AGE-DIFFERENCES IN THE FREE VERTICAL MOMENTS DURING STEPPING DOWN - PILOT

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The aim of this study was to understand age-differences in body control during stepping down by investigating free vertical moments (FVMs). Two older adults and two young adults participated in this study. During each trial, lower extremities kinematics were measured using a 10 camera Vicon system (250Hz) and ground reaction forces were recorded using two Kistler force platforms (1000Hz). FVM was calculated by ground reaction forces using Visual3D software. The results indicated young adults showed adduction-FVM (ADD-FVM) but older adults presented abduction-FVM (ABD-FVM) during double-stance phase. Older adults seemed to exert more ABD-FVM than young adults while in the single support phase. It was concluded that the FVMs seemed to point to different strategies between older adults and young adults.

KEY WORDS: FVM, rotational kinetics, strategy.

INTRODUCTION: Older adults had been reported high incidence of falling when descending steps/stairs (Buckley, Jones, & Johnson, 2010). In an attempt to reduced the risk of a fall, older adults utilise certain movement adaption when descending stairs/steps, including slower speed, greater frontal and transverse plane motion (Lee & Chou, 2007; Mian, Thom, Narici, & Baltzopoulos, 2007), and trial-limb maintains a foot-flat position for longer (Lark, Buckley, Bennett, Jones, & Sargeant, 2004). Older adults also use a greater percentage of their passive ankle dorsiflexion range of motion (Lark et al., 2004).
In order to highlight age-related differences in how steps/stairs are negotiated, analysis of FVM can be a useful biomechanical tool (Buckley et al., 2010). Most voluntary movements are initiated in an asymmetrical manner, thus typically involves rotation about the body's vertical-axis. The resulting rotational movement-kinetics can be quantified by investigating the ground reaction torque generated about the body's vertical-axis (free vertical moment, FVM). Previous research has shown that older adults tended to gain vertical-axis angular momentum during single-limb support in order to be dissipated following landing (Buckley et al., 2010). It remains unknown if older adults might be unable to exert the same vertical-axis control during single support as young adults. Therefore, the purpose of this study was to understand age-differences in body control of double and single support phases during stepping down by investigating FVM.

METHODS: Two older adults (78.4 ±2.5 y; 1.74 ±0.04 m; 65.5 ±8.5 kg) and two young adults (25.5 ±2.1 y; 1.71 ±0.06 m; 58.2 ±1.8 kg) participated in this study. Lower extremities kinematics were recorded using a 10 camera Vicon 10 MX 13+ system (250 Hz). Ground reaction forces (GRFs) were recorded using two Kistler force platforms (1000 Hz). Each subject performed a stepping down trial (20 cm) and then forward walking (Figure 1). Five trials for each participant were recorded. Free vertical moment was calculated by GRF using Visual3D software. The equation of FVM is as following: FVM = Mz - (*CPx*·Fy) + (*CPy*·Fx) and *CPx* = - My/Fz ; *CPy* = Mx/Fz. Then FVMs normalized by height (m) and weight (N).

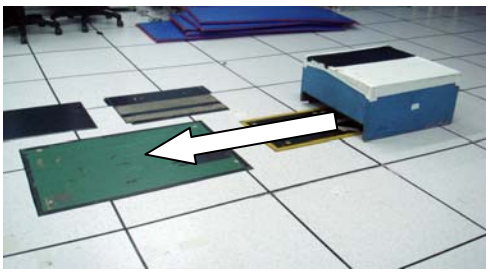

Figure 1: Experiment layout.

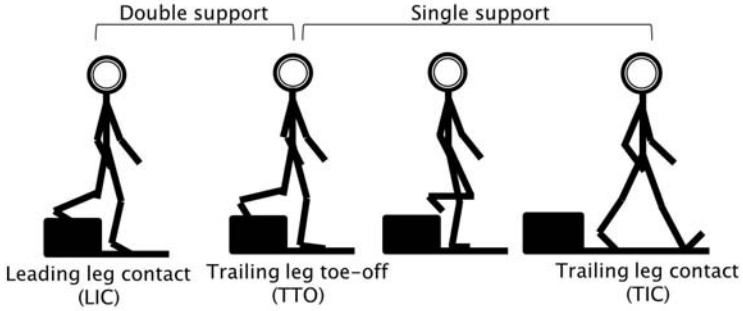

Figure 2: The definitions of two phases.

The single-support phase was defined as starting at initial contact of leading leg and ended at toe-off of the trailing leg. Double-support phase was initiated at toe-off of the trailing leg and finished at contact to the ground of the trailing leg (shown as Figure 2). We filtered the markers trajectories using a Butterworth low-pass filter with a cut off frequency of 6 Hz. Step-length and step-width were respectively calculated lengths between toes of two feet at initial contact of leading leg, and then normalized by body height. The results are presented using means and standard deviations.

RESULTS: The data of peak abduction/adduction FVMs and COP path during double and single support phases between young adults and older adults group are shown in Table 1 and Figure 3. During the double-support phase, young adults presented adduction FVM (ADD-FVM) but older adults showed abduction FVM (ABD-FVM). During single-support phase, young adults tended to transfer ADD-FVM to ABD-FVM instead that older adults tended to maintain ABD-FVM.

