Age-Related Changes in Postural Control: transitional task

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Research article

Keywords: step initiation, posturography, crossing obstacle, stair negotiation

Posted Date: July 17th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-42683/v1

Version of Record: A version of this preprint was published on January 6th, 2021. See the published version at https://doi.org/10.1186/s12877-020-01985-y.

Abstract

Background

Aging, being a natural process, involves many functional and structural changes within the body. Identifying the onset of age-related postural changes will provide insight into the role of aging on postural control during locomotion. The aim of this study was to identify age-related postural changes during a transitional task under different conditions.

Methods

Sixty healthy females divided into three age groups: A (50–60 y/o), B (60–70 y/o), and C (70–80 y/o). The transitional task was measured by two force platforms. The procedure consisted of three phases: quiet standing, transfer onto a second platform, and quiet standing on the second platform. Four different conditions were applied: unperturbed transfer, obstacle crossing, step-up, and step-down. Double-support time, transit time, and stability time before and after the step task were analyzed.

Results

The transit time was longer by 30% for subjects over 70 y/o. The double-support time was longer by 11% among adults 60–70 y/o, while in people over 70 y/o it was longer by almost 50% compared to the 50–60 y/o subjects. The stability time before the transitional task was longer by 17% among adults over 60 y/o compared to middle-age subjects. The stability times before and after the transitional task were longer for adults in the 50–60 y/o category.

Conclusion

The proposed procedure is adequate for assessing age-related changes in postural control while undergoing a transitional task. An analysis of the double-support time and stability time before and after the step task enabled the detection of early signs of balance changes in middle-age adults. Independent of age, the transitional task parameters changed with the increasing difficulty of the tasks.

Introduction

Aging, being a natural process, involves reduced muscle strength, inclined posture, and impaired process of motor control [1]. In addition, the elderly present gait deterioration, such as changes in walking rhythm, shortening of the step length, and decreases in gait speed. These factors, combined with age-related lower activity levels, lead to postural instability and an increased risk of falls. These falls may occur during daily activities [2], which is a major problem as the consequences might induce a loss of mobility, decreased independence and quality of life, or even increased mortality among the elderly population.

There is evidence that one of the main factors influencing falling is poor balance [3]. Changes in postural control, which lead to a balance deficit, appear prior to a fall incident. Therefore, an early and proper balance diagnostic is crucial in preventing serious injuries as a consequence of falls.

Balance can be assessed using either clinical balance tests such as the Tinetti test, Berg Balance Scale, Timed Up and Go, and Functional Reach test or more objective measures such as posturography. However, clinical tests only assess visible balance deficits, and they cannot always be used as a preventive diagnostic. According to Boulgarides et al. [4] the results of some subjective tests, combined with health and demographic factors, were insufficient to predict falls among the community-dwelling elderly. Therefore, developing a more sensitive testing procedure to measure postural changes, which are undetectable by standard clinical tests, is reasonable.

The elderly experience changes in the neuromuscular system with age, which is visible in the changes in gait pattern characteristics. The step length becomes narrower, the variability of the step length increases, gait speed and cadence slows, and double support time lasts longer [5, 6]. In addition, some authors claimed that falls occur predominantly during short distance movements [7]. For example, the elderly have balance control problems during a transitional task, including step initiation, which is a common everyday activity. It is well-known that everyone must adjust to varying environmental constraints (i.e., ground unevenness and/or a curb) and/or stair negotiation. These can be very demanding tasks for the elderly and can even lead to falls. Thus, we examined step initiation under four different transitional task conditions (unperturbed crossing, obstacle crossing, step-up and step-down).

The World Health Organization consider the onset of old age as occurring at 65 y/o. However, changes in postural control might appear earlier [8]. Thus, the following becomes an important question: “How quickly do these changes progress with age?” Therefore, in our study the participants were divided into three decades, 50–60, 60–70, and 70–80 y/o, to determine the dynamic of these changes. Identifying the onset of age-related postural changes will provide insight into the role of aging on postural control during locomotion.

