LOWER LIMB MOTION DURING A STEPPING ON AND OFF GAIT TASK: COMPARISON BETWEEN YOUNG AND ELDERLY FIT FEMALES

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Supposing that adaptive responses to exercise could counteract the effect of aging on the locomotion, the gait of two groups of fit females differing on their age was compared during three tasks: unobstructed walk, stepping up and stepping down on a raised surface of 17.5 cm height. Fundamental gait parameters including temporal, spatial and spatial-temporal variables were appraised by bi-dimensional kinematics analysis. The results showed a similar gait pattern between the groups on the unobstructed path, but in accomplishment of the more demanding locomotive tasks like ascending and descending the elderly demonstrate a conservative behavior throughout obstacle crossing.

It can be concluded that in spite of the high levels of functional locomotive status of the senior subjects, they showed a growing need of using pro-active strategies to increase the levels of stability and safety during the step negotiation.

KEY WORDS: elderly, gait kinematics, obstructed gait, step negotiation

INTRODUCTION:

Obstructions are commonly found in the everyday environment and the demands of obstructed gait pose a great threat to stability in elderly adults. Older individuals are frequently prone to accidents like trips, stumbling and missteps in public places, which can lead to falls and consequences such as fractures, self-imposed decrease of activity, and even death (Hamel and Cavanagh, 2005). Step negotiation has been suggested to be the most challenging and hazardous type of locomotion which old adults usually deal with (Lee and Chou, 2006) leading to a large proportion of self-reported falls.

Thus, a considerable amount of research has been recently done on gait adaptations to raised surface (Lee and Chou, 2006; Andre et al., 2005; Hamel and Cavanagh, 2005; Begg & Sparrow, 2000;) suggesting that older adults appear to use less efficient transposition strategies and therefore fall predisposition.

Chen and Schultz (1991) demonstrates that elderly tend to reduce the crossing speed and step length when stepping over obstacles, revealing a gait instability during the transposition. In the study of Begg and Sparrow (2000) the older adults also showed a conservative behavior during the obstacle negotiation. They placed their feet farther from the step edge inducing a greater risk of tripping, and consequently falling, in the event of disturbance to the lead foot trajectory.

In our previous study (Machado et al., 2004) we found differences in gait kinetics characteristics between young and older individuals. In spite of the fact that older subjects exhibited on the unobstructed path a gait pattern similar to the young one's, the results showed higher breaking demands in obstacle crossing, especially during the stepping off task. These results showed the need of adaptive strategies by the elderly to reduce the risk of fall in demanding tasks like ascent and descent.

The present investigation focus on the kinematics of the lower limb motion of two groups of female subjects while they negotiate a raised surface. The main goal was to identify if exercise could exert positive adaptive responses in physical capacities that might counteract the effect of aging in gait pattern of elderly. To verify whether age would be a predictor factor of the results of the variables, a correlation study was done to investigate the effects of aging in the seniors' behavior.

METHOD:

Data Collection: Two groups of physically fit females were included in the study: ten elderly subjects (age: 67.60 ± 5.74 yrs, weight: 63.32 ± 9.61 kg, height: 1.54 ± 0.06 m, lower limb height: 0.72 ± 0.04 m, mean ± SD) who regularly participate in a step exercise program and exhibit a score above the 65 percentile in the Senior Fitness Test (Rikli & Jones, 2001); and ten young fitness instructors (age: 21.70 ± 1.42 yrs, mass: 55.19 ± 3.08 kg, height: 1.61 ± 0.05 m, lower limb height: 0.76 ± 0.04 m).

