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ORIGINAL RESEARCH

Kinematics analysis of older adults when obstacle crossing

Análise cinemática de pessoas idosas durante a tarefa de ultrapassagem de obstáculos

Análisis cinemático de personas mayores durante la tarea de superar obstáculo

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ABSTRACT | Tripping over obstacles while walking has been reported as one of the main causes of falls in the older population. In this age group, it is important to consider that the trunk plays a significant role in maintaining dynamic balance. This observational case-control study aimed to analyze the kinematics of the trunk and pelvis of older adults during the crossing of obstacles. For the experimental group (EG), this study included 13 older women with a mean age of 67.00 ± 5.07 years who attended a water aerobics program. Meanwhile, for the control group (CG), 13 young healthy adult women, with mean age of 21.00 ± 1.54 years, were included. Both groups were subjected to the task of obstacles crossing at various heights using the Vicon® three-dimensional motion analysis system. We analyzed three-dimensional angular variables of the trunk (thoracic and lumbar spine) and pelvis. The results showed that the older adult participants exhibited greater three-dimensional amplitudes of these body segments. Greater trunk flexion range and thoracic spine inclination were observed from the height of 15%, in the trunk rotation amplitude at 35% and 40%, as well as in the thoracic spine rotation range and pelvis flexion at all obstacle heights. This study concludes that older adults, in general, exhibit greater postural adaptations to cross obstacles safely, as shown by their greater range values of the trunk and pelvis compared to young adults.

Keywords | Aged; Gait; Biomechanical Phenomena; Obstacle Crossing.

RESUMO | Tropeçar em obstáculos durante a marcha tem sido reportado como uma das principais causas de quedas na população idosa. Nessa faixa etária, é importante considerar que, para a manutenção do equilíbrio dinâmico, o tronco desempenha uma função relevante. Este estudo observacional de caso controle objetivou analisar a cinemática do tronco e da pelve de pessoas idosas durante a tarefa de ultrapassagem de obstáculos. A amostra foi constituída de 13 pessoas idosas com média de idade de 67,90 ± 5,07 anos frequentadoras de um programa de hidroginástica, que fizeram parte do grupo experimental (GE), e 13 mulheres adultas jovens e saudáveis com idade média de 21,00 ±1,58 anos, para compor o Grupo Controle (GC). Os dois grupos foram submetidos à tarefa de ultrapassagem de obstáculos de diferentes alturas utilizando o sistema de análise de movimento tridimensional Vicon®. Foram analisadas variáveis angulares tridimensionais do tronco (coluna torácica e lombar) e da pelve. Os resultados evidenciaram que as pessoas idosas desempenharam maiores amplitudes tridimensionais desses segmentos corporais. Maior amplitude de flexão do tronco e inclinação da coluna torácica observadas a partir da altura de 15%, na amplitude de rotação do tronco em 35% e 40%, amplitude de rotação da coluna torácica e de flexão da pelve em todas as alturas de obstáculos. Conclui-se com este trabalho que as pessoas idosas, de modo geral, apresentam maiores adaptações da postura para a ultrapassagem a fim de vencer com segurança os obstáculos em decorrência do aumento das amplitudes de tronco e pelve em comparação a adultas jovens.

Descritores | Pessoas Idosas; Marcha; Cinemática; Ultrapassagem de Obstáculos.

