Effects of Aging on Lower Extremity Joint Power Profiles During Stair Negotiation

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Introduction

Falls on stairs are a leading cause of accidental death in the elderly (Startzell et al., 2000) yet only a limited number of biomechanical studies related to stair negotiation exist. The goal of this study was to investigate the effects of aging on the required joint power profiles of the lower extremity in the mid-stair region during stair ascent and descent.

Methods

Healthy female volunteers (Young (Y): n=12, age=24 ± 3, BW=620N ± 61N; Elderly (E): n=10, age=74 ± 3, BW=656N ± 108N) participated in the study. All subjects were free from any musculoskeletal or neurological impairments, and gave their informed consent prior to the testing. Five trials at 0.65 m/s were collected for both stair ascent and stair descent on a 7-step staircase (run = 28 cm, rise = 18 cm). Motion and force data on step 4 were obtained from a VICON 370 and a Kistler 9286 portable force platform. Joint power was obtained by using MARey package, which employs an inverse dynamic approach (Cavanagh et al., 2001).

The net joint power was given by \( P = \vec{M} \cdot \vec{\omega} = M_x \omega_x + M_y \omega_y + M_z \omega_z \), where \( \vec{M} \) and \( \vec{\omega} \) are respectively the net internal joint moment and the joint angular velocity expressed in the proximal segment frame. Power generation and absorption resulted when \( P > 0 \) and \( P < 0 \), respectively. Although joint power is a scalar quantity, both the total power (\( P \)) and its components (e.g., \( M_x \omega_x \)) were analyzed to investigate the functions of the entire joint and respective muscle groups about each rotation axis (Eng et al., 1995).

To indicate if power generation or absorption occurred in the entire leg as one unit, the total leg power (\( P_{\text{TOT}} \)) was also calculated as the algebraic sum of the power at the ankle, knee, and hip joints (Okita, 2000).

Results & Discussion

During stair descent, significant differences were found in power generation peaks (Y>E) in the knee flexors during initial impact and power absorption peaks (Y<E) in the knee extensors during controlled lowering (Figure 1). Power profiles at the hip joint demonstrated extra power absorption peaks in the hip abductors of the elderly during single leg support and differences in power generation (Y<E) in the hip flexors at terminal stance. The total leg power profiles (\( P_{\text{TOT}} \)) were similar between the two groups (\( P_{\text{ANOVA}} > 0.1 \)), as shown in Figure 2.
During stair ascent, remarkable differences between the young and elderly groups were found in the power profiles of the knee extensors. Power generation was significantly greater in the young compared to the elderly in the knee extensors during early stance and an extra power generation peak was found in the elderly group during the second half of stance (Figure 3). Prior to the second power burst in the knee extensors, additional absorption peaks were found in the ankle external rotators, knee abductors and internal rotators of the elderly. Additional power generation peaks were also found in the ankle abductors, ankle external rotators, and knee internal rotators of elderly coincident with the additional knee extensor peak. As shown in Figure 4, significant differences in the total leg power ($P_{TOT}$) profiles between the two groups were also found.

**Figure 1**: Knee power profiles in flexion/extension during stair descent. Significant differences are shown in the lower panel.

**Figure 3**: Knee power profiles in flexion/extension during stair ascent.

**Figure 2**: Total leg power profiles during stair descent.

**Figure 4**: Total leg power profiles during stair ascent.
These results demonstrate strategic differences in power characteristics between young and elderly women during stair locomotion. During stair descent, the elderly accomplished the task with poorer balance control, represented by the more cautious lowering of the body and increased efforts at stabilization. During stair ascent the difference in strategy was characterized by an extra power generation burst in the elderly during the second half the stance phase, utilizing the extensors of all three joints. This strategic difference may be the result of a decline in the concentric muscular strength of the lower extremity joints (Okita, 2000). The results of the total leg power profiles seem to support this observation: the elderly accomplished the stair ascent task by generating lower peak power that was sustained for a longer period of time compared to their younger counterparts.

References

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