Therefore, the aim of our study was to identify the postural changes that appear with age during a transitional task. We hypothesized that the difficulty of the transitional task and all analyzed posturographic parameters would increase with age.

Methods

Sixty females voluntarily participated in the study. They were divided into three age groups: A (50-60 y/o), B (60-70 y/o), and C (70-80 y/o) (Table 1). The inclusion criteria included a minimum age of 50 and maximum age of 80. The exclusion criteria were as follows: severe neurological, cognitive impairments, or lower limb injuries. One of the subjects in group C failed to complete the entire research procedure. The subjects provided a written informed consent for voluntary participation in the study. The research was approved by the Institutional Ethics Committee of the Medical University of Warsaw (number KB/28/2014).

The transitional task was measured by two force platforms (AMTI, Accugait, Watertown, MA, USA) that registered the ground reaction forces and moments at a 100 Hz sampling frequency. The raw data was processed off-line with a dual-pass 7 Hz low-pass Butterworth filter using MATLAB software (Mathworks, Natic, MA).

The starting position for all trials was quiet standing with the feet positioned shoulder-width apart, arms alongside the body. The trial started with 15 seconds of quiet standing, followed by an acoustic signal for subjects to transfer from one to another platform, and after the transitional phase subjects performed quiet standing until the end of the trial (Figure 1). The transitional task was executed under four different conditions: unperturbed crossing, crossing obstacle, and step-up and step-down (Figure 2). A 16cm/4cm (height /width) wooden block was used as an obstacle. In the step-up and step-down conditions, one platform was placed on a 17-cm base directly at the edge of the other platform.

Figure 1. Experimental set-up – three phases [9]

Figure 2. Four conditions of the transitional task [9]

The trials were repeated 3 times and lasted 35 s each. Before being examined, the subjects practiced the transitional task on the force platforms. The participants were instructed to start with their dominant leg.

The recording of center of foot pressure (COP) displacements was divided into three phases (see Juras et al.[9]): 1st Phase – quiet standing before the transitional phase, 2nd Phase – transit phase, and 3rd phase – quiet standing until measurement completion. The following variables were analyzed: TT (s) – transit time, the duration of the transit phase; S1 (s) – stability time 1 (preparatory stability time), the time from exiting quiet standing to the time when the leading foot was resting on the second platform; S2 (s) – stability time 2 (regained stability time), the time from raising the foot from the first platform to the end of the 2nd Phase; DST (s) – double-support time, when each foot is in contact with one of the platforms.

The Shapiro-Wilk test was used to check the data for a normal distribution. Variance homogeneity was checked with Levene's test. The Kruskal-Wallis test was conducted to compare data between the three groups. Differences between the different transitional task conditions were determined by Friedman's ANOVA. The level of significance was set at
$p \leq 0.05$. All calculations were carried out using STATISTICA v.13.1 (StatSoft, Inc., USA).

Results

There was a group effect on transit phase in unperturbed crossing, crossing the obstacle, and step-up conditions (Table 2). The greatest differences were observed between group A and C. Group C presented significantly higher values for TT, S1, S2, and DST under unperturbed crossing, crossing the obstacle, and step-up conditions compared to group A. Additionally, group B obtained significantly higher values of TT and S2 relative to group A while crossing the obstacle. Group B also showed significantly higher values of S1 and S2 during the step-up condition compared to group A. The least differences were observed between group B and C. Group B presented significantly lower value only in DST during unperturbed crossing, crossing obstacle compared to group C. There were no significant differences between groups during the step-down condition.

There was a significant effect with regard to the testing conditions on transit time (TT) (Chi2 = 16.74; $p < 0.001$), stability time 1 (S1) (Chi2 = 22.53; $p < 0.001$), stability time 2 (S2) (Chi2 = 11.70; $p < 0.008$), and double-support time (DST) (Chi2 = 34.74; $p < 0.001$) in group A. The subjects presented the longest TT, S1, and S2 during the step-down condition. At the same time, the results showed significantly higher values for DST during the step-up condition relative to other conditions (Figure 3).