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RESUMEN | Los tropezones han sido reportado como una de las principales causas de caídas en la población anciana. En este grupo de edad, es importante tener en cuenta que el tronco desempeña una función relevante para mantener el equilibrio dinámico. Este estudio observacional de caso-control tuvo como objetivo analizar la cinemática del tronco y de la pelvis de personas mayores durante la tarea de superación de obstáculos. La muestra se constituyó de 13 personas mayores, con una edad promedio de 67,00 ± 5,07 años, que asistían a un programa de aerobic acuático y formaron parte del Grupo Experimental (GE), y 13 mujeres adultas jóvenes y saludables, con una edad promedio de 21,00 ± 1,54 años, que conformaron el Grupo Control (GC). Los dos grupos fueron sometidos a la tarea de superación de obstáculos de diferentes alturas utilizando el sistema de análisis de movimiento tridimensional Vicon®. Se analizaron variables angulares tridimensionales del tronco (columna torácica y lumbar) y de la pelvis. Los resultados mostraron que las personas mayores presentaron mayores amplitudes tridimensionales de estos segmentos corporales. Se observaron mayor amplitud de flexión del tronco e inclinación de la columna torácica a partir de una altura del 15%, en la amplitud de rotación del tronco al 35% y 40%, en la amplitud de rotación de la columna torácica y de flexión de la pelvis en todas las alturas de obstáculos. Se concluye que las personas mayores, em general, presentaron mayores adaptaciones de la postura para superar los obstáculos con el fin de vencer con seguridad los obstáculos debido al aumento de las amplitudes del tronco y de la pelvis en comparación con los adultos jóvenes.

Palabras clave | Anciano; Marcha; Fenómenos Biomecánicos; Superación de obstáculos.

INTRODUCTION

Aging, environmental factors and lifestyle interfere with the quality of performing activities of daily living (ADLs) of older adults, namely: dressing, moving, eating, and shopping[1]. In this sense, gait is vital as an instrument for the maintenance of this population's activities and social interaction.

Considering gait as a condition of continuous disturbance of balance in the process of transferring the center of gravity from one foot to the other, adaptations in its patterns can be expected in older populations due to the changes in the motor and cognitive systems that follow aging[2]. The main biomechanical adaptations observed in gait with advancing age include reduced speed, stride length, range of motion of the hip, pelvis, ankle, and spine joints, changes in the position of the center of mass, in addition to increased support base and double support time[3,4]. For these analyses, Kinematics has been widely employed. This method enables studying body movement independently of the causes of the movement, quantifying the linear and angular positions of the segments in space[5].

Crossing obstacles during gait has become an important object of study, as tripping has been reported as one of the main causes of accidents among older adults, representing from 35 to 53% of all falls suffered[6-8]. The trunk plays an important role in the execution of gait, contributing to the transmission of impulse, propulsion, and transfer of body mass from one side to the other. We highlight that few studies have quantified the biomechanical contributions of the trunk during gait involving obstacle crossing[9,10]. The literature on the subject presents other aspects related to overcoming obstacles, mainly related to the kinematic behavior of the lower limbs. Among them are the analysis of asymmetry comparing healthy older adults and those with Parkinson's disease[11], studies on individuals with Multiple Sclerosis during obstacle crossing and avoidance[12], and gait characteristics underlying falls, particularly those related to tripping over obstacles[13].

In this study, in addition to investigating the trunk's contributions to the task, we also aimed to scale the obstacle height based on the subject's lower limb length, differing from existing research, which used predetermined heights. Thus, the objective was to verify whether there is a significant change in the kinematics of the trunk and pelvis of older adults when obstacle crossing of different heights.

METHODOLOGY

Study design

This observational case-control study was developed based on the analysis of two groups of individuals intentionally selected[14].

Sample

The experimental group (EG; n=13), composed of females, gad a mean age of 67.90±5.07 years, height of 1.56±0.08 m, and body mass of 68.61±15.01 kg. An invitation to participate in the study was extended to all 23 attendees of an outreach program affiliated with the Department of Physical Education (DEF) at a public university in southern Brazil. The control group (CG; n=13) had a mean age of 21.00±1.58 years, height of 1.64±0.05m, and body mass of 58.52±9.10kg. The CG was intentionally selected and composed of young university women, enrolled in the Physical Education course and invited to participate in the study. This group was selected considering the importance of studying healthy individuals, as it can provide data to determine the normative aspects of functional movement performance. This knowledge can serve as a diagnostic parameter for comparison with other groups, such as people with dysfunctions, as well as different age groups and/or levels of functional performance[15].