Table 1. The FVM and COP path of young adults and older adults.

	young adults	older adults
Double-support phase		
Duration (s)	0.08±0.01	0.18±0.04
Peak ABD-FVM (*10-3)	-	3.08±0.77
Peak ADD-FVM (*10-3)	-2.93±0.85	-0.65±0.17
COP_x path (cm)	10.7±3.4	10.2±3.3
COP_y path (cm)	3.1±2.2	5.1±1.9
Single-support phase		
Duration (s)	0.37±0.02	0.45±0.05
Peak ABD-FVM ($*10^{-3}$)	1.99±0.67	2.49±1.35
Peak ADD-FVM ($*10^{-3}$)	-3.08±0.99	-1.06±1.16
COP_x path (cm)	5.0±1.8	5.7±2.4
COP_y path (cm)	2.6±0.4	2.3±1.3
Step-length (%Ht)	37.7±1.1	22.9±5.0
Step-width (%Ht)	5.7±1.7	4.5±1.5

*Step-length (%Ht): length between two toes of leading leg and trailing leg, and normalized by body height. *Step-width (%Ht): width between two 5th metatarsal-phalandeal joints of leading leg and trailing leg, and normalized by body height.

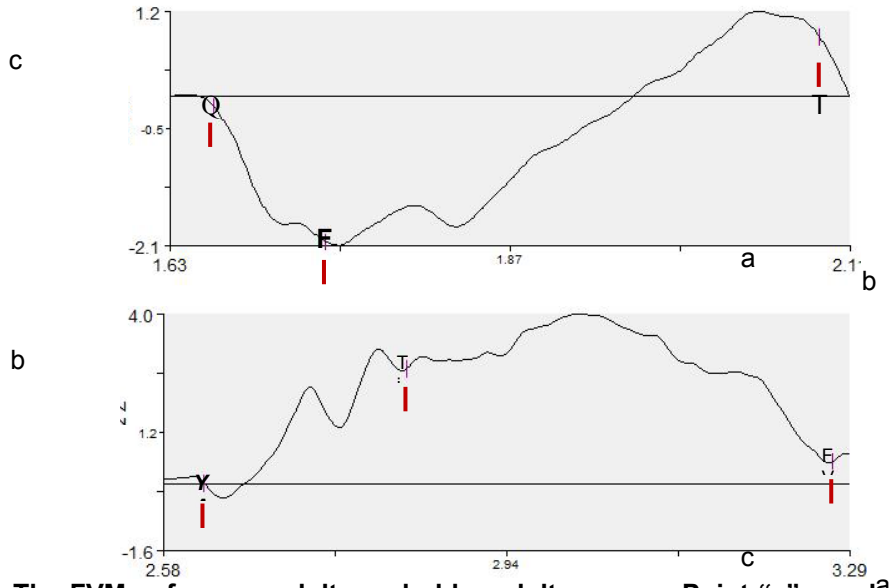

Figure 3: The FVMs of young adults and older adults group. Point "a" was labelled as "initial contact of leading leg", point "b" was "toe-off of trailing leg", and point "c" was "contact to the ground of the trail leg".

DISCUSSION: All participants stepped down by using the right side as the leading leg, the negative FVM indicated ADD-FVM, and positive FVM presented ABD-FVM (Figure 4). Before stepping down using the right leg, the body would generate counterclockwise rotational kinetics about the body's vertical axis, and then stretched the right leg and stepped downward. While initially contacting the ground, the right foot would present a negative (counterclockwise) moment. As the trailing leg left the step, the single-support phase started and the body would generate a clockwise moment to complete the contralateral swinging. FVMs of young adults group showed that tendency (Figure 2 - young adults group), but older adults group presented different patterns. FVMs of older adults group presented positive (clockwise) moment both single and double support phase.

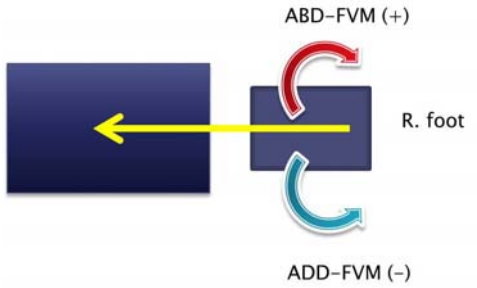

Figure 4: Schematic diagram of FVMs.

Double-support phase: young adults showed ADD-FVM (negative) but older adults presented ABD-FVM (positive). Buckley et al. (2010) indicated that increasing the rotational kinetics of the body caused an increase in downwards movement, and FVMs of young adults were greater than older adults. In other words, young adults exerted more rotational energy during stepping down. In our study, young adults seemed to continue ADD-FVM from the stepping-down movement. Because the trailing leg still stood upon the step and older adults stepped down more carefully, peak FVMs of leading leg in older adults showed ABD-FVM. older adults tended more duration time and less peak ADD-FVM because they stepped down more carefully and less step-length. The strategies of older adults seemed to avoid the ADD-FVM while stepping down, and older adults seemed to generate more ABD-FVM to rotate their hip and let following contralateral swinging earlier. COP_x and COP_y paths were similar between two groups.

Single-support phase: In our study, during the single support phase, young adults tended to alter ADD-FVM to ABD-FVM because the body generated clockwise moments to

accomplish the contralateral swinging. older adults presented ABD-FVMs might because older adults would prevent the instability while FVM crossing the "zero line" during single-support phase. older adults also took longer to complete the swing phase. older adults might unable to exert the same vertical-axis control during single support as young adults (Buckley et al., 2010). But in our study, older adults tended to produce more rotational kinetics to accomplish the contralateral swinging. COP_x and COP_y paths were similar between two groups.

The different curves between two groups were meaningful signs, also presented the stepping-down strategies in older adults. It's necessary to enlarge sample sizes to clarify the clear mechanisms of FVMs exerting during stepping down.

CONCLUSION: The FVMs seemed to point different strategies between older adults and young adults, it might be caused by instability and worse ability to swing contralateral leg in older adults. The suggestion is that to enlarge sample sizes to clarify the clear mechanisms of FVMs exerting during stepping down.

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