ARE ASYMMETRIES IN JOINT KINETICS RELATED TO LIMB DOMINANCE?

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INTRODUCTION

Bilateral asymmetries have been documented for kinematic, kinetic, and electromyographic data during normal gait, yet their causes remain unclear (Sadeghi et al., 2000). One explanation for these asymmetries has been termed functional asymmetry. According to this explanation, the non-dominant (ND) leg contributes more to supporting the center of mass, while the dominant (D) leg contributes more to propulsion of the center of mass (Sadeghi et al., 2000). Impulses due to vertical and propulsive ground reaction forces are symmetrical during normal gait (Seeley et al., In Press), indicating that, at a global level, the ND and D legs contribute similarly to support and propulsion. However, these symmetrical impulses do not necessarily imply symmetry for "local" measures, such as joint kinetics. Asymmetries in joint kinetics may be related to different functional roles of the ND and D legs, in a manner that is consistent with the functional asymmetry perspective.

The purpose of this study was to determine if joint kinetic asymmetries during normal gait are related to these hypothesized functional differences between the ND and D legs (support and propulsion, respectively). We formulated three hypotheses that were based upon this idea of functional asymmetry: 1) joint mechanical work associated with support during gait would be greater for the ND leg than for the D leg, 2) joint work associated with propulsion would be greater for the D leg, relative to the ND leg; and 3) with increases in walking speed, propulsion-related joint work would increase disproportionately for the D leg, when compared to the ND. This limb × speed interaction was not predicted for support-related work because, although propulsive requirements increase as walking speed increases, support requirements remain relatively steady due to the constancy of gravity.

METHODS AND PROCEDURES

The gaits of 20 healthy subjects (age = 25 ± 3 yr; ht = 1.7 ± 0.1 m; mass = 70 ± 14 kg) were evaluated at three walking speeds: preferred (1.49 ± 0.20 m/s), -20% (1.24 ± 0.15 m/s), and +20% (1.78 ± 0.20 m/s). We quantified joint mechanical work associated with support and propulsion by integrating joint mechanical power, with respect to time, during specific power bursts that are associated with support or propulsion (Eng & Winter, 1995; Allard et al., 1995). Power bursts associated with support included the first ankle sagittal (A1S), combined first and second knee sagittal (K1S/K2S), first hip sagittal (H1S), and second hip frontal (H2F). Propulsion-related bursts included the second ankle sagittal (A2S) and third knee sagittal (K3S). Power was the product of joint angular velocity and net joint moment. Work was normalized to body weight × limb length. A repeated measures ANOVA ($\alpha = 0.05$) was performed (SPSS) to detect the effects of limb and speed on joint work. Variables exhibiting a limb × walking speed interaction were bilaterally compared at each speed via *post hoc* analyses. All other data were pooled from each speed and compared bilaterally.

RESULTS

For mechanical work associated with support: 1) significantly more work was performed by the ND leg during the A1S (data were pooled from each speed) and K1S/K2S (preferred and fast speeds) power bursts; and 2) significantly more work was performed by the D leg during the H2F power burst (data pooled from each speed; Table 1). Regarding propulsion-related work, significantly more work was performed by the ND leg during the A2S (data were pooled from each speed) and K3S (fast speed) power bursts (Table 1).

DISCUSSION

The data did not consistently support our hypotheses, indicating that asymmetries in joint work during walking are probably not related to different functional roles of the ND and D legs, as conceptualized within the functional asymmetry framework. Mechanical work performed during the A1S, K1S/K2S, H1S, and H2F joint power bursts is associated with center of mass support. As expected, the work performed during two (A1S and K1S/K2S) of these bursts was greater for the ND. However, there was no difference for work performed during the H1S burst, and work performed during the H2F burst was significantly greater for the D, which was in opposition to our first hypothesis. Propulsion-related work (A2S and K3S) consistently contradicted our second hypothesis, as both were greater for the ND. Finally, the walking speed manipulation described in the third hypothesis was not supported, as the only limb × speed interaction observed for propulsion-related work, was in a direction that was opposite to the third hypothesis.

SUMMARY

Bilateral asymmetries for joint mechanical work are probably not related to limb dominance in a manner that is consistent with the functional asymmetry idea, which states that the ND and D legs contribute more to support and propulsion, respectively. Other causes of asymmetries in joint kinetics should be explored, as clarification of this issue will advance our understanding of normal gait.

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Mean Work × 10^{-3}					
Support	**ND**	**D**	**Propulsion**	**ND**	**D**
A1S * (p < 0.001)	17 ± 5	10 ± 4	A2S * (p < 0.001)	26 ± 6	15 ± 5
K1S/K2S (slow)	13 ± 7	12 ± 5	K3S (slow)	11 ± 6	12 ± 5
K1S/K2S (preferred) * (p = 0.008)	19 ± 6	15 ± 5	K3S (preferred)	14 ± 8	14 ± 5
K1S/K2S (fast) * (p < 0.001)	28 ± 8	22 ± 6	K3S (fast) * (p < 0.001)	22 ± 6	17 ± 5
H1S	21 ± 12	21 ± 13			
H2F * (p < 0.001)	3 ± 4	10 ± 6			

Table 1. Work, normalized to body weight × limb length, performed at the ankle, knee, and hip joints of the non-dominant (ND) and dominant (D) legs during specific joint power bursts (see text for details) during normal gait. * Asterisks indicate statistical significance.

CAN ELECTROMYOGRAPHIC ASYMMETRIES DURING GAIT BE EXPLAINED BY LIMB DOMINANCE?

