Sloped Walking with Prosthetic Ankle Power: The Effects of Tuning

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1 Introduction

When people with a leg amputation walk using a powered prosthesis, their metabolic demands are equivalent to those of non-amputees over a wide range of speeds on level ground [1]. However, the metabolic demands incurred by people with a leg amputation using a powered prosthesis to walk up and down slopes are not known. Further, it is not clear if a powered prosthesis tuned for level-ground walking can accommodate sloped walking. Thus, we measured and compared the biomechanics and metabolic demands of walking uphill and downhill with two tuning strategies of a powered prosthesis (BiOM Inc.); the optimal tuning for level-ground (LVL), and the optimal adjusted tuning for each slope (ADJ). We hypothesized that the ADJ would result in a lower metabolic demand compared to LVL at all slopes.

2 Methods

We recruited three males with a unilateral transtibial amputation and fit each with the BiOM powered prosthesis. Subjects walked on a dual-belt, force-treadmill at 1.25 m/s on 7 slopes (0°, ± 3°, ± 6°, ± 9°) while using the BiOM. We measured lower body kinematics and optimized the tuning of the BiOM for level-ground and at each slope by iteratively changing the tuning parameters until the prosthetic ankle joint biomechanics matched those of non-amputees (NA) within 1 SD [2]. On two consecutive days, we measured metabolic power via indirect calorimetry for five minutes during standing and walking at each slope for LVL and ADJ in a randomized trial order. We calculated net cost of transport (COT) using a standard equation and subtracting standing from walking COT.

3 Results

Prosthetic ankle net work values for ADJ were within one standard deviation of non-amputee values [2] at ± 3° and +6° (Fig. 1). We found a trend for net COT to be lower for ADJ compared to LVL at ± 3°, ± 6°, and for net COT to be lower for LVL compared to ADJ at ± 9° (Fig. 2).

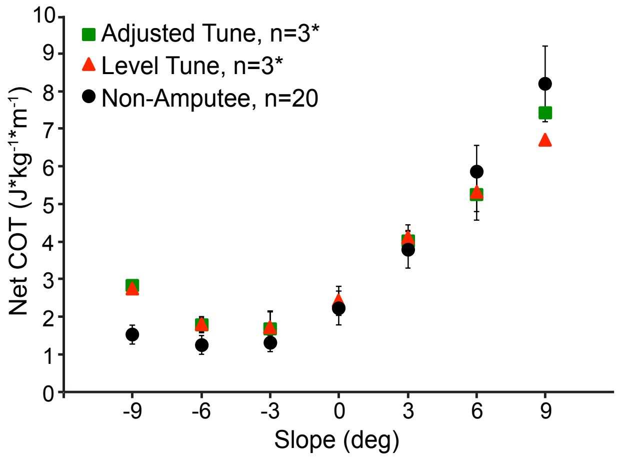

Figure 2: Net metabolic cost of transport (COT) for subjects walking at 1.25 m/s. Non-amputee data from [2]. *At +6° n=2, and at +9° n=1.

4 Conclusion

We tuned the BiOM such that the net prosthetic ankle work matched non-amputee net ankle work at ± 3° and +6°. Tuning the BiOM for each slope resulted in lower metabolic costs at ± 3° and ± 6°. LVL lowered metabolic cost at ± 9°, which did not support our hypothesis, but because only one subject could complete +9°**,** our results may be limited. It is possible that the design of the BiOM limits the ability to match biological ankle biomechanics and metabolic costs when walking ± 9°. We intend to conduct future studies to further understand the effects of walking up and down slopes with powered prostheses on people with a leg amputation.

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References

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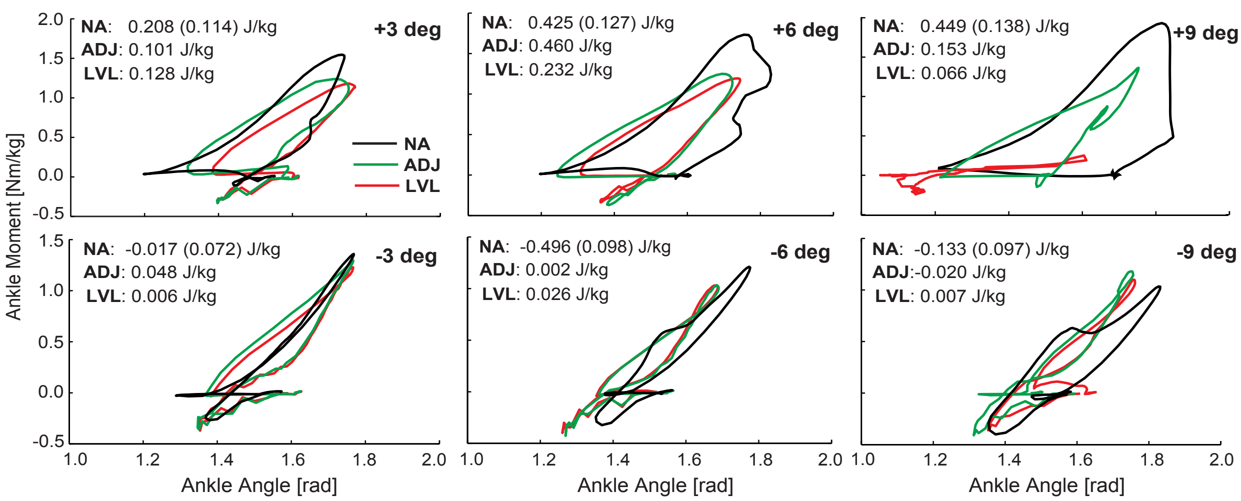

Figure 1: Ankle Moment [Nm/kg] vs. Ankle Angle [rad] for three* subjects using ADJ and LVL tuning of the BiOM walking at 1.25 m/s. Ankle net work (S.D.) reported in upper left corners. NA data from [2]. *At +6° n=2, and at +9° n=1.