Figure 3. Median value of transit time, stability time 1, stability time 2, double-support time (minimum, maximum marked as error bars) in the four conditions (2nd phase) among groups A, B, and C. The horizontal bars indicate statistically significant differences within the groups (Friedman ANOVA repeated measures with the post hoc test).

Abbreviations: flat – unperturbed crossing; obstacle – perturbed crossing

There was a significant effect with regard to the testing conditions on transit time (TT) (Chi2 = 9.54; $p < 0.05$), stability time 1 (S1) (Chi2 = 16.32; $p < 0.001$), stability time 2 (S2) (Chi2 = 11.10; $p < 0.05$), and double-support time (DST) (Chi2 = 42.31; $p < 0.001$) in group B. Group B obtained the highest values of TT and S1 during the step-up condition compared to group A. The same changes were observed when analyzing the DST variable, whereas the highest S2 values were achieved among subjects during the step-down condition (Figure 3).

There was no significant testing conditions on all analyzed variables except for double support time (DST) (Chi2 = 41.04; $p < 0.001$). The subjects obtained the longest time for DST during the step-up condition and the shortest time for DST during the step-down condition (Figure 3).

Discussion

Identifying the onset of age-related gait changes will provide insight into the role of aging on postural control during locomotion. In this study, we aimed to determine whether age-associated changes affect postural stability during a transitional task in various conditions. In our case, we provide a procedure which allows the assessment of postural stability among adults of various ages.

In this study, all parameters (TT, S1, S2, DST) increased linearly with age. We assumed that higher values of the measured parameters indicate impaired postural control during the performance of a transitional task. The transit time was longer by 30% in subjects over 70 y/o, which lead to prolonged DST, S1, and S2. In previous studies, the authors analyzed various gait parameters in the elderly, mostly gait speed, step length, and stride length, and rarely double-support time [10, 11]. Some authors [12] observed that adults aged 65–79 y/o present a 20% slower gait speed relative to young adults (20–25 y/o). The decrease in gait speed may reflect a protective adaptation to a perceived threat to stability, as the center of mass (COM) must be accelerated from a stationary state, and the relatively small base of support in the first step [12]. Although gait speed has been identified as an important predictor of the onset of immobility and balance disorders among the elderly [13, 14, 15], our results support the idea that double-support time might also be a valuable predictor of age-related changes in locomotion. Moreover, there is convincing evidence that DST is highly correlated with gait speed [16]. In our study, DST was longer by 11% among adults 60–70 y/o, but in people over 70 y/o, it was longer by almost 50% compared to middle-age subjects. Since decreased gait speed predicts balance deficits in the elderly, we assumed that a longer DST, which is associated with slower gait speed, indicates impaired postural control during gait among the elderly population.

Step initiation consists of an anticipatory postural adjustment (APA) and a stepping phase, both of which are impaired in the elderly. Our results demonstrate that the postural preparation time (S1) was longer in adults over 60 y/o and increased by 17% compared to middle-age subjects. These results suggest that APA might be impaired by age-related physiological changes, which are reflected in reduced somatosensory and visual information. In addition, there is evidence that the elderly present less variability in muscle activity than younger adults during the anticipatory phase [17], which also confirms that the elderly are unable to respond effectively to balance perturbations [18]. Thus, impaired postural preparation comes with a potential for balance loss in the elderly.

Additionally, we have noticed a longer regained stability time (S2) in adults over 60 y/o with respect to middle-age participants. The S2 time increased by 18% among adults 60–70 y/o, but in participants over 70 y/o, it increased by 32%. Gait termination changes the gait patterns and thereby threatens the stability of the elderly [19], and the elderly also generated less braking force than the middle-aged group [20]; therefore it takes more time to regain a stable posture after movement. Our results support these findings; we have noticed that adults over 70 y/o present difficulties with regaining stability after a motor task.

