Influences of Age and Light Touch on the Preparation for Protective Stepping Reactions

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Objective: *The present study examined the effect of light touch on the preparation for fall-induced protective stepping in elderly and young individuals.*
Material and Method: *The subjects were perturbed with forward pull with no-touch and light touch conditions. Anticipatory periods, lift-off onset, center of pressure displacement and velocity were measured and analyzed.*
Results: *The authors observed a stabilizing effect during with light touch in pre-perturbation periods. During the perturbation, the elderly took steps earlier than did the young individuals by reducing anticipatory periods; however, their anterior stability limit was similar to that of the youth, indicating that the step was pre-selected. In the youth, a delay in anticipatory onset and shorter periods were observed with light touch, resulting from a limitation in lateral limb loading. Additionally, the stabilizing effect in the pre-perturbation period did not influence stabilization of preparatory period before stepping. In the elderly, shorter anticipatory periods and lower stability limits were also shown in light touch conditions. The authors concluded that the elderly were more concerned with a postural task than with light touch.*
Conclusion: *Protective stepping is reflected in the state of balance stability and involves a pre-selection process. Light touch enhances postural stability in stance and impacts the stepping.*

Keywords: *Light touch, Postural balance, Stepping*

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Falling is a serious problem facing elderly persons, causing injury and disability. Stepping is commonly executed in daily situations when one desires to avoid falling. This strategy is believed to serve as a last resort if ankle and hip strategies fail to keep the center of mass (COM) within the stability limits of the base of support (BOS). However, it is commonly initiated very early even when the COM is well within the stability limits. Stepping is initiated more often than necessary and often occurs earlier in elderly people, suggesting that it is also a marker for risk of falling[1]. It is possible that older adults prefer to use the stepping strategy, i.e. pre-selected, when an input trigger arrives even before the step may actually be required. During stepping, the anticipatory event is determined by commands from the nervous system before executing a step and presumably serves to promote stability during subsequent leg movement. Anticipatory postural adjustment (APA) onset represents information processing of the nervous system, i.e. reaction time. The APA event acts to propel the COM toward the stance limb before lifting swing foot. This event is typically diminished during inducted stepping[1]. As a result, it increases the tendency of the COM to fail toward the stepping limb during swing phase. APA event for lateral weight transfer includes APA and unloading (UL) durations. This sequence ends after heel off, which represents speed of response. During induced stepping, the elderly showed reduced APA durations, earlier step onset in maintaining balance following perturbation exposure[2] than the young.

Sensory-related postural control light touch (LT) has been reported to be important for controlling both static standing balance and dynamic postural stability while walking[3,4] and stabilization after reactive perturbation[5,6]. The effectiveness of LT was also shown to be greater in the elderly than in young individuals[3]. In the present study, the researchers examined the effect of LT on the preparation for induced protective stepping in the elderly and young individuals. If effects on the stepping strategy were observed, the authors would expect to find the capacity in changing

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the preparation period among youth and the elderly. We hypothesized that if stepping is not preferred or a pre-selection strategy in older adults, then combining light touch with a perturbation would delay the triggering of induced stepping. Additionally, if the stabilizing effect were higher among the elderly, their initiation timing of triggering would be longer than among young individuals.

Material and Method

Young individuals (20-30 years old) and elderly (60-80 years old) female subjects were recruited in this study. They were right leg dominant and excluded if they had the following criteria: neurological disorder, impairment or loss of sensation, vertigo, history of fall within past six months, and recent musculoskeletal injury. All participants understood and signed the consent form approved by the Institutional Review Board at Mahidol University (COA. No. MU-IRB 2010/022.1401). Before testing, the participants practiced a LT task, not exceeding 1 Newton.

During testing, they wore a safety harness and pulling belt and stood with each foot on a separate force platform, conditions that were replicated for all trials. They were pulled forward using a weight drop method[7] (20% of body weight of subject) under randomly ordered conditions of no touch (NT) and LT, with three trials for each condition. Weight was freely released and traveled 35 cm at random without warning. The following instruction was provided: "Try to keep yourself from falling. If you will fall, take a step". In the beginning of the trial, subjects stood with both arms beside their body, either no touching (NT condition) or touching the force sensor on the right side (LT condition) at subject's waist level. An auditory alarm was provided whenever the vertical contacting force exceeded 1 N in. The online monitoring of vertical ground reaction force (Fz) beneath both limbs and feedback were given to adjust subjects in a symmetrical weight-bearing position before the perturbation. The onset of perturbation was defined as time zero. Fz and anteroposterior center of pressure (AP-COP) position were collected at 1,000 Hz and separately analyzed inpre-(-1,000 to 0 ms) and post perturbation (0 ms to liftoff onset) periods. In the pre-perturbation period, the AP-COP velocity was the mean value derived from the AP-COP position. Within the time boundaries after onset of perturbation, the Fz beneath the stepping limb was classified in four events including APA onset, APA duration, UL duration, and LO onset according to Rogers et al[2] in 2003. The example is shown in Fig. 1.

