IMPLICATIONS OF ALTERNATE STAIR DESCENT STRATEGIES ON KNEE BIOMECHANICS: BACKWARDS DESCENT IS LESS DEMANDING

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INTRODUCTION

Considerable research has been dedicated to understanding the demands imposed by stair ambulation (McFadyen and Winter, 1988; Reiner *et al.*, 2001). Peak knee moments and powers are larger in descent than ascent and level-walking, rendering descent a difficult mechanical task. In descent, lower limb muscles are required to generate force while lengthening, thereby dissipating gravitational energy and performing negative work. As such, elderly and clinical populations commonly develop compensatory gait strategies to modulate the imposed demand. However, we know little about the mechanics of these strategies. The purpose of this research was to delineate differences between traditional forwards stair descent and two alternate patterns; forwards step-by-step and backwards descent. Only the peak knee extensor moments and dissipative powers will be considered here, which represent the knee dissipating energy and contributing to controlled lowering during single-support, when the contralateral limb is in terminal swing.

METHODS AND PROCEDURES

Healthy males (n=9) and females (n=9) participated in the study. All subjects were free of neurological and musculoskeletal conditions. Subjects performed 10 trials in forwards (FD) and backwards descent (BD). Trials were initiated with the subject's preferred limb and performed at a self-selected pace. Twenty step-by-step (SBS) trials were performed, 10 to analyze lead limb kinetics (STSL), 10 for trail limb kinetics (SBST). Condition presentation was counterbalanced across subjects.

The staircase was instrumented with four force plates embedded in steps 2 through 5 (step 2 & 5: Kistler 9286A; step 3 & 4: AMTI OR6-7-1000 & OR6-7-2000). The stairs dimensions were 30 cm run and 20 cm rise (Ontario Building Code, Section *9.8.3*, 2006). Force platform data were sampled at 200 Hz. Seven Vicon MX-13 cameras sampled displacement data at 200 Hz. Analog data were low-pass filtered with a 4th-order Butterworth digital filter (f_c=10 Hz force; 6 Hz for displacement data). Data were ensemble averaged and subjected to 4 × 4 repeated-measures ANOVA with stair step and condition as factors for peak knee extensor moments and powers.

RESULTS

Peak knee extensor moment depended on stair ($F_{(3, 15)}$ = 6.45, p<0.001) and condition ($F_{(3, 15)}$) = 59.59, p<0.001) main effects and a stair × condition interaction ($F_{(9, 9)}$ = 10.93, p<0.001). Figure 1 shows that both main effects were annulled by the interaction.

Peak knee extensor power was influenced by stair ($F_{(3, 15)}$ = 8.81, p<0.001) and condition ($F_{(3, 15)}$ = 110.6, p<0.001) main effects and a stair × condition interaction (($F_{(9, 9)}$ = 14.62, p<0.001). Figure 1 shows the stair step main effect was washed out by the stair step × condition interaction.

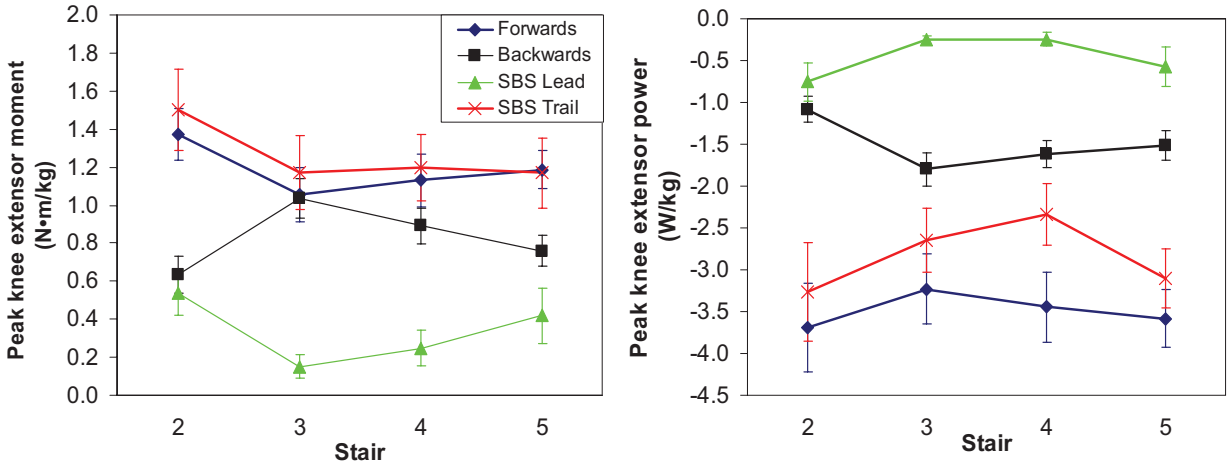

Figure 1. Body-mass normalized peak knee extensor moments and powers over four consecutive gait cycles in forwards, backwards and step-by-step stair descent (lead and trail limbs). Error bars show 95% confidence intervals.

DISCUSSION

In all conditions, the peak knee moment decreased into the mid-stair region and stabilized. Conversely, in BD the trend was opposite. While the lowest peak knee moments were associated with SBSL, there were no apparent differences between those associated with SBST and FD. The condition main effect was preserved for peak knee extensor power. Peak knee extensor powers were larger in FD and smaller in SBSL than other conditions. In BD, peak powers were smaller than those observed at the SBST knee. In terms of the interaction, peak knee power was largest during transition and decreased in absolute magnitude thereafter, except in BD, where the trend was reversed.

SUMMARY

Peak knee extensor moments and powers stabilized following one complete gait cycle. Further, peak knee moments and powers were larger in FD than the alternate gait patterns. As such, compensatory strategies reduced the demand at the knee during stair descent. However, the overall pattern of net moments and powers was idiosyncratic; it depended on both strategy and stair. This was illustrated with BD, where peak knee moments and powers increased at the step 1 transition but decreased thereafter. As such, BD is recommended as an alternative to FD for individuals with pronounced weakness of knee extensor musculature. Furthermore, reduced powers with BD imply forces were applied at lower levels. While similar results were observed in SBS descent, the reduction only occurred for the lead limb. Therefore, BD might represent a more feasible strategy in individuals with bilateral knee extensor weakness.

REFERENCES

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