In addition, all of the measurements changed across the different conditions. Our results demonstrate that independent of age, TT, S1, and S2 increased while crossing an obstacle. An explanation of these findings consists of the fact that stepping over obstacles increases gait challenges at every age, even in the middle-age population [21, 22]; however, this motor task is still more demanding for the elderly compared to young adults [23]. Previous studies reported that the elderly used a more conservative strategy for crossing obstacles relative to young adults, including a slower crossing speed and higher foot clearance while crossing over obstacles [24, 25]. Our study supports these findings, as adults over 60 y/o present a longer TT; in other words, they needed more time for negotiating an obstacle. In addition, TT increased in middle-age adults, which corresponds with recent studies [26]. However, the changes in obstacle crossing in the middle-aged group were observed only in the most challenging tasks (obstacle height 26 cm) [26].

Additionally, we noticed that TT increased during step-up and step-down conditions. There is evidence that ascending and descending stairs is a hazardous activity of daily life for adults over 60 y/o [27]. However, our findings show that the postural control alteration while negotiating stairs already occurs in middle-age. The preparatory time and the regained stability time increased in adults over 50 y/o, which is a very important sign, because it may mark the onset of age-related gait changes. Moreover, we observed several changes in DST. Independent of age, we noticed longer DST in the step-up condition compared to flat crossing, which may be an indication of balance disorders imposed on the elderly during stair climbing. Prolonged DST provides evidence that older adults need to spend more time on double limb support before transitioning to a single support phase while stepping up. These changes are also already apparent in adults 50–60 y/o, further evidence proving the early signs of age-related gait changes.

In addition, during step initiation before descending stairs, the elderly present decreased stability relative to younger participants [28]. Bosse et al. [28] claimed that the elderly generated less braking forces while descending stairs, thus they sway forward like a pendulum instead of controlling the movement of COM; this offers evidence that the elderly may not be able to effectively reduce their body sway before the initiation of stepping down. In our case, the most surprising issue was the decreased DST in every age group of adults during the step-down condition. On the basis of the above literature, we assumed that adults with impaired postural control are not able to control the forward COM movement, therefore they shorten the double support phase during the descending step task. Moreover, in the elderly over 70 y/o every task was difficult; we have not noticed differences between all conditions. Therefore, we assumed that the elderly in the 70–80 y/o category would present advanced postural control impairments during transitional task.

A limitation of the study was that our procedure included one step, while in other studies the subjects usually performed a few steps. This one step did not reflect exactly the same conditions as during normal daily life situations. However, our procedure is the simplest and less complicated compared to standard measures of gait initiation. Furthermore, in our study, we investigated only three ranges of age; therefore, we recommend that future studies should include more age groups to better assess the onset of age-related gait changes.

In conclusion, the proposed procedure is adequate for assessing age-related changes in postural control while completing a transitional task. The analysis of DST enabled the detection of early signs of balance changes in middle-age adults. Furthermore, the elderly demonstrated postural impairments before movement initiation and also after a motor task. Additionally, independent of age, the transitional task parameters changed with the increasing difficulty of tasks. The most noticeable difference was observed during the double support phase in a group of adults over 60 y/o, and the most demanding task for all groups of adults was the step-down condition.

Abbreviations

flat: unperturbed crossing; obstacle– perturbed crossing

Declarations

Ethics approval and consent to participate:

The subjects provided a written informed consent for voluntary participation in the study. The research was approved by the Institutional Ethics Committee of the Medical University of Warsaw (number KB/28/2014).

Consent for publication:

Not applicable

Availability of data and materials:

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests

Funding:

The study was supported by the National Center for Research and Development Grant under the program STRATEG MED III within the “VB-Clinic” project no. STRATEGMED3/306011/1/NCBR/2017.

Authors' contributions:

KJS, and GJ contributed to the conception and the design of the study. JM, AK, MS, and GS, carried out the data acquisition. JM, and AK performed the analysis, JM, and AK drafted the article. KJS has critically revised the article. All authors have approved the final draft.

