METABOLIC COSTS OF LOCOMOTION WHEN WALKING WITH AND WITHOUT ANKLE AND KNEE BRACES

Jeremy D. Smith, Caitlin Kievenaar, Victoria Falgien and Jennifer Wilmes

University of Northern Colorado, School of Sport and Exercise Science, Biomechanics Lab
email: jeremy.smith@unco.edu, web: www.unco.edu/nhs/ses

INTRODUCTION

Effective walking requires the ability to rotate the lower extremity joints in a coordinated manner to produce forward progression of the body. However, when joint function is impaired energetic penalties are often observed. There appears to be a relationship between joint impairment and energetic costs during walking. For example, in amputees, the higher the level of amputation, typically the higher the metabolic cost during walking; a transfemoral amputee expends ~0.24 $ml \cdot kg^{-1} \cdot m^{-1}$, a through-knee amputee expends ~0.20 $ml \cdot kg^{-1} \cdot m^{-1}$, and a transtibial amputee expends ~0.18 $ml \cdot kg^{-1} \cdot m^{-1}$ walking at their preferred speeds [1,2]. To better understand the influence of joint function on metabolic costs, previous researchers [2] have systematically casted each lower extremity joint and measured the effects on metabolic costs during walking. In general, greater metabolic costs occurred when more joints were restricted, which is consistent with results seen in higher levels of amputations. However, casting a joint requires the addition of a significant amount of mass that can also increase the metabolic cost of walking. The use of other lighter weight orthotics to restrict joint motion would minimize effects due to increased mass. A further limitation of the previous work [2] was that walking speed was not controlled and decreased with increased joint restriction. Therefore, the purpose of this study was to investigate the effects of restricted lower extremity motion on the metabolic costs of walking, and address limitations of previous work in this area.

METHODS

Four males and six females participated in this study (age = 22.67 ± 1.58yrs, weight = 70.4± 10.08kg, height = 171.33 ± 6.93 cm). Inclusion criteria for this study included: a) no lower extremity injury within the previous three months and b) participation on a competitive sports team. The University's IRB approved the study and all participants provided informed written consent prior to participation.

Participants were asked to complete a single laboratory session, in which they were asked to complete a series of 8-minute treadmill walking bouts under 4 different conditions. Participants walked at a fixed walking speed of 1.5 m/s velocity for all treadmill walking bouts. Participants were instructed on the operation of the treadmill they would be using during data collections and then practiced walking on the treadmill for a minimum of 10 minutes. During this treadmill practice, participants also practiced walking with the headgear and mouthpiece they were to wear during the actual data collection. Participants completed a series of 8-minute treadmill walking bouts under 4 different conditions while metabolic data were recorded. A minimum of at least 5 minutes was provided to participants to rest between conditions and give researchers time to change the bracing condition. The four conditions were: a) baseline (no bracing), b) knee brace only, c) ankle and knee brace and d) ankle brace only.

The rate of oxygen consumed and carbon dioxide produced (expressed in $ml \cdot kg^{-1} \cdot min^{-1}$) and heart rate (HR) were measured during the 8-minute trial. For each trial metabolic and heart rate data were averaged over the last two minutes and used in statistical analyses. Weir's equation [4] and a conversion to Joules was used to express the metabolic data as an energetic cost (Ecost) of walking (expressed in $J \cdot kg^{-1} \cdot s^{-1}$). Single factor ANOVAs with repeated measures were used to determine the effects of restricting lower extremity ($p<.05$ determined significance).

RESULTS AND DISCUSSION

Systematic increases in net metabolic cost (i.e., Net Ecost) and heart rate (HR) were observed during walking as the level of joint restriction increased (Figure 1). The bracing condition had a significant effect on Ecost ($F = 16.174$, $p < .001$) and HR ($F = 9.469$, $p = .002$). Follow-up pairwise comparisons showed that with the knee braced with or without the ankle also being braced, Ecost and HR were greater than baseline walking ($p<.005$ for all comparisons). When only the ankle was braced the observed increases in Ecost and HR over baseline walking was not significant. However, ankle bracing with knee bracing together significantly increased Ecost and HR compared to walking only with the knee braced ($p<.05$ for all comparisons).

