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ORIGINAL RESEARCH

Falls risk detection based on spatiotemporal parameters of three-dimensional gait analysis in healthy adult women from 50 to 70 years old

Medidas temporoespaciais indicativas de quedas em mulheres saudáveis entre 50 e 70 anos avaliadas pela análise tridimensional da marcha

La detección de los riesgos de caídas en muyeres sanas de 50 a 70 años de edad desde el análisis de medidas temporoespaciales de la marcha

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ABSTRACT | The aim of this study was to compare and correlate spatiotemporal parameters that would indicate falls risk. Thirty-five healthy women without a history of falls in the previous year were selected. Five spatiotemporal parameters were collected from right (R) and left (L) lower limbs using three-dimensional gait analysis. Two groups: young women (20-40 years) and adult/older women (50-70 years) were analyzed. The comparisons between the groups differed in R (p=0.003) and L (p=0.002) stride length, R (p=0.008) and L (p=0.001) step length, L stance period (p=0.008), R step period (p=0.049), L double support time (p=0.003), step width (p=0.005), L loading response time (p=0.001), R (p=0.001) and L (p=0.001) pre-swing time. Gait cycle percentage data also showed statistical difference in L stance (p=0.001), L swing (p=0.001), L single support (p=0.025), L loading response (p=0.001), R (p=0.014) and L (p=0.001) pre-swing. Linear regression indicated that step and stride length increased 18% and gait velocity increased 20% with age variation. The results propose that functional measures (velocity, step and stride length) decrease as age increases, while stability measures (stance, double support and pre-swing time) increase. These findings suggest that women aged between 50-70 years may have falls risk. Women aged 50-60 are usually considered as having low falls risk.

Keywords | Gait; Accidental Falls; Women's Health; Middle Age; Biomedical Technology.

RESUMO | Objetivou-se comparar e correlacionar medidas temporoespaciais da marcha indicativas de quedas. Participaram do estudo 35 mulheres saudáveis, sem histórico de quedas no ano da avaliação. A análise computadorizada tridimensional da marcha forneceu cinco medidas temporoespaciais de cada participante, dos membros inferiores direito (D) e esquerdo (E). A análise inferencial abordou dois grupos de mulheres: jovens (20 40 anos) e adultas-idosas (50-70 anos). Houve diferença estatística significativa entre os grupos para comprimento da passada D (p=0,003) e E (p=0,002); passo D (p=0,008) e E (p=0,001); tempo de apoio E (p=0,008); tempo de passo D (p=0,049); tempo de apoio duplo E (p=0,003); largura da base E (p=0,005); resposta à carga E (p=0,001); pré-balanço D (p=0,001) e E (p=0,001) e para algumas medidas em percentil do ciclo de marcha: apoio E (p=0,001); balanço E (p=0,001); apoio simples E (p=0,025); resposta à carga E (p=0,00); pré-balanço E (p=0,001) e pré-balanço D (p=0,014). A regressão linear indicou que a variação da idade modificou em média 18% as medidas de comprimento do passo e da passada e em 20% a velocidade da marcha. Com o avanço da idade, as medidas funcionais diminuíram; e, consequentemente, as medidas de estabilidade, como duração dos períodos de apoio, apoio duplo e pré-balanço, aumentaram.

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Essas modificações indicam risco de queda na faixa etária de 50 a 70 anos. Algumas medidas de marcha podem apresentar alteração em uma faixa etária ainda considerada de baixo risco.
Descritores | Marcha; Acidentes por Quedas; Saúde da Mulher; Meia-Idade; Tecnologia Biomédica.