Acknowledgements:

Not applicable

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Tables

Table 1. Characteristics of participants

	Group A	Group B	Group C	p value
Sample size	20	20	19	-
Age (y)	54.5 ± 3.5	66.5 ± 2.0	73.5 ± 2.5	< 0.05
Height (cm)	164.6 ± 6.8	160.6 ± 6.2	160.8 ± 6.0	> 0.05
Weight (kg)	68.0 ± 9.0	68.2 ± 10.7	69.8 ± 8.5	> 0.05

Table 2. Intergroup comparison between three groups A, B, and C

variables	conditions	group A	group B	group C	H & p value	Intergroup comparison		
		Mdn (min-max)	Mdn (min-max)	Mdn (min-max)		A vs. B	B vs. C	A vs. C
TT [s]	unperturbed crossing	2.70 (2.35-3.85)	3.32 (2.69-4.50)	3.57 (2.88-4.89)	H = 17.97 p = .0001	+	-	+
	obstacle crossing	3.01 (2.51-3.91)	3.45 (2.845-4.63)	3.48 (2.94-6.54)	H = 15.78 p = .0004	+	-	+
	step-up	2.93 (2.50-4.50)	3.50 (2.64-4.71)	3.77 (3.07-5.83)	H = 13.56 p = .0011	-	-	+
	step-down	3.28 (2.53-4.44)	3.30 (2.65-5.10)	3.68 (3.05-5.06)	H = 5.77 p = .0559	-	-	-
S1 [s]	unperturbed crossing	1.11 (0.95-2.7)	1.29 (1.02-1.73)	1.37 (1.05-2.18)	H = 8.37 p = .0153	-	-	+
	obstacle crossing	1.30 (1.02-2.03)	1.36 (1.05-1.93)	1.47 (0.97-2.53)	H = 4.76 p = .0926	-	-	-
	step-up	1.12 (0.97-2.39)	1.27 (1.02-2.14)	1.35 (1.03-2.24)	H = 12.77 p = .0017	+	-	+
	step-down	1.32 (1.03-2.80)	1.37 (1.15-2.78)	1.50 (1.28-2.33)	H = 5.46 p = .0654	-	-	-
S2 [s]	unperturbed crossing	1.28 (0.82-2.51)	1.67 (1.19-2.24)	1.74 (1.30-2.74)	H = 12.87 p = .0016	-	-	+
	obstacle crossing	1.40 (1.03-2.13)	1.72 (1.44-2.36)	1.83 (1.40-3.60)	H = 16.56 p = .0003	+	-	+
	step-up	1.46 (1.17-2.45)	1.82 (1.19-2.88)	1.95 (0.99-3.09)	H = 11.82 p = .0027	+	-	+
	step-down	1.58 (1.31-2.12)	1.63 (1.09-2.94)	1.82 (1.41-3.40)	H = 5.85 p = .0536	-	-	-
DST [s]	unperturbed crossing	0.27 (0.15-0.44)	0.32 (0.23-0.47)	0.40 (0.26-0.71)	H = 18.19 p = .0001	-	+	+

	obstacle crossing	0.27 (0.17-0.40)	0.27 (0.22-0.54)	0.36 (0.28-0.61)	H = 22.14 p = .0000	-	+	+
	step-up	0.34 (0.19-0.91)	0.40 (0.26-0.79)	0.50 (0.25-0.79)	H = 8.85 p = .0120	-	-	+
	step-down	0.22 (0.13-0.66)	0.24 (0.18-0.41)	0.21 (0.07-0.34)	H = 4.47 p = .1068	-	-	-

Abbreviations: TT – transit time; S1 – stability time 1; S2 – stability time 2; DST – double support time; group A – 50-60 years old; group B – 60-70 years old, group C – 70-80 years old, '+' – significant differences between groups (p < 0.05); '-' – no significant differences between groups (p > 0.05)