The inclusion criteria for the EG were belonging to a physical activity group (water aerobics) and being aged over 60 years. For the CG, the inclusion criteria were to be regularly enrolled in a university course and to be aged from 18 to 25 years. The exclusion criteria included suffering from any musculoskeletal disorder that prevented developing independent gait, using an assistive device, and/or being able to perform the tasks.

Anthropometric measurements

Body mass (kg) and height (m) were measured using a scale and a stadiometer (Welmy®), respectively. A measuring tape and a blunt-point caliper were used to measure the following on both sides of the body: lower limb length; shoulder joint width; hand thickness; and the width of the knee, ankle, elbow, and wrist. These measurements are required for the biomechanical full body Plug-In Gait model of the Vicon® system.

Three-dimensional kinemetry

For the three-dimensional kinematic evaluation, an adjustable height obstacle was employed, with two vertical wood rods (60cm), and a horizontal bar of tubular newsprint covered with adhesive tape (65cm). The subjects performed the gait with obstacle crossing at self-selected speed. In total, three complete cycles of strides were recorded at each obstacle height. Height varied from 10% to 40% of the length of the lower limb of each participant, with an interval of 5%. The entire procedure was randomized. Kinematic analysis was performed with six infrared cameras adjusted to operate at a 100Hz acquisition frequency (Vicon®). Then, following the biomechanical model, 42 retroreflective markers were positioned in specific anatomical regions The segments analyzed included the pelvis and trunk, considered as a single segment divided into two portions, corresponding to the thoracic and lumbar spine. To estimate the angular movement of the thoracic and lumbar spine, two independent local reference frames were created, and the results were found by calculating Euler angles using MATLAB MathWorks®. The absolute angle of the trunk (single segment) was obtained via the thoracic segment, formed by markers placed on the clavicle, sternum, and seventh cervical vertebra (C7), along with the laboratory's global coordinate system in three planes. The absolute angle of the thoracic spine was estimated using Euler angles, with a local thoracic reference frame created using markers on C7, tenth thoracic vertebra (T10), and a point positioned on the right, having the laboratory's global coordinate system in three planes as a reference. The absolute angle of the lumbar spine was determined by estimating Euler angles from a local lumbar reference frame, created using points positioned at the fifth lumbar vertebra (L5) and the right and left posterior superior iliac spines, as described by Larivière[16] and Reynold, Snow, and Young[17].

Data analysis

Data distribution was verified by the Shapiro-Wilk test. A $p \leq 0.05$ significance level was adopted, and the following statistical tests were employed: Student's *t*-test, Mann-Whitney U, Friedman, Wilcoxon, and Pearson correlation. The magnitudes of the correlation coefficients were interpreted as follows: weak (0.10–0.35), moderate (0.36–0.67), and strong (0.68–1)[18]. Data were described as means and standard deviations.

RESULTS

Regarding the intergroup comparison of trunk flexion range (TFR), significant differences were observed between the groups, except at the 10% height, with higher angular range values being found for the EG (15%, p=0.006; 20%, p=0.000; 25%, p=0.010; 30% and 35%, p=0.005; 40%, p=0.002). In the trunk inclination range (TIR), no significant differences were found between the groups. In the trunk rotation range (TRR), the angular values of the EG were higher than those of the CG at heights of 35% (p=0.003) and 40% (p=0.002). Figure 1 shows the intragroup comparisons considering obstacle crossing heights and the TFR, TIR, and TRR variables.

