding the idea that walking speed affects functional asymmetry. The first hypothesis was supported, but the second and third were not. The observed leg \times speed interaction for propulsive impulse was predicted and in the expected direction. As speed increased, the dominant leg contributed disproportionately more to propulsion (Figure 1B), supporting the idea that functional asymmetry is related to walking speed and more prevalent at increased speeds. A lack of statistical bilateral difference for propulsive impulse at any of the increased walking speeds contradicted the second hypothesis. A qualitative view, however, of the propulsive impulse data (Figure 1B) indicates that whole-leg contributions to support do vary in a manner that fits with the idea that functional asymmetry is influenced by walking speed. Lastly,

the observed leg \times speed interaction for support impulse contradicted the third hypothesis. Speculating, it appears that dominant leg contributions to support decrease disproportionately, relative to non-dominant leg contributions as walking speed increases (Figure 1A); this observation also fits with the idea that functional asymmetry is more prevalent at increased walking speeds.

CONCLUSIONS

Although our data failed to support two of the three hypotheses, support of the first hypothesis and other trends in the data indicate that functional asymmetry may be related to walking speed.

REFERENCES

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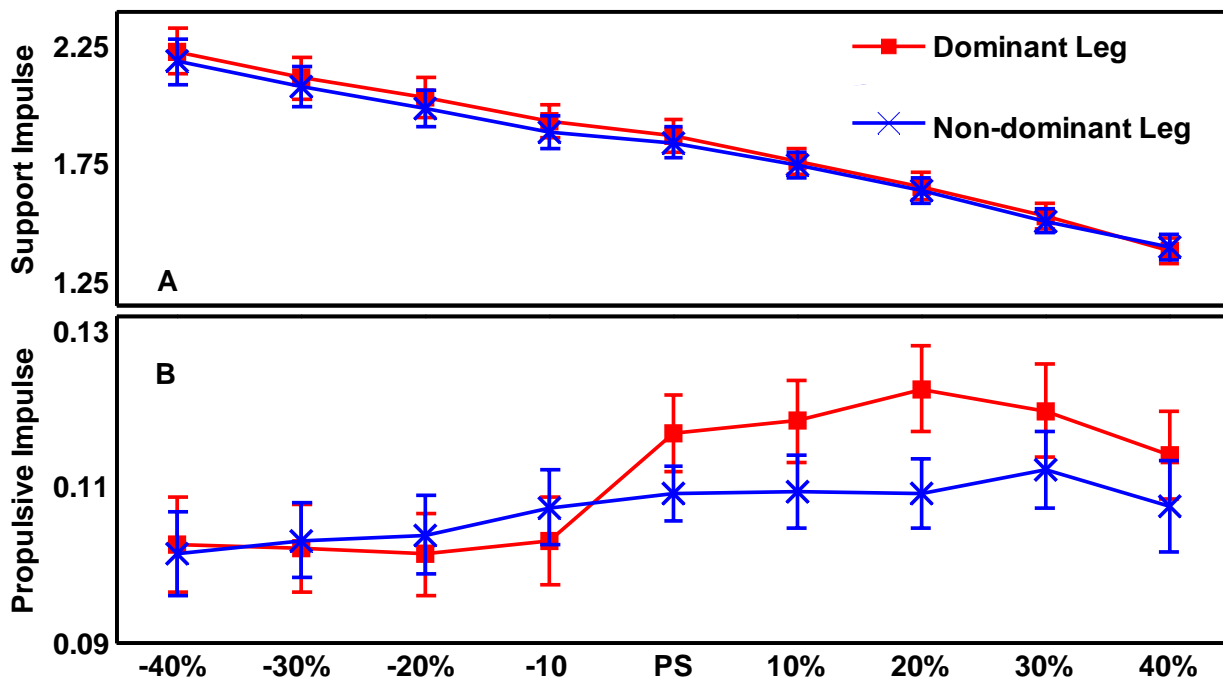


Figure 1. Means and standard errors for support (A) and propulsive (B) impulse for walking at nine different speeds. Normalized impulse is on the vertical axis. Walking speed is on the horizontal axis: preferred speed (PS) is in the middle, and slow (-) and fast (+) speeds are on the left and right, respectively.