Figures

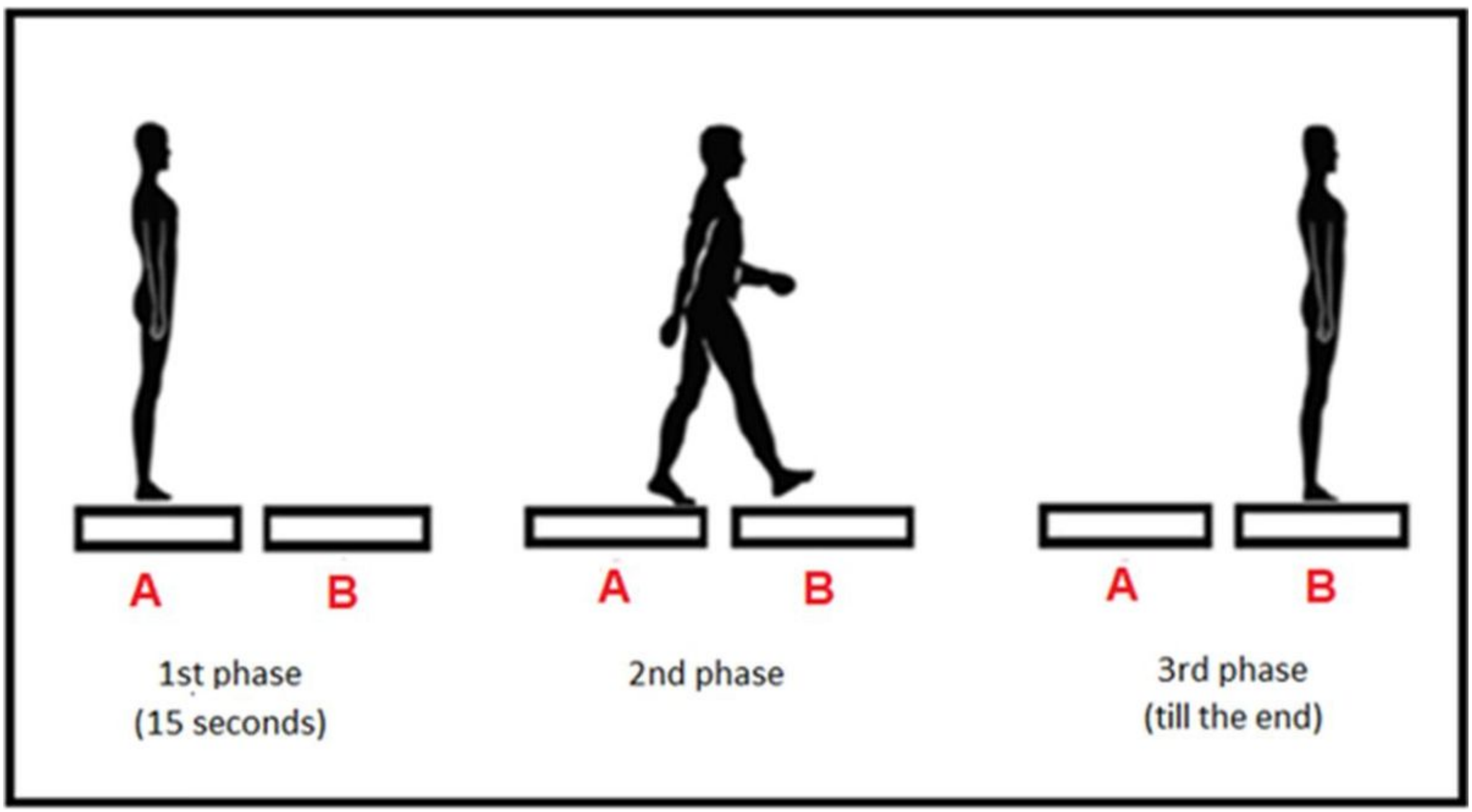

Figure 1

Experimental set-up – three phases [9]