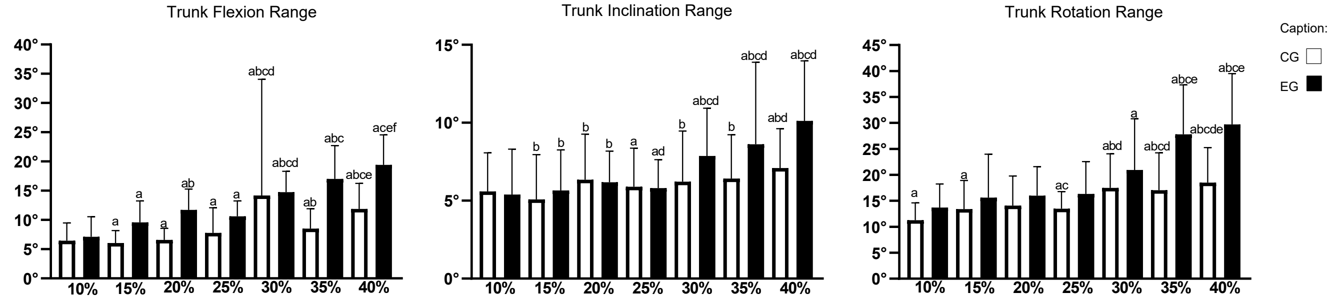

Figure 1. Intragroup comparisons of trunk angular variables considering obstacle crossing heights

Note: Intragroup Comparisons: Friedman test. a= difference for the 10% height; b= difference for the 15% height; c= difference for the 20% height; d= difference for the 25% height; e= difference for the 30% height; f= difference for the 35% height.

Regarding intergroup comparison, in the thoracic spine flexion range (TSFR), the angle of the EG was significantly higher than that of the CG only at the height of 35% (p=0.015). In the thoracic spine inclination range (TSIR), except for the height of 10%, significant differences were observed between the groups, with higher angular amplitude values observed for the EG (15%, p=0.014; 20%, p=0.000; 25%, p=0.007; 30%, p=0.010; 35%, p=0.000; 40%, p=0.002). In the thoracic spine rotation range (TSRR), higher angular values for the EG were observed at the heights of 10% (p=0.038), 25% (p=0.008), 35% (p=0.001), and 40% (p=0.000). Figure 2 shows the intragroup comparisons considering the height of the obstacles and the variables TSFR, TSIR, and TSRR.

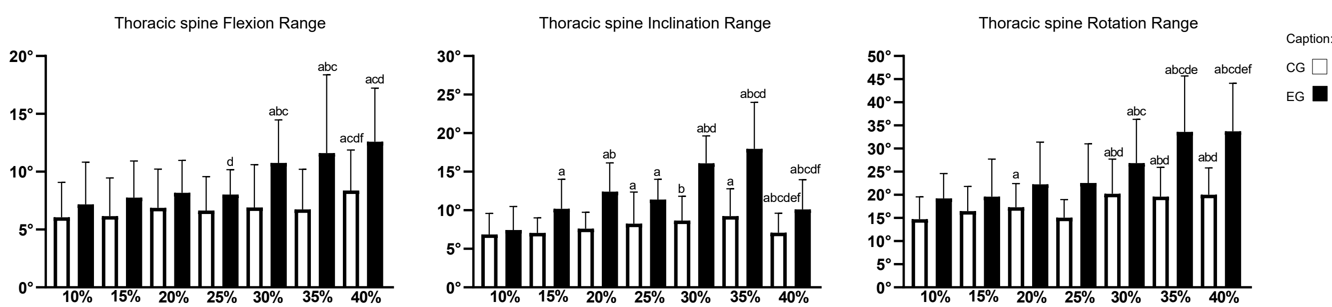

Figure 2. Intragroup comparisons of thoracic spine angular variables considering obstacle crossing heights

Note: Intragroup Comparisons: Friedman test. a= difference for the 10% height; b= difference for the 15% height; c= difference for the 20% height; d= difference for the 25% height; e= difference for the 30% height; f= difference for the 35% height.