The subjects were asked to walk at a comfortable speed along a 6m pathway. A bi-dimensional kinematics analysis was applied in order to compare the gait of the subjects during three tasks: unobstructed walk, stepping on and stepping off a raised surface of 17.5 cm height. Weight, height and lower limb length were measured in each subject, and the following anatomical points were marked in with hemisphere-shaped reflectors: Forefoot right/left (R/L), Foot tip R/L, Heel R/L, Maleolus lateralis R/L, Maleolus medialis R/L, and Acromium R/L. The following variables were analyzed in this study:

1- Spatial variables: Stride Length (**SL**), Lead Foot Vertical Clearance (**LVC**), Trail Foot Vertical Clearance (**TVC**), Approach Distance of the Trail Foot (**AD**), Horizontal Clearance of the Lead Foot (**HC**), Maximal ROM of the Lead Foot Ankle (**LAROM**), Maximal ROM of the Trail Foot Ankle (**TAROM**),

2- Temporal variables: Stride Time (**ST**), Swing Time (**SWT**), Swing Time of the Lead Foot (**SWTL**), Swing Time of the Trail Foot (**SWTL**), Double Support Duration (**DSD**)

3- Spatial-Temporal variables: Stride velocity (**SV**); Initial Contact Velocity of the Lead foot (**ICV**), in which the heel was the reference point on step-up task and metatarsal on step-down task; Crossing Velocity of the Lead Foot (**CVL**); Crossing Velocity of the Trail Foot (**CVT**); Maximal Dorsiflexion Velocity of the Lead Foot Ankle during single support phase (**MDVLA**); Maximal Dorsiflexion Velocity of the Trail Foot Ankle during single support phase (**MDVTA**).

Data Analysis: The lower limb images were collected at a sampling rate of 50Hz by a single camera (JVC GRDVL 9800 EG) positioned perpendicular to the plane of motion, and the APAS software was used to process the data. Kinematics' data was smoothed using a 8 Hz low-pass zero lag filter, the filter cutoff was defined using FFT analysis.Statistical Analysis was done with the SPSS 12 software. The paired T-test was applied to compare kinematics variables between groups. Within the oldest group linear regression analysis was used to determine the relationship between age and gait variables within the oldest group. The significance level of $p<0.05$ was employed for all statistical analysis considering only the models of linear regression with r^2 equal or above 0.5.

RESULTS AND DISCUSSION:

Table 1 demonstrates that during unobstructed walking, elder individuals showed a similar behavior to the youth subjects in all of the appraised parameters.

Table 1 – Mean values ± standard deviation for kinematics variables during unobstructed condition for elderly and young subjects. Effect of age on the temporal, spatial and spatial-temporal variables analyzed in elderly group. The spatial variables are presented as percentage of leg length (%LL), the temporal variables expressed in seconds (s) and the spatial-temporal in meters per second (m/s)

	Elderly	Young	P	Equation	r^2
Step Length (%LL)	0,89 ±0,10	0,88 ±0,08	Ns	-	-
Stride Length (%LL)	1,79 ±0,15	1,77 ±0,15	Ns	-	-
Step time (s)	0,13 ±0,04	0,14 ±0,16	Ns	-	-
Stride time (s)	0,58 ±0,08	0,63 ±0,04	Ns	-	-
Double support time (s)	1,13 ±0,15	1,21 ±0,06	Ns	$y= -0.560 + 0.04a$	0.5
Swing time (s)	1,15 ±0,17	1,08 ±0,08	Ns	$y= 1.056 - 0.004a$	0.5
Stride velocity (m/s)	0,45 ±0,05	0,49 ±0,03	Ns		

* $p<0,05$, **$p<0,01$, NS= not significant, y = dependent variable, a = age (independent variable)

These findings provide evidence that high levels of physical activity in the older group might exert a protective effect in the decrease of locomotion functionality across the aging process. Nevertheless, the senior subjects revealed a growing need to improve the stability through aging, by means of an increased period of double support (r^2=0.5) and a reduction in the single support duration (r^2 =0.5).

The data in Table 2 reinforce the previous findings, showing that fit elderly were able to successfully negotiate a raised surface using almost the same temporal and spatial-temporal motor patterns of the youngsters, pointing out their high functional capabilities. Yet, the differences found on approach velocity are suggestive of a different strategy used by the elderly for the transposition, what, in according with our previous study (Machado et al., 2004), shows an increasing need of breaking before crossing the obstacle to enhance the safety.