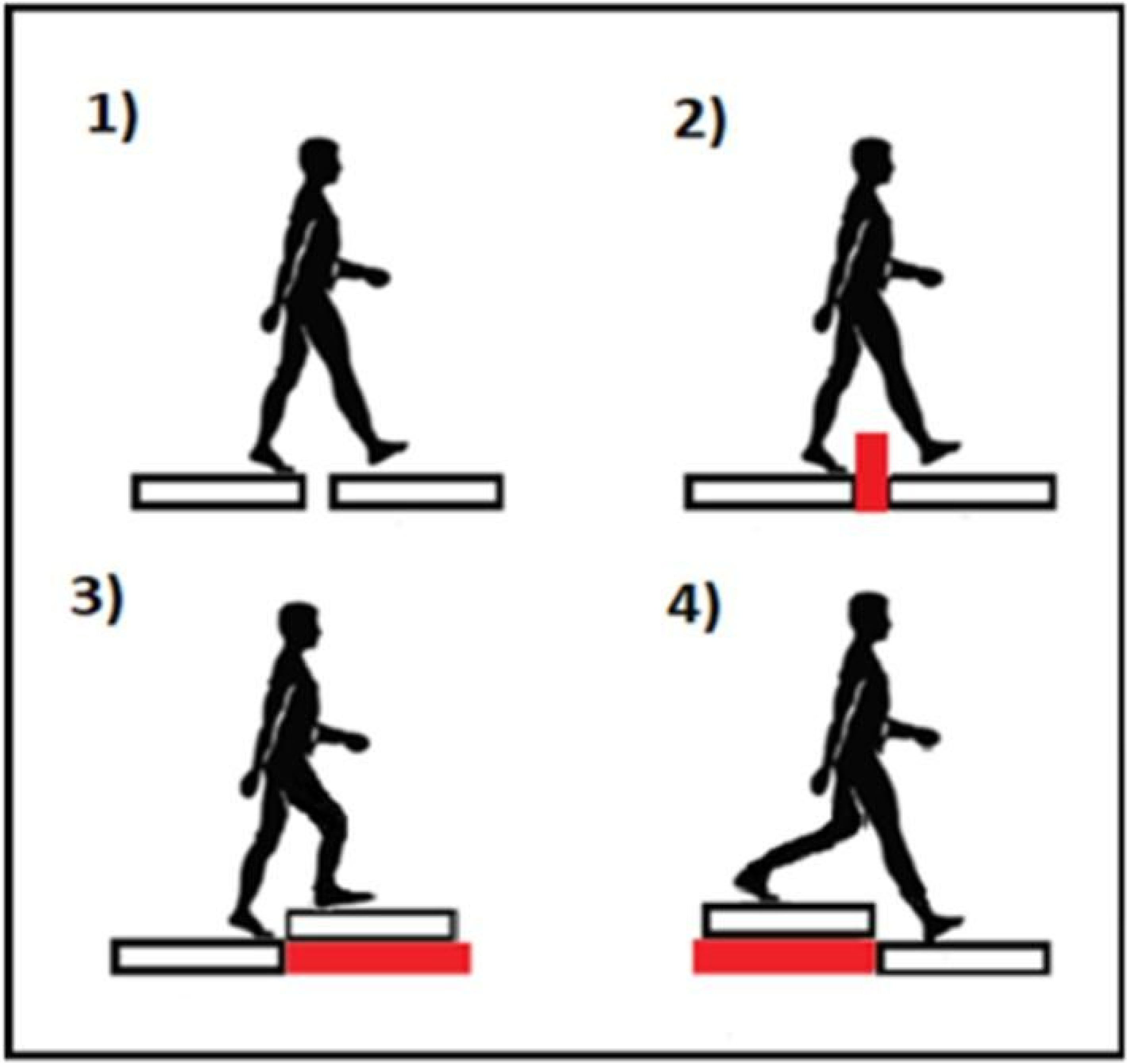

Figure 2

Four conditions of the transitional task [9]