Regarding intergroup comparison of pelvic flexion range (PFR), significant differences were observed between the groups, with higher angular range values for the EG at all obstacle crossing heights. In the pelvic inclination range (PIR), no significant differences were observed. However, in the pelvic rotation range (PRR), the angular values for the EG were significantly higher at the heights of 20% (p=0.027), 30% (p=0.027), and 40% (p=0.013). Figure 3 presents the intragroup comparisons considering the obstacle crossing heights and pelvic variables.

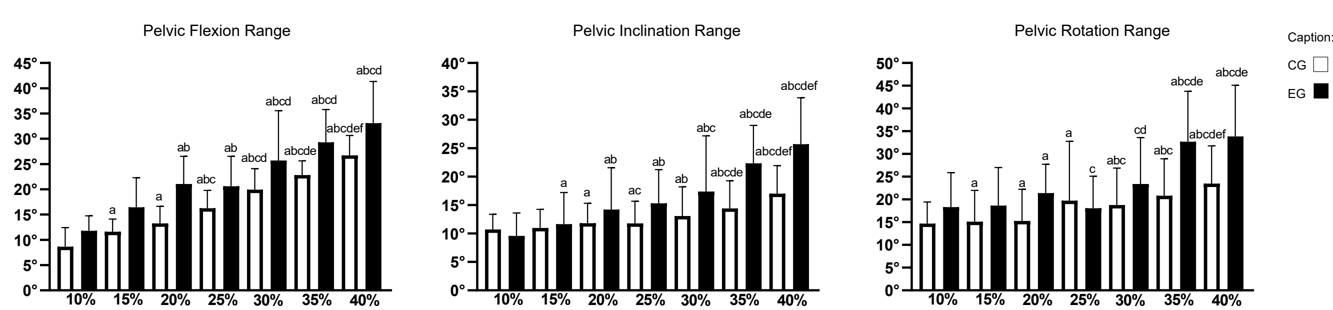

Figura 3. Intragroup comparisons of angular variables of the pelvis considering obstacle crossing heights.

Note: Intragroup Comparisons: Friedman test. a= difference for the 10% height; b= difference for the 15% height; c= difference for the 20% height; d= difference for the 25% height; e= difference for the 30% height; f= difference for the 35% height.

Regarding intergroup comparison of lumbar spine flexion range (LSFR), the angular value for the EG was significantly higher than that for the CG only at the 30% height (p=0.005). In the lumbar spine inclination range (LSIR), the angular values for the EG were significantly higher at the heights of 15% (p=0.008), 20% (p=0.001), 25% (p=0.002), 35% (p=0.000), and 40% (p=0.006). In the lumbar spine rotation range (LSRR), the results for the EG were significantly higher than those for the CG only at the heights of 20% (p=0.008) and 35% (p=0.003). Figure 4 shows the intragroup comparisons for these variables considering the different obstacle heights.

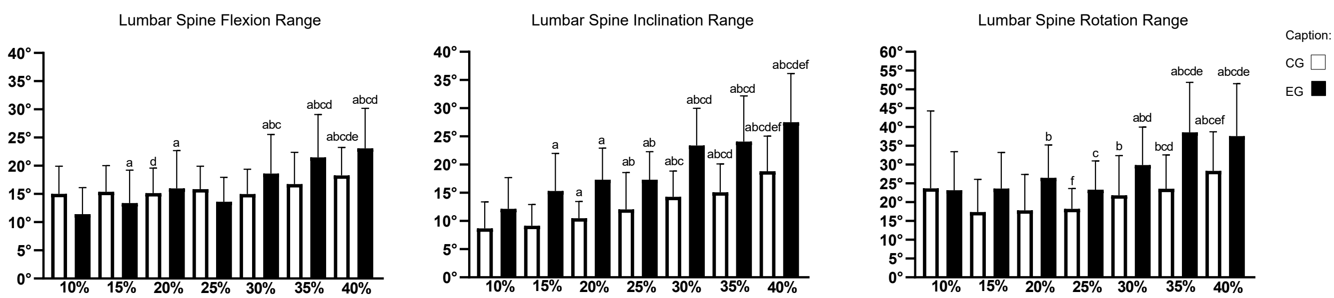

Figure 4. Intragroup comparisons of angular variables of the lumbar spine considering obstacle crossing heights

Note: Intragroup Comparisons: Friedman test. a= difference for the 10% height; b= difference for the 15% height; c= difference for the 20% height; d= difference for the 25% height; e= difference for the 30% height; f= difference for the 35% height.

