TRANSITION WORK IN SIMULATED PATHOLOGICAL WALKING

Caroline Soo and J. Maxwell Donelan

School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada, chsoo@sfu.ca
URL: http://www.sfu.ca/locomotionlab

INTRODUCTION

The energy expenditure of pathological walking is significantly elevated relative to healthy walking (Waters and Mulroy, 1999). Our research aims to understand the determinants of this increase in metabolic cost.

Mechanical work is needed to redirect the centre-of-mass velocity during step-to-step transitions (Donelan et al., 2002). Physics-based mathematical models show that, during transitions, the front leg performs negative work while the back leg performs positive work to redirect the centre of mass velocity into the next step. This model also predicts that there is an optimal way to perform this work (Ruina, et al., 2005; Kuo et al., 2005). *Optimal transitions* occur when equal magnitudes of positive and negative work are performed in a coordinated fashion. If one or both legs are not able to perform this, the walking models predict that *sub-optimal transitions* will require a greater magnitude of total mechanical work than optimal transitions.

Healthy humans perform near-optimal transitions at all walking velocities (Donelan et al., 2002). However, no studies to date have looked at the mechanical consequence of sub-optimal transitions in humans. Our general hypothesis is that the major cause of increased metabolic demands underlying all pathological walking, regardless of aetiology, is the inability to perform transition work with the correct magnitude and timing. We test whether sub-optimal transitions increase the total amount of mechanical work.

METHODS AND PROCEDURES

The major determinant of the metabolic cost of walking is transition work, contributing to 65 – 70% of the total metabolic cost (Kuo et al., 2005). To isolate transitions from other contributors of the metabolic cost of walking such as leg swing (Doke et al., 2005), we use an established sagittal plane rocking paradigm (Soo et. al., 2007).
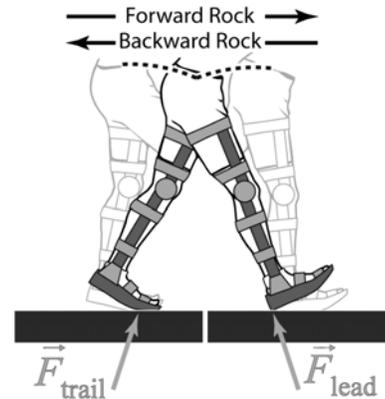

Figure 1. Sagittal plane rocking paradigm.

To simulate the biomechanical effects of gait pathology while controlling for other contributors of the metabolic cost associated with pathology such as spasticity (Waters and Mulroy, 1999), we immobilise the knee and ankle joints using braces in healthy subjects (Figure 1). We compare three conditions: (a) both legs unlocked, (b) locked back leg and (c) locked front leg. Subjects rock at 0.04 Hz and at 80% of their leg length to ensure that subjects perform a substantial amount of work. We use ground reaction forces to calculate individual limb work (Donelan et al., 2002) of each leg.
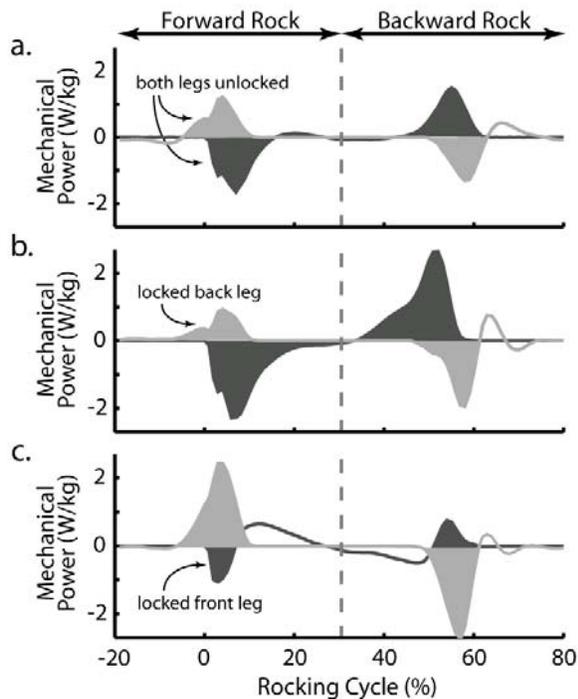
RESULTS

Figure 2. Leg mechanical power for one subject showing (a) both legs unlocked, (b) back leg locked and (c) front leg locked conditions. Shaded areas represent leg work. Dark grey areas are front leg work; light grey areas are back leg work.

Preliminary analyses have shown that the braces can simulate sub-optimal transitions. When both legs were unlocked (Figure 2a), the subject was able to perform near optimal transitions as evidenced by relatively equal positive and negative work magnitudes. When the back leg was braced (Figure 2b), the subject was unable to perform positive work resulting in net negative total mechanical work during forward rock. When the front leg was braced (Figure 2c), the subject was unable to perform negative work resulting in net positive mechanical work during forward rock. For this subject, immobilising the leg to produce sub-optimal transitions has increased the total positive mechanical work by 146% and 122% for the back leg locked condition and the front leg locked condition,

respectively, compared to the unlocked condition.

DISCUSSION

Further analyses will assess the relationship between sub-optimal transitions and the total mechanical work. Irrespective of the hypothesized outcomes, these experiments will be the first to determine the effect of sub-optimal transitions on mechanical work. The outcome of this study may provide a novel biomechanical approach to explain why pathological gait is so expensive.

SUMMARY

We hypothesize that the inability of one or more legs to perform transition work with correct magnitude and timing increases the total mechanical work. Preliminary results show that biomechanically simulating sub-optimal transitions does increase the total mechanical work.

REFERENCES

Brockway, JM (1987). *Hum Nutr Clin Nutr*, 41(6): 463-471.
Donelan, JM et al. (2002). *J Exp Biol*, 205: 3717-3727.
Doke J et al. (2005). *J Exp Biol*, 208:439-445.
Kuo, AD et al. (2005). *Exerc Sport Sci Rev*, 33(2):88-97.
Ruina, A et al. (2005). *J Theo Biol*, 235:170-192.
Soo, CH et al. (2007). *Proceedings from ISPGR Conference 2007*. University of Vermont, Vermont.
Waters, R and Mulroy S (1999). *Gait & Posture*, 9(3):207-231.

ACKNOWLEDGEMENTS