Table 2 – Mean values ± standard deviation for kinematics variables during stepping on and off task for elderly and young subjects. The spatial variables are presented as percentage of leg length (%LL), the temporal variables expressed in seconds (s) and the spatial-temporal in meters per second (m/s) or percentage of Stride time (ST).

	Step on					Step off				
	Elderly		Young		P	Elderly		Young		P
Double support time (%ST)	0,19	±0,02	0,19	±0,02	NS	0,16	±0,03	0,15	±0,03	NS
Swing Time of the Lead Foot (%ST)	0,82	±0,03	0,81	±0,03	NS	0,85	±0,02	0,84	±0,02	NS
Swing Time of the Trail Foot (%ST)	0,81	±0,02	0,81	±0,02	NS	0,84	±0,03	0,85	±0,03	NS
Step Time(s)	0,66	±0,04	0,69	±0,05	NS	0,49	±0,04	0,52	±0,03	NS
Stride Time (s)	1,19	±0,07	1,27	±0,08	*0,02	1,20	±0,09	1,24	±0,08	NS
Stride Velocity (m/s)	1,06	±0,09	1,05	±0,09	NS	1,04	±0,15	1,02	±0,10	NS
Aproach Velocity (m/s)	1,36	±0,11	1,21	±0,14	*0,01	1,43	±0,15	1,25	±0,08	*0,00
Crossing Velocity of the Lead Foot (m/s)	1,16	±0,09	1,10	±0,15	NS	0,98	±0,18	1,00	±0,11	NS
Crossing Velocity of the Trail Foot (m/s)	0,91	±0,12	0,96	±0,09	NS	1,19	±0,17	1,13	±0,11	NS
Step lenght (%LL)	0,86	±0,04	0,88	±0,06	NS	0,82	±0,09	0,76	±0,07	NS
Stride Lenght (%LL)	1,75	±0,08	1,74	±0,12	NS	1,71	±0,14	1,65	±0,11	NS

* p<0.05, **p<0.01, NS=not significant

Despite the high levels of capacity in the functional tests and a similar gait pattern to the young one's on the unobstructed path, the challenge of ascending and descending was reflected on elderly gait pattern, as shown on figure 1.