Table 1 presents the Pearson correlation coefficient between the study variables and the obstacle heights for the CG and EG.

Table 1. Pearson correlation coefficient between the study variables and the obstacle heights for the experimental (EG) and control (CG) groups

Paramter	CG		EG	
	r	p	r	p
TFR	−0.17	0.116	0.70*	0.000
TIR	0.18	0.080	0.44*	0.000
TRR	0.39*	0.000	0.57*	0.000
PFR	0.87*	0.000	0.72*	0.000
PIR	0.43*	0.000	0.61*	0.000
PRR	0.34*	0.001	0.51*	0.000
TSFR	0.18	0.092	0.43*	0.000
TSIR	0.42*	0.000	0.70*	0.000
TSRR	0.31*	0.003	0.52*	0.000
LSFR	0.19	0.075	0.53*	0.000
LSIR	0.56*	0.000	0.60*	0.000
LSRR	0.19	0.079	0.46*	0.000

Note: Pearson correlation. *Significant correlation. **Caption:** Trunk Flexion Range (TFR); Trunk Inclination Range (TIR); Trunk Rotation Range (TRR); Pelvic Flexion Range (PFR); Pelvic Inclination Range (PIR); Pelvic Rotation Range (PRR); Thoracic Spine Flexion Range (TSFR); Thoracic Spine Inclination Range (RTSI); Thoracic Spine Rotation Range (TSRR); Lumbar Spine Flexion Range (LSFR); Lumbar Spine Inclination Range (LSIR); Lumbar Spine Rotation Range (LSRR).

For the CG, a strong correlation (r=0.87) was found for the pelvic flexion range (PFR) with the obstacle heights, a moderate correlation (r=0.56) for the lumbar spine inclination range (LSIR), and a weak correlation for the trunk rotation range (TRR) (r=0.39), pelvic inclination and rotation ranges (PIR; PRR) (r=0.43; r=0.34), and thoracic spine inclination and rotation ranges (RTSI; TSRR) (r=0.42; r=0.31).

For the EG, a strong correlation was found for the trunk flexion range (TFR) (r=0.70), pelvic flexion range (PFR) (r=0.72), and thoracic spine inclination range (RTSI) (r=0.70). A moderate correlation was observed for the trunk rotation range (TRR) (r=0.57), pelvic inclination and rotation ranges (PIR; PRR) (r=0.61; r=0.51), thoracic spine inclination and rotation ranges (RTSI; TSRR) (r=0.70; r=0.52), and lumbar spine flexion and inclination ranges (LSFR; LSIR) (r=0.53; r=0.60). Finally, weak correlations were observed for the trunk inclination range (TIR) (r=0.44), thoracic spine flexion range (TSFR) (r=0.43), and lumbar spine rotation range (LSRR) (r=0.46).

DISCUSSION

The main findings of this study indicate that the group of older adults, during obstacle crossing at different heights, exhibited higher angular range values in key variables such as trunk flexion and rotation, thoracic spine inclination and rotation, and pelvic flexion.

In both groups, the angular ranges of the trunk in flexion, inclination, and rotation were impacted by the variation in obstacle height during the crossing (Figure 1).

