

EFFECTS OF AGE AND INSTRUCTIONS LIMITING THE NUMBER OF STEPS ON THE THRESHOLD OF BALANCE RECOVERY

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INTRODUCTION

We have recently demonstrated that instructions limiting the number of steps did not affect the threshold of balance recovery in younger adults (YA) [1,2]. Indeed, results showed that the effect of using only a single step, no more than 2 steps or no limit on the number of steps on the maximum forward lean angle as well as on kinematic [1] and kinetic [2] performance measures was too small to be pertinent. However, experimental evidence has shown that older adults (OA) are more likely than YA to take more than one step to recover balance following small and medium postural perturbations [3]. The purpose of this study was thus to determine if the threshold of balance recovery was also not affected by limits on the number of steps in OA.

METHODS

As with our 28 YA (24.8 ± 2.6 yrs), we determined the maximum forward lean angles from which 10 OA (68.4 ± 3.0 yrs) could be suddenly released and still recover balance using: i) only a single step, ii) no more than two steps and iii) no limit on the number of steps. Balance recovery was considered unsuccessful if a participant recovered balance using more steps than allowed (stepping failure) or if more than 20% of body weight was supported by the safety harness cable (harness failure).

Using 3 force platforms (OR6-7, AMTI, Newton MA), 2 load cells (FD-2 and MC3A, AMTI, Newton MA) and 4 optoelectronic position sensors (Optotrak, NDI, Waterloo ON), the following performance measures were obtained: maximum lean angle (θ_{max}) and reaction time (RT) as well as weight transfer time (WTT), stride time (ST), stride velocity (SV) and stride length (SL) of all the steps taken by the participants.

One-way repeated measures analyses of variance (rm-ANOVA) were used to separately determine the effect of limits on the number of steps in YA [1] and OA. Two-way rm-ANOVA were then used to determine the effect of age and its interaction with the three limits on the number of steps.

RESULTS AND DISCUSSION

Effect of age on the performance measures: OA demonstrated a poorer ability to recover balance to avoid a fall than YA (Table 1). OA had smaller θ_{max} , longer WTT1 and WTT2, slower SV1 and SV2, and shorter SL1 than YA.

Effects of limits on the number of steps on θ_{max} : Instructions limiting the number of steps significantly affected θ_{max} in both age groups (Table 1). However, the effect was larger in OA ($\Delta\theta_{2-1}=2.7$ deg, $\Delta\theta_{N-1}=4.1$ deg) than in YA ($\Delta\theta_{2-1}=1.0$ deg, $\Delta\theta_{N-1}=1.0$ deg).

Effects of limits on the number of steps on the other performance measures: At θ_{max} , limits on the number of steps also significantly affected RT ($\Delta RT_{2-1}=4$ ms), WTT1 ($\Delta WTT_{1_{2-1}}=-9$ ms), SV1 ($\Delta SV_{1_{N-1}}=-18$ cm/s), SL1 ($\Delta SL_{1_{2-1}}=-9$ cm, $\Delta SL_{1_{N-1}}=-8$ cm) and SV2 ($\Delta SV_{2_{N-2}}=-69$ cm/s) in YA (Table 1). However, they significantly affected ST1 ($\Delta ST_{1_{N-1}}=-38$ ms), SV1 ($\Delta SV_{1_{2-1}}=35$ cm/s) and SV2 ($\Delta SV_{2_{N-2}}=69$ cm/s) in OA. The strategy used to improve the ability to recover balance as more steps were allowed was thus different in the two age groups. YA used slower SV1 and SV2 and shorter SL1 as more steps were allowed, while OA used shorter ST1 and faster SV1 and SV2.

Number of steps taken at θ_{max} : For no more than two steps, 29% of YA used 1 step and 71% used 2 steps, whereas 50% of OA used 1 step and 50%

Table 1: Mean \pm standard deviation results at the maximum lean angles for both younger [1] and older adults ($N_{YA}=28$ and $N_{OA}=10$).

	1 step		2 steps		No limit		Psteps		Page
	YA	OA	YA	OA	YA	OA	YA	OA	
θ_{max} (deg)	29.7 \pm 2.3	19.8 \pm 6.0	30.7 \pm 2.8	22.5 \pm 5.4	30.7 \pm 2.9	23.9 \pm 4.6	**	***	***
RT (ms)	70 \pm 11	82 \pm 16	74 \pm 8	70 \pm 13	73 \pm 10	77 \pm 12	*		
First stride									
WTT1 (ms)	160 \pm 21	184 \pm 46	151 \pm 20	190 \pm 31	154 \pm 21	183 \pm 38	*		**
ST1 (ms)	195 \pm 23	213 \pm 35	182 \pm 28	190 \pm 32	185 \pm 26	176 \pm 17		*	
SV1 (cm/s)	506 \pm 51	361 \pm 83	490 \pm 44	396 \pm 74	488 \pm 50	394 \pm 70	*	**	***
SL1 (cm)	98 \pm 14	76 \pm 18	89 \pm 17	75 \pm 18	90 \pm 16	70 \pm 16	**		***
Second stride									
WTT2 (ms)	n/a	n/a	54 \pm 20	219 \pm 240	52 \pm 36	109 \pm 56			**
ST2 (ms)	n/a	n/a	272 \pm 54	358 \pm 75	347 \pm 165	414 \pm 196			
SV2 (cm/s)	n/a	n/a	423 \pm 98	235 \pm 130	354 \pm 138	304 \pm 136	**	**	*
SL2 (cm)	n/a	n/a	113 \pm 28	85 \pm 45	108 \pm 33	105 \pm 26			

θ_{max} : Maximum lean angle, RT: Reaction time, WTT: Weight transfer time, ST: Stride time, SV: Stride velocity, SL: Stride length.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

used 2 steps. For no limit on the number of steps, 21%, 71% and 7% of YA used 1, 2 and 3 steps, respectively, whereas 20%, 30%, 10%, 10% and 30% of OA used 1, 2, 3, 4 and 5 steps, respectively. However, much less effort was put into these additional steps as they had slower SV and shorter StepL than the preceding steps.

Failure type above θ_{max} : For only a single step, 11% of YA had stepping failures and 89% had harness failures, whereas 60% of OA had stepping failures and 40% had harness failures. For no more than two steps, 4% and 96% of YA had stepping and harness failures, respectively, whereas 40% and 60% of OA had stepping and harness failures, respectively.

Correlations between limits on the number of steps: Despite all the significant effects stated above, θ_{max} and SV1 between the three limits on the number of steps were highly inter-correlated (Table 2).

CONCLUSIONS

In YA, the effect of instructions limiting the number of steps was considered too small to be pertinent. The additional steps did not help to increase θ_{max} by more than 1.0deg and the first step performance measures were nearly identical ($\Delta = \pm 4-10\%$). In OA, however, the effect was larger. The additional steps increased θ_{max} by 4.1deg and the first step performance measures did change ($\Delta = \pm 9-19\%$).

OA were clearly able to use shorter ST1 and faster SV1 to improve their ability to recover balance as more steps were allowed. However, unlike YA, OA were either unable or unwilling to respect the instructions when only one or two steps were allowed. Nevertheless, the strong correlations between the three limits on the number of steps indicate that experiments at the threshold of balance recovery limiting the number of steps are still predictive of those not limiting the number of steps.

REFERENCES

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Table 2: Pearson correlation coefficients (r) between the three limits on the number of steps

	θ_{max}	SV1
1 step vs 2 steps	0.937	0.867
1 step vs No limit	0.893	0.881
2 steps vs No limit	0.903	0.892

θ_{max} : Maximum lean angle, SV: Stride velocity.