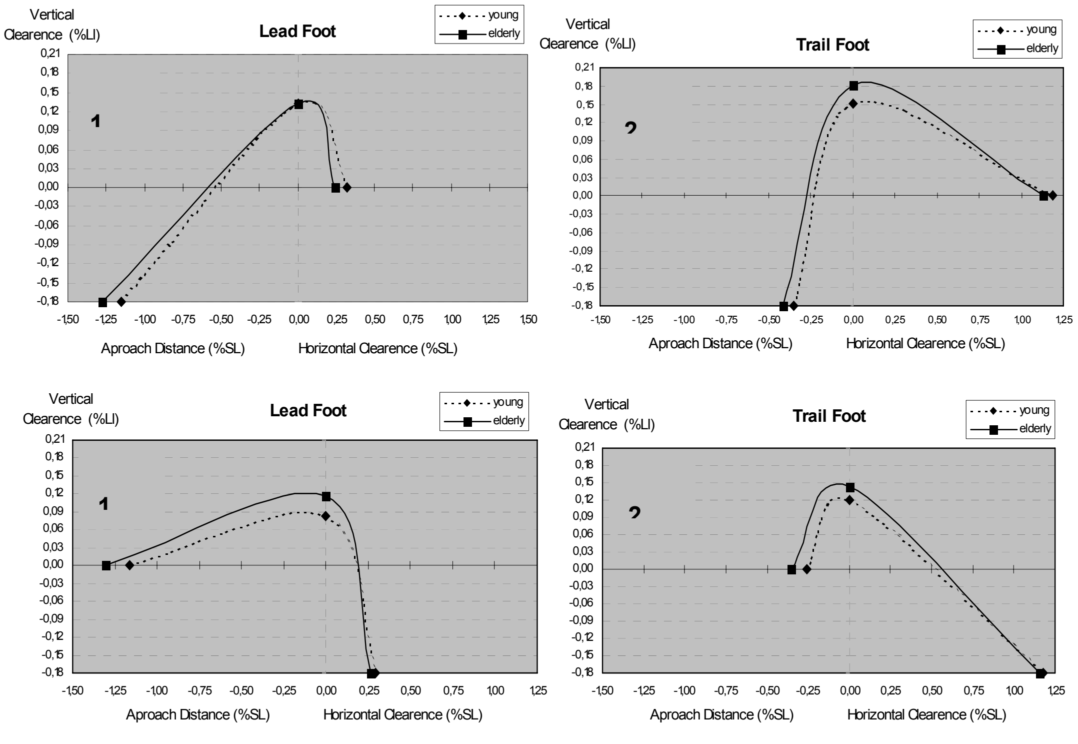

Figure 1 – Lead (A1, B1) and Trail foot (A2, B2) trajectory during the obstacle transposition in stepping on (A) and stepping off (B) task. The spatial variables are presented as percentage of the Leg Length (LL) or the Stride Length (SL).

Lead and trail foot placements' pre and post step edge demonstrate a conservatism in crossing strategy by the older group, as the approach distance was significantly higher and horizontal clearance was lower than young subjects'. Even though this strategy could reduce the risk of contact of the trail foot with the obstacle, it leads to an improving risk of falling due to the difficulty in correcting the movement in case of disturbance of balance during the lead foot transposition (Begg & Sparrow, 2000).

In addition, Figure 1 also underlines the conservative behaviour of the elder participants, when considering the vertical tragectory of the feet during the transposition. All the values of vertical clearance were higher in the older group, with exception of the lead foot during the stepping-on task which showed no statistical differences between the groups. The easier crossing motion pattern during the ascending phase could probably be associated to specific stability adaptations of the exercise program in which the senior subjects were involved. The lack of positive adaptations promoted by exercise on stepping down crossing movement can be explained by the fact that in the step program the descending phase is executed backwards, unlike the movement of step transposition.

Table 3 – Effect of age on the temporal, spatial and spatial-temporal variables analyzed in elderly group.

Task	Dependent Variable	Equation	r^2
Step on	Step time	Y= 0.340 + 0.005 a	0.5
	Stride time	Y= 0.663 + 0.008 a	0.5
	Stride velocity	Y= 1.812 - 0.011 a	0.5
	Crossing speed — trail foot	Y= 1.979 - 0.016 a	0.6
Step off	Step time	Y= 0.173 + 0.005 a	0.5
	Stride time	Y= 0.388 + 0.012 a	0.6
	Vertical Clearence — lead foot	Y= - 0.138 - 0.003 a	0.5

y= dependent variable, a= age (independent variable)

As shown on Table 3, the results of the correlation study corroborates these findings, demonstrating that the descending phase seemed to be the task that evidenced larger levels of difficulty for the senior females. The older the subjects, the higher the need to increase the lead foot vertical clearance during the transposition (r^2=0.5). Age was also positively associated with stride duration (r^2=0.5) and step duration (r^2=0.5), and negatively with stride velocity (r^2= 0.05) and crossing speed on trail foot (r^2= 0.6) when stepping-on. On the stepping-off task age was positively associated with stride duration (r^2=0.6) and step duration (r^2=0.5), demonstrating a tendency to slow down the motion with aging process.

CONCLUSION:

This study provides evidence of significant improvements in gait function of female older adults with a step-exercise program. Nevertheless, this positive effect is reduced in the case of more demanding walking tasks, suggesting that intervention programs aimed at improving locomotion functionality should emphasizes the use of specific motion patterns that reproduce daily living tasks. In spite of the high levels of functional locomotive status of the senior subjects, the results showed a growing need of using pro-active strategies to increase the levels of stability and safety throughout obstacle crossing, which might be probably derived from the functional decline across the aging process.

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