RESUMEN | El propósito de este estudio fue comparar y correlacionar las medidas temporoespaciales de la marcha, indicativas de caídas. Del estudio participaron 35 mujeres sanas, sin historial de caídas en el periodo del estudio. El análisis computadorizado tridimensional de la marcha brindó cinco medidas temporoespaciales de cada participante, de los miembros inferiores derecho (D) e izquierdo (I). En el análisis inferencial se evaluaron dos grupos de participantes: jóvenes (20-40 años) y adultas-personas mayores (50-70 años). Hubo diferencia estadísticamente significativa entre grupos en la longitud del paso D (p=0,003) e I (p=0,002); paso D (p=0,008) e I (p=0,001); tiempo de apoyo I (p=0,008); tiempo de paso D (p=0,049); tiempo de doble apoyo I (p=0,003); longitud de la base I (p=0,005); respuesta a la carga I (p=0,001); preoscilación D (p=0,001) e I (p=0,001) y para algunas medidas en percentil de ciclo de marcha: apoyo I (p=0,001); oscilación I (p=0,001); apoyo simples I (p=0,025); respuesta a la carga I (p=0,00); preoscilación I (p=0,001) y preoscilación D (p=0,014). La regresión lineal mostró que la variación de la edad cambió en media un 18% en las medidas de la longitud del paso y del movimiento y un 20% en la velocidad de marcha. Avanzado la edad, las medidas funcionales disminuyen, y, en consecuencia, aumentan las medidas de estabilidad, como duración de los periodos de apoyo, doble apoyo y preoscilación. Esos cambios señalan el riesgo de caída en la franja etaria de 50 a 70 años. Algunas medidas de marcha pueden presentar alteraciones en una franja etaria que todavía la consideran de bajo riesgo.
Palabras clave | Marcha; Accidentes por Caídas; Salud de la Mujer; Mediana Edad; Tecnología Biomédica.

INTRODUCTION

The most consistent factor to predict falls is the intrinsic gait modification[1], usually undetected by clinical scales[2]. Thus, the three-dimensional instrumented analysis is the gold standard evaluation for the study of the gait.[3].

Velocity[4], step length[2] and stride length[5,6], pre-swing time and double support[7] are the gait measures most frequently associated with the risk of falling among senior fallers and non-fallers over 65 years old.

The prevalence and the incidence of gait alterations increase with age[8]. Gait alterations related to falls risk in women in the age range between adulthood and old age were not identified by Brazilian literature, and international studies are also very few[9]. The detection of dynamic instability in age groups which are not considered risk groups could offer information about the prevention of changes in mobility and of the decrease of functional abilities, in addition to encouraging changes in the daily habits that promote healthy aging[10], which minimizes physical, financial and social aggravations.

The present study aimed at comparing and correlating the spatiotemporal gait measures that predict falls in young women and older women.

MATERIALS AND METHODS

An analytical cross-sectional study performed at the Dr. Cláudio de Almeida Borges Movement Laboratory of the Federal University of Goiás (UEG), approved by the Research Ethics Committee of the Federal University of Goiás, protocol no. 741,298/2014. All volunteers signed the free and clarified consent form.

Sample

A purposive sample composed of healthy women from the metropolitan region of Goiânia, Goiás, who were invited to participate. The sample calculation for the study considered a 95% confidence interval, a 0.05 significance level (type I error), power of 95% (type II error), effect size 1.29. Using the stride length measure, the calculation showed the need for 34 subjects, 17 for the group of young women and 17 for the group of adults and seniors. The calculation was made using the GPower software version 3.2. Considering a 10% loss, the n determined corresponded to 19 subjects in each group.

The exclusion criteria were: informing osteoarthrosis in the spine and/or endoprosthesis in the lower limbs; medical diagnosis of rheumatoid arthritis, neuromuscular or neurodegenerative disease, including diabetes mellitus; sequela of neurological disease; joint pain or edema in the last 30 days; an abdominal volume that prevented the visualization of reflective markers on the pelvis; visual disability; body mass index (BMI) equal to or higher than 30 kg/m^2; use of auxiliary devices for the stride; regular physical activity11; no history of falls in the year before the evaluation of the gait.

Functional limitations and falls increase with age for women12. A BMI higher than 30 causes gait alterations in the elderly caused by obesity13,14. Gender and age mark the difference between the spatiotemporal gait parameters starting from the age of 70, regardless of the fall history8. The association between these factors justifies conducting this study with a sample of women stratified into the groups of young women and adults/older adults, without a fall history.

Study procedures

In orthostatism, reflective markers were placed in the participants, following the Helen Hayes model15. The collections were performed individually while the woman walked barefoot at a self-selected velocity, in a walkway with 8 meters of length with two force plates (AMTI® model OR6; OR7) located on the ground, until five valid footages were obtained for each woman.