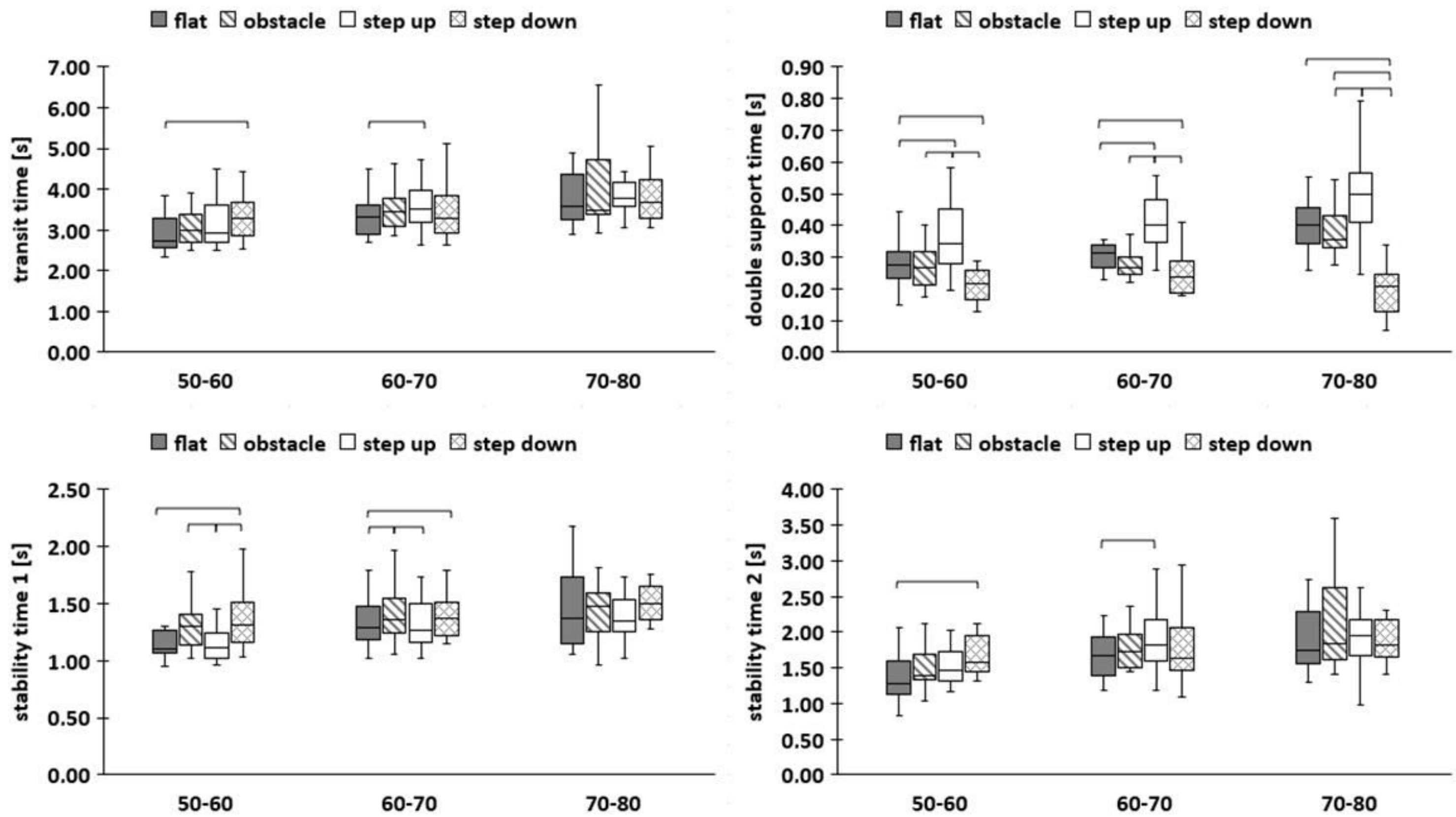

Figure 3

Median value of transit time, stability time 1, stability time 2, double-support time (minimum, maximum marked as error bars) in the four conditions (2nd phase) among groups A, B, and C. The horizontal bars indicate statistically significant differences within the groups (Friedman ANOVA repeated measures with the post hoc test). Abbreviations: flat – unperturbed crossing; obstacle – perturbed crossing