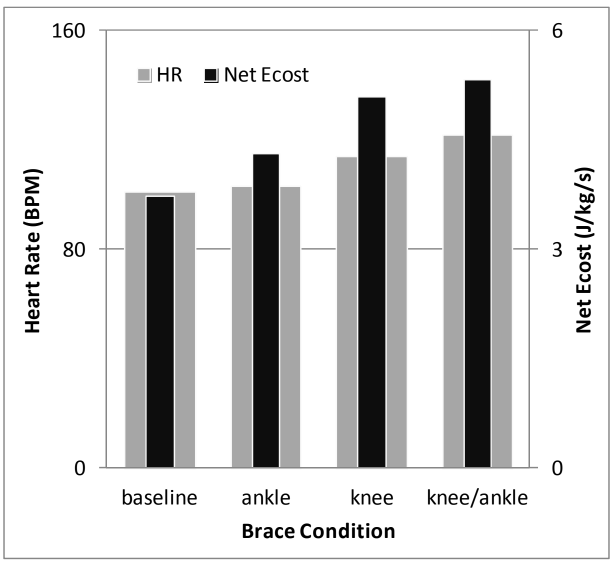

Figure 1: Effects of bracing on heart rate (fat bars) and net metabolic cost (skinny bars).

These results are consistent with trends that have been reported in the amputee literature. For example, Waters & Mulroy [1] found that when comparing across amputations levels in traumatic amputees Ecost was 14% and 43% higher in transtibial and transfemoral amputees compared to a non-amputee group walking at the same speed. Considering our results as relative increases compared to baseline walking we observed similar trends as reported by Waters and Mulroy [1] for higher amputation levels (Figure 2). Specifically, if you consider the ankle condition as a traumatic transtibial amputee our observed 16% increase is similar to the 14% increase reported for transtibial amputees. In addition, our observed 43% increase with the knee and ankle both braced is similar to that reported for transfemoral amputees compared to non-amputees. Comparing our results with those of Waters et al. [2] illustrates that the use of the lighter weight orthotic for restricting joint motion was more consistent with actual energetic costs seen in amputees. For example, for the cast condition which restricted knee and ankle motion, Waters et al. observed a 60% in Ecost compared to our 43% for the same condition. For the ankle cast only condition Waters et al. reported a 27-33% increase compared to our observed 16% increase. In conclusion, our results suggest that the higher costs of locomotion often reported for higher levels of amputation is likely due in large part to the loss of joint function resulting from the amputation.

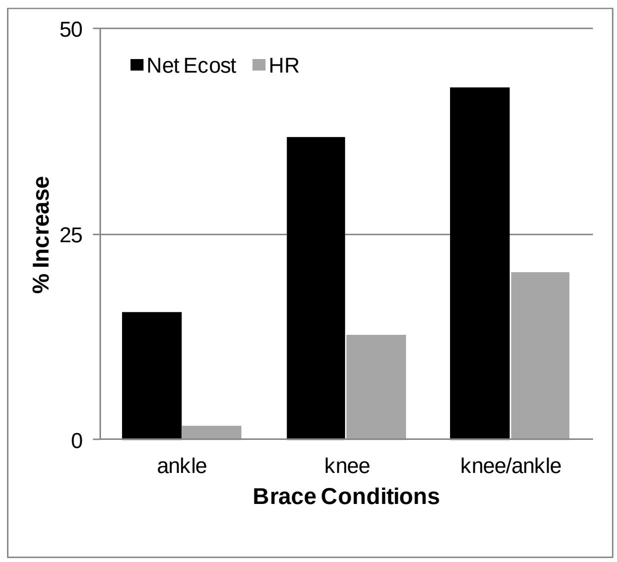

Figure 2: Relative percent increases in heart rate and net metabolic costs with bracing.

REFERENCES

1. Waters, RL & Mulroy, S (1999). *Gait and Posture* ***9****, 207-231.*
2. Waters RL et al. (1982). *J Bone Joint Surg Am.* ***64*****,** 896-899
3. Weir, J. B. (1949). *J Physiol,* ***109*****(1-2),** 1-9.