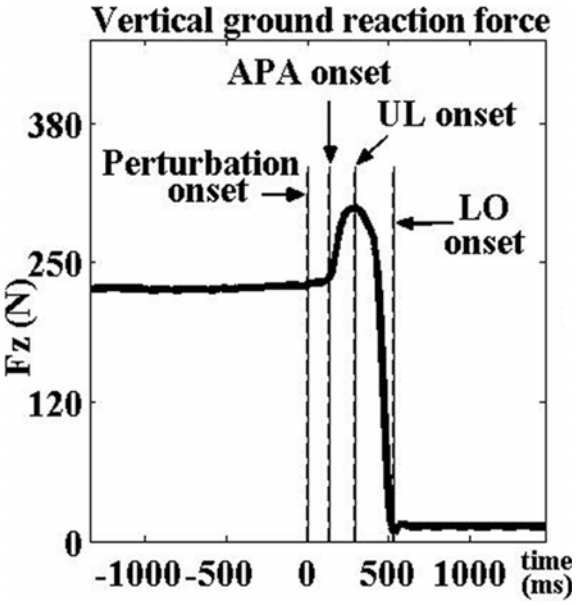

Fig. 1 Example of vertical ground reaction force (Fz) beneath stepping.The vertical lines mark onset of perturbation, anticipatory postural adjustment (APA), unloading (UL) and liftoff (LO).

1. APA onset (ms) is the time between onset of perturbation and the initial limb loading toward stepping limb greater than 2% of body weight.

2. APA duration (ms) is the time between initial limb loading and maximum of Fz.

3. LO onset (ms) is the time between onset of perturbation and the Fz reached zero.

4. UL duration (ms) is the time between maximum of Fz and Fz reached to zero.

The peak AP-COP displacement corresponded to the maximum forward COP displacement from initial position. The peak AP-COP velocity was obtained from differentiating the peak AP-COP displacement. Statistical analysis was performed using SPSS for Microsoft Windows, release 14.0, with $a<0.05$. The Kolmogorov-Smirnov Goodness of Fit test was used to verify normal distribution. For non-normally distributed data, the Wilcoxon Signed-rank and Mann-Whitney U tests were used to analyze all parameters for comparing within and among subjects, respectively.

Results

All subjects stepped for all perturbation trials. Across all trials, the elderly mostly executed the step with the left limb (60% in NT and 63% in LT conditions) and the young individuals usually stepped with the right limb (73% in NT and LT conditions). Before

perturbation, no significant difference was observed in the Fz beneath the left and right limbs ($p>0.05$) in all conditions. No significant differences were found between the elderly and the young individuals in the AP-COP velocity ($p>0.05$) in both touch conditions. Compared between touch conditions, we observed a significantly lower AP-COP velocity beneath stepping limb in the elderly ($p<0.05$) and stance limb among the young individuals ($p<0.05$) under LT condition. The results are shown in Table 1.

After the perturbation period, the characteristics of Fz beneath the stepping limb were observed as an increased loading to the stepping side and an unloading to lift the foot off. Across age groups in NT condition, the elderly showed a significantly shorter LO onset ($p<0.01$) and lower APA duration ($p<0.05$) than the young individuals. Across the age groups in LT condition, the elderly showed a significantly shorter LO onset ($p<0.01$) than the young individuals. However, no significant differences were observed in APA onset, APA duration and UL duration. For AP-COP displacement and velocity, no significant differences between the elderly and the young individuals in these parameters ($p>0.05$) were observed in both NT and LT conditions.