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INTRODUCTION

Subtle asymmetries exist in kinematic, kinetic, and electromyography (EMG) data describing able-bodied gait, yet the causes of these asymmetries remain unclear (Sadeghi *et al*., 2000). Some scientists have suggested that these bilateral asymmetries may reflect differences in functional roles of the lower limbs, with the non-dominant (ND) limb contributing more to support, while the dominant (D) limb contributes more to propulsion (Sadeghi *et al.,* 2000). However, bilateral symmetry has been demonstrated for impulses due to vertical (i.e., support) and propulsive ground reaction forces during normal gait (Seeley *et al.,* submitted) indicating that, at a global level, each lower limb contributes equally to support and propulsion. Symmetrical impulses, however, do not necessarily imply "local" bilateral symmetry for measures such as EMG or joint kinetics. Sadeghi et al. (2003) proposed that such local asymmetries may represent compensatory strategies that help ensure global symmetry of lower-limb function.

The purpose of this study was to determine if local asymmetries in EMG are related to hypothesized functional differences (support and propulsion) of the lower limbs during normal gait, and to see if these differences depend on walking speed. Bilateral EMG was monitored for specific muscles throughout intervals of the gait cycle during which these muscles have been shown to contribute to support or propulsion (Anderson & Pandy, 2003; Neptune *et al.,* 2004). Two general hypotheses were expected to be supported if EMG asymmetries are related to functional asymmetry. First, support-related muscles would be more active for the ND limb and propulsion-related muscles would be more active for the D limb. Second, with increases in walking speed, D-limb muscle activity related to propulsion would increase disproportionately compared to ND-limb counterparts. This limb × speed interaction was not predicted for support-related muscles, as gravity is independent of speed.

METHODS

Bilateral surface EMG data were collected (1200 Hz) from the gluteus maximus (GMX), gluteus medius (GMD), vastus lateralis (VLA), semitendinosis (SMT), and soleus (SOL) during walking for 20 subjects (age = 25 ± 3 yr; ht = 1.7 ± 0.1 m; mass = 70 ± 14 kg) at three speeds: preferred (1.61 ± 0.01 m/s), -20% (1.37 ± 0.01 m/s), and +20% (2.02 ± 0.04 m/s). EMG data were normalized to maximal voluntary isometric contraction amplitude and time normalized to a full gait cycle. Mean muscle amplitudes during intervals of the gait cycle for which those muscles have been shown to contribute to support or propulsion were averaged across five trials for each subject, limb, and speed. Mean amplitudes associated with support were GMX, GMD, VLA, and SOL during the first 30% of the gait cycle. Mean amplitudes associated with propulsion were SMT during the first 30% of the gait cycle, and SOL between 30 and 50% of the gait cycle. A repeated measures ANOVA ($\alpha = 0.05$) was performed to detect effects of limb and walking speed on dependent variables. Bonferroni-Holm *post hoc* analyses were conducted to detect bilateral differences at each walking speed.

RESULTS AND DISCUSSION

No significant limb × speed interactions were indicated, so data pooled from each speed were compared bilaterally for each dependant variable. GMD activity related to support was 25% less for the ND limb. SOL amplitudes related to support and propulsion were 55% and 31% less for the ND limb, respectively (Table 1).

The data offered little support for the first hypothesis and no evidence for the second hypothesis. Support-related muscles (GMX, GMD, VLA, and SOL during the first 30% of the gait cycle) were expected to be greater for the ND limb. However, only GMD and SOL were bilaterally different, and these differences were opposite to the predictions. Propulsion-related muscles (SMT between 0 and 30%, and SOL between 30 and 50%) amplitudes offered limited support for the first hypothesis. SMT activity was not bilaterally different, yet, as was predicted, mean propulsion-related SOL amplitude was greater for the D limb. Present data failed to support the second hypothesis, as no limb × speed interactions were indicated. During gait, propulsion requirements increase disproportionately in comparison to support requirements as walking speed increases. This is because gravity remains constant. Consequently, propulsive D-limb SMT and SOL activity were expected to increase disproportionately in comparison to ND-limb counterparts as walking speed increased, yet this was not observed.

Table 1: Mean EMG amplitudes (%MVIC) during specific intervals of the gait cycle (see text for details). *Asterisks indicate statistical significance.

	Mean Amplitude	
Support	**ND**	**D**
GMX	8.6 ± 0.9	11.8 ± 1.9
GMD* ($p = 0.02$)	8.1 ± 0.5	10.1 ± 0.7
VLA	8.8 ± 1.1	7.7 ± 0.7
SOL* ($p = 0.02$)	10.8 ± 0.9	16.7 ± 1.9
Propulsion		
SMT	4.9 ± 0.4	5.5 ± 0.6
SOL* ($p = 0.03$)	31.8 ± 2.8	41.6 ± 4.4

SUMMARY/CONCLUSIONS

Present results indicate that bilateral EMG asymmetries are not likely related to lower-limb task differences, as conceptualized within the functional asymmetry framework (Sadeghi *et al.*, 2000). Only one of the six bilateral comparisons supported the first hypothesis that was based on functional asymmetry. Additionally, the walking speed manipulation failed to support the idea that EMG asymmetries are related to lower-limb functional differences. Other plausible causes of local EMG asymmetries during normal gait including lower-limb morphological asymmetry or environmental issues should now be explored. Elucidation of this issue may advance our understanding regarding the role of the neuromuscular system during cyclic activities such as gait.

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