Each footage lasted seven seconds and was recorded with two VHS cameras in the sagittal and frontal views, and with six Pulmix® infrared cameras of 120hz per second (model TM 6701AN). Data processing was carried out with the Vicon Peak 9.2®16-18 software.

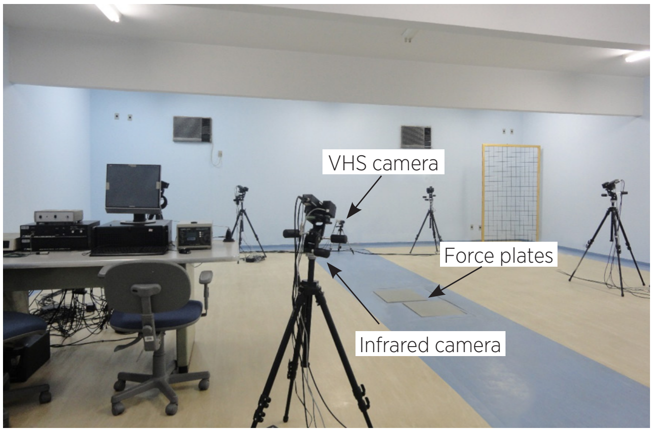

Figure 1. Panoramic view of the UEG Laboratory, indicating force plates, infrared cameras and VHS cameras

The spatiotemporal measures considered in the research led to a total of 46 variables, considering the right and left sides independently, as defined in the chart below[19,20].

The statistical analysis verified the normality of the distribution of the data with the Shapiro-Wilk test, considering $p \leq 0.01$. An inferential analysis was performed with the average, the standard deviation and the confidence interval. The group averages were compared using T-Student and Mann-Whitney tests, following the distribution of the variable. Linear regression was used to analyze the prediction of alterations in the spatiotemporal gait variables caused by age. Statistical Package for Social Sciences software, version 22.0, confidence level 95%.

Chart 1. Description of the spatiotemporal gait parameters applied in the research

Gait parameters (unit of measurement)	Description
Step length (meters)	Anteroposterior distance from the initial contact of one foot until the contact of the other foot.
Stride length (meters)	Anteroposterior distance between two consecutive steps of one foot.
Base width (meters)	Perpendicular distance to the line of progression between the points of contact of the feet.
Cadence (steps/minute)	Number of steps per minute.
Step period (second)	The period of time taken from the initial contact of one foot to the initial contact of the other foot.
Stride period (second)	The period of time between the initial contacts of two consecutive steps of the same foot.
Stance period (second)	The period of time between the initial contact of one foot to the moment the same foot leaves the ground.
Swing period (second)	The period of time between the moment one foot leaves the ground and the initial contact of the same foot.
Single support time (second)	The period of time when only one foot is in contact with the ground.
Double support time (second)	The period of time when both feet are in contact with the ground.
Cyclic parameters (percentage)	Corresponds to all the events of a gait cycle measured in percentage.
Gait velocity (meters/second)	Distance covered in a certain period of time.

Results

The sample is composed of two groups of women: young women (n=19, average age 28.5 ± 5.6) and adults-older adults (n=19, average age 61.2 ±6,9) (Table 1).

The adults and older adults of the study were eutrophic, with an average BMI of 23.0 kg/m2 (21). A statistically significant difference was observed in the comparison between young women and adults/older adults for many spatiotemporal parameters (Table 2).

The comparison (table 2) and the linear regression (table 3) presented results that indicate differences between both groups, with the presence of measures of falls risk.