Across touch conditions in the young individuals, no significant difference was found in UL duration or LO onset ($p>0.05$). However, a significantly longer APA onset ($p<0.01$) and shorter APA duration ($p<0.01$) were exhibited under LT. This study also

Table 1. Mean (SD) of APA onset, APA duration, UL duration, LO onset, touching force, COP displacement and velociy in elderly (E) and younger (Y) across NT and LT conditions

	Elderly		Younger		*p*-value			
	NT	LT	NT	LT	E-Y		NT-LT	
					NT	LT	E	Y
Pre-perturbation								
AP-COP velocity								
Stepping limb (m/s)	0.007 (0.003)	0.006 (0.003)	0.005 (0.003)	0.005 (0.002)			$p<0.05$	
Stance limb (m/s)	0.007 (0.004)	0.006 (0.003)	0.005 (0.002)	0.004 (0.001)				$p<0.01$
Touching force (N)		0.32 (0.15)		0.17 (0.12)		$p<0.05$		
Post-Perturbation								
APA onset (ms)	114.10 (36.72)	125.77 (37.75)	108.79 (35.24)	131.56 (44.31)				$p<0.01$
APA duration (ms)	120.18 (43.45)	101.97 (40.45)	167.39 (39.63)	149.91 (30.10)	$p<0.01$	$p<0.01$	$p<0.05$	
UL duration (ms)	162 (24.65)	155.72 (25.19)	177.35 (40.60)	180.62 (48.12)				
LO onset (ms)	394.29 (72.95)	381.47 (58.47)	451.54 (61.19)	460.10 (69.82)	$p<0.01$	$p<0.01$		
AP-COP displacement								
Stepping limb (mm)	99.96 (30.30)	90.56 (29.48)	93.59 (26.02)	93.46 (27.95)			$p<0.05$	
Stance limb (mm)	81.26 (34.69)	72.23 (31.06)	73.07 (26.85)	73.79 (26.35)				
AP-COP velocity								
Stepping limb (m/s)	0.45 (0.23)	0.41 (0.14)	0.34 (0.17)	0.374 (0.21)				
Stance limb (m/s)	0.37 (0.15)	0.35 (0.14)	0.27 (0.16)	0.315 (0.16)				$p<0.05$

observed a significantly higher AP-COP velocity (p<0.05) with LT beneath the stance limb.

Across touch conditions among the elderly, this study identified a significant reduction in APA duration (p<0.05) in LT condition. A significant lower value in peak AP-COP displacement (p<0.05) beneath the stepping side was shown in LT condition.

In addition, the present study reported a significantly higher level of touching force among the elderly (p<0.05) before perturbation. The pattern of force was still higher among the elderly over time after perturbation. The peak forces were 1.211 and 0.8429 N for the elderly and the young individuals, respectively.

Discussion

We identified reported the effect of light touch and age on the preparation period of induced protective stepping. The following section will present the findings under the context of the effects of age followed by the effects of touch conditions.

Effects of age

After the perturbation in NT condition, the elderly executed a step earlier than did the young individuals to recover balance. This trend was associated with a significantly shorter APA duration. This result confirmed previous observations[2] that the elderly triggered induced steps more rapidly than did the young individuals. Although the LO time was executed earlier than did the young individuals among the elderly, their forward threshold boundary and AP-COP displacements were similar. This finding supported a previous study[2], which observed that the elderly executed a step before the step was actually needed. Compared with the young individuals in LT condition, the elderly also initiated a step faster than did the young individuals as in the NT condition. This confirmed that the stepping strategy is preferred by the elderly as previous reported.

Effects of touch conditions

Compared with NT, the AP-COP velocity was significantly reduced with LT in both age groups indicating increased static standing balance. Consistent with a previous study[8], the nervous system received somatosensory cues from the fingers that provided spatial orientation to control balance. The present study observed a significantly higher contact force among the elderly to achieve postural stabilization. It could be interpreted as a compensatory strategy to help overcome the deficit in tactile sensation because of age-related physiological change[9].

Comparing with the NT condition in the young individuals, APA onset was delay-activated in the LT condition. This result confirmed that LT influences the preparation for induced stepping[3,4]. The present study observed its effect caused the nervous system to delay the triggering of response. LT also influenced the anticipatory event as evidenced by a reduction in APA duration. Touching at the side could modify this event as a constraint to the sideways weight transference before lifting the foot off. Additionally, the authors also observed a slower peak AP-COP velocity under the stance limb in the NT condition indicating greater stability than LT. Previous studies revealed that LT contact led to decreased sway[3] and decreased the levels of muscular activities[3,8] relative to NT. Without touching, lower extremity muscles are activated more strongly to stabilize the body, which could result in lower COP velocity. It could be stated that the stabilizing effect due to LT during perturbation among the young individuals influenced less than in the pre-perturbation period.