When comparing the groups, in the trunk flexion range, significant differences were observed at all heights except for the 10% height. This suggests that, for obstacles at heights equal to or greater than 15%, older adults differ from young adults, exhibiting greater trunk oscillation in the sagittal plane to perform the crossing. In other words, older adults perform postural adjustments to incline the trunk before starting the crossing step and subsequently adopt a trunk extension posture at the end of the movement[19].

In general, the EG had larger trunk ranges than the CG. These findings differ from those found in the study of Kovacs[20], who, in conducting a literature review on kinematic and physiological factors that change with aging, suggested that older adults adopt a more "rigid" posture as a strategy to ensure trunk stability. In this study, a possible explanation for the increased trunk ranges is that, in order to cross the obstacle with the second lower limb, these older adult women made adjustments to ensure this movement. The individual losing visual contact with the obstacle could also intensify this action.

In the thoracic spine, the data also suggest that the obstacle crossing height promoted significant changes in angular ranges (Figure 2). However, we found no progressive increase in range due to the height increment in either group, as observed in other variables. In the comparison of thoracic spine movements between the groups, we found that, for thoracic spine flexion, the older adult group showed a significantly higher value only at the 35% height. For inclination of this segment, the values for the older adults were higher, except at the 10% height. Hahn and Chou[13], using obstacle heights of 2.5%, 5%, 10%, and 15% of the individual's size, suggested that older adults, when crossing higher obstacles, exhibited greater ranges in the sagittal plane compared to young adults.

Considering the differences observed in the results of the trunk and thoracic spine, the data suggests that older adults need a greater range of these segments to fulfill the task. This crossing characteristic can be confirmed by the moderate correlation for trunk inclination range and the strong correlation for thoracic spine inclination range.

In the pelvis, we found that the ranges of flexion, inclination, and rotation progressively increased with the rise in obstacle height in both groups (Figure 3). In the comparisons between the groups, the data point that the older adults had higher values of angular flexion range at all obstacle crossing heights. In rotation, the EG values were higher at the heights of 20%, 30%, and 40%. These results suggest that older people have a different pattern than young people, rotating the pelvis more when crossing higher obstacles.

In the lumbar spine, obstacle height also promoted significant differences in angular range (Figure 4). In general, the EG presented higher angular range values when compared to the CG. In lumbar flexion, the angular range of older adults was higher at 30% height. For inclination, the values were higher starting at the 15% height, and for rotation, at the 20% and 35% heights. Moreover, the data from this study suggested that lumbar flexion and inclination in the EG showed a moderate correlation with obstacle heights. Finally, we highlight that the participants were selected intentionally, which is a limitation of this study.

Given the findings of this study, it can contribute to further research and discussions regarding the influence of the trunk and pelvis in the task of obstacle crossing. Moreover, the results show practical implications and can contribute to healthcare professionals developing physical activity and rehabilitation programs based on scientific data. These data can aid assess task intensity to improve motor aspects that enable older adults to perform the task of obstacle crossing with autonomy and safety.

CONCLUSION

Although the general locomotion strategies were similar between young and older adults, the gait behavior appeared to be heterogeneous. The greater variability in the older adult group (EG) was possibly due to age-related biomechanical changes. The EG, to ensure obstacle crossing, increased the range of motion of the trunk. In summary, postural adjustments in the trunk, thoracic spine, lumbar spine, and pelvis were necessary for these older adult women to perform the task. The results support the hypothesis that older adults show a linear increase in trunk and pelvis displacement during the crossing task as the obstacle height increases.

We suggest that further studies be conducted with groups of older adults with physical restrictions and/or illnesses, as well as individuals in the developmental stages, such as children and adolescents. Additionally, the potential benefits of intervention programs and the use of biomechanical equipment, such as accelerometers or electromyographs, should be explored. The results may aid Physical Education professionals and physical therapists with new information regarding the strategies employed by older adults to cross obstacles, especially in relation to the trunk. In this way, exercises and activities aimed at mobility and strengthening of the trunk and hip can be included in the physical activities of this population.

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