Compared between LT and NT conditions among the elderly, this study did not observe a significant change of APA onset and speed of LO in LT condition. This could imply that the stabilizing effect due to LT had insufficient power to delay the triggering of induced stepping among the elderly. Similar findings[6,10] were observed in the postural stability response to surface translation. Their results demonstrated that LT had no significant effect on COP onset latencies of responses in healthy elderly people. They also concluded that LT may not reliably act as a sensory trigger for postural stability. Combining the level of touching force during the perturbation, a significantly higher level of touching force was shown among the elderly than among the young. This could result in limiting forward COP movement within BOS while the body was pulled forward. A previous study explained this finding by the fact that the LT cue provided an environmental reference[6].

Conclusion

In summary, protective stepping not only reflects the state of balance stability; it also involves a pre-selection process that we observed among the elderly. During induced stepping, the elderly seemed to lift the foot earlier and before it was actually needed. The use of LT did not only have powerful effects on postural stability during standing but it also affected the preparation for induced stepping. LT influenced

the anticipatory period for stepping by limiting the limb loading duration; thus, LT does not only provide a sensory spatial reference, but also constrains the movements of the body after a perturbation is suggested. However, the stabilizing effect due to LT before perturbation did not have a significant influence on the postural stability among the young individuals during perturbation. This also suggests that the elderly seemed to be more concerned with the response to perturbation than the contact task.

What is already known on this topic?

Protective stepping strategy is commonly executed more frequently among the elderly than young individuals to recvoer balance as preferred strategy.The stabilizing effects of LT for controlling postural balance during stance and walking have been observed. Research focusing on the influence of light touch on preparation for induced stepping has not been clearly described.

What does this study add?

The present study confirmed that protective stepping involved a pre-selection process. The use of LT affects preparation for induced stepping. LT had influence on anticipatory control by providing a sensory spatial reference and reducing the limb-loading period. The authors also observed that the stabilizing effect due to LT during the perturbation did not influence as much as before perturbation.

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Potential conflicts of interest

None.

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กลไกภายใต้การก้าวขาเพื่อป้องกันการล้ม: ผลของแรงสัมผัสเบาและอายุ

ทิพวัลย์ โอภาสกรุณา, โสภา พิชัยยงค์วงศ์ดี, จารุกูล ตรีไตรลักษณะ, รุ่งทิวา วัจฉละฐิติ

วัตถุประสงค์: การก้าวขาเป็นกลไกที่ใช้บ่อยในชีวิตประจำวันเพื่อป้องกันการล้มการสัมผัสเบาช่วยเพิ่มความมั่นคงในการทรงท่า งานศึกษานี้ศึกษาผลของแรงสัมผัสเบาต่อปฏิกิริยาการก้าวขา

วัสดุและวิธีการ: ผู้สูงอายุและคนหนุ่มสาวถูกดึงไปทางด้านหน้าในภาวะที่มีการสัมผัสเบาและไม่สัมผัส

ผลการศึกษา: พบว่าการทรงท่าในช่วงก่อนถูกดึงมีความมั่นคงขึ้นขณะมีการสัมผัสเบา ช่วงถูกดึงผู้สูงอายุยกขาเร็วกว่า คนหนุ่มสาวในทั้งสองภาวะโดยช่วงเวลาเตรียมการก่อนยกเท้ามีค่าลดลงขณะที่การเคลื่อนของน้ำหนักที่เท้าไม่ต่างจากคนหนุ่มสาว อาจสรุปว่าผู้สูงอายุได้เตรียมกลไกนี้ไว้แล้ว ในหนุ่มสาวพบว่าการเตรียมการก่อนการยกเท้าเกิดช้า และใช้ช่วงเวลาสั้นขณะสัมผัสเบา เป็นผลจากการถูกจำกัดการถ่ายน้ำหนักไปทางด้านข้าง และยังพบอีกว่าความมั่นคงที่เพิ่มขึ้นในช่วงก่อนถูกดึงไม่มีผลต่อความมั่นคงในช่วงหลังถูกดึงในผู้สูงอายุ ขณะสัมผัสเบาพบว่าเวลาเตรียมการสั้นลงเช่นเดียวกันและการเคลื่อนของน้ำหนักที่เท้าลดลง เมื่อพิจารณาร่วมกับผลที่ผู้สูงอายุใช้แรงสัมผัสที่มากกว่า สรุปได้ว่าผู้สูงอายุให้ความสำคัญต่อการทรงตัวมากกว่าการควบคุมแรงสัมผัส

สรุป: การก้าวขาเกี่ยวข้องกับความมั่นคงในการทรงท่าและเป็นกลไกที่ได้ถูกเตรียมไว้แล้ว การสัมผัสเบาเพิ่มความมั่นคงของร่างกาย และส่งผลต่อกลไกการก้าวขา