Table 1. Average, standard deviation (SD), Shapiro-Wilk test and confidence interval (CI) of 95% of the anthropometric variables, comparing the age groups of young women (20-39 years old) (n=19) and older women (50-67 years old) (n=16), using the T-test for independent samples

Anthropometric variables	Average (SD)		Shapiro-Wilk	T-test (p<0.05)
	Young women	Adults/older adults	Young woman/ adult-older adult	
Age (years)	28.5 (5.66)	61.2 (6.99)	0.07/0.14	< 0.001*
Weight (kilograms)	54.7 (7.88)	59.7 (8.87)	0.70/0.35	0.073
Height (meters)	1.59 (0.06)	1.56 (0.06)	0.04*/0.58	0.125
Body mass index (kg/m^2)	21.7 (2.96)	24.5 (3.04)	0.40/0.39	0.007*

*Significant difference between groups
Source: Elaboration of the research

Table 2. Comparison of the spatiotemporal gait parameters of young women (n=19) (20-40 years old) and adult and older adults (n=16) (50-70 years old), adopting a statistical significance of p<0.05, using Student's t-test

Gait variables	Average/Median/(SD)		CI (95%)		p
	Young women	Adults and older adults	Upp.	Low.	
Stride length R (m)	1.30±0.07	1.20±0.08	1.33	1.16	0.003
Stride length L (m)	1.31±0.07	1.21±0.09	1.34	1.16	0.002
Step length R (m)	0.67±0.04	0.61±0.05	0.69	0.58	0.008
Step length L (m)	0.64±0.04	0.59±0.04	0.66	0.57	0.001
Stance period L (s)	0.64±0.04	0.39±0.02	0.66	0.38	0.008
Step period R (s)	0.54±0.03	0.55±0.02	0.56	0.52	0.049
Double support L (s)	0.24±0.03	0.28±0.04	0.31	0.22	0.003
Base width L (m)	0.12 *	0.1 *	0.13	0.08	0.005[1]
Loading response L (m)	0.14±0.01	0.16±0.01	0.17	0.14	0.001
Pre-swing R (s)	0.14±0.01	0.16±0.01	0.17	0.14	0.001
Pre-swing L (s)	0.10±0.02	0.12±0.02	0.14	0.09	0.011
Stance period L (%GC)	61.26±1.24	63.27±1.88	64.27	60.66	0.001
Swing period L (%GC)	38.74±1.23	36.72±1.88	39.34	35.72	0.001
Single support period L (%GC)	37.68±1.14	36.64±1.44	38.23	35.87	0.025
Loading response time L (%GC)	13.67±0.82	14.94±1.11	15.54	13.28	>0.001
Pre-swing period R (%GC)	13.76±0.88	15.11±1.28	15.79	13.34	0.001
Pre-swing period L (%GC)	9.90±1.80	11.68±2.26	12.89	9.04	0.014

Source: Elaborated by the researcher.
Caption: Upp.– upper; Low.-lower; R- right; L- left; *median values; 1 Mann-Whitney; % GC- percentage of the gait cycle; m.- meters; s.-seconds.

Table 3. Analysis of the prediction of age on the alterations of spatiotemporal gait parameters. Using linear regression, containing the values of R and R^2 and considering the values of p <0.05 significant

Spatiotemporal gait parameters	R	R^2(%)	(p<0.05)
Stride length R	0.44	0.195	0.002
Stride length L	0.42	0.184	0.003
Step length R	0.43	0.189	0.003
Step length L	0.4	0.155	0.007
Stance period R	0.41	0.171	0.005
Stance period L	0.48	0.234	0.001

to be continued...

Tabela 3. Continuation

Spatiotemporal gait parameters	R	R^2(%)	(p<0.05)
Double support period R	0.48	0.237	0.001
Double support period L	0.6	0.368	<0.001
Pre-swing period R	0.62	0.386	<0.001
Pre-swing period L	0.53	0.288	<0.001
Pre-swing R in percentage of the cycle	0.56	0.324	<0.001
Pre-swing L in percentage of the cycle	0.53	0.285	<0.001
Average velocity	0.45	0.204	0.002

Source: Elaborated by the researcher.
Caption: R_right; L_left

DISCUSSION

In the study, women aged between 50 and 70 years showed a premature alteration in the spatiotemporal gait parameters, indicating falls risk. Gait alterations in older adults start to occur between the ages of 60 and 65 years[22,23], without considering the falls risk of the population of age between 45 and 65 years[24].

Other biomechanical markers of alterations in the locomotor system which indicate falls risk were also identified. Muscle weakness, changes in joint mobility, in flexibility and in balance are conditions that characterize aging and influence gait, regardless of the age defined for the senescent[25].

There was a significant difference for the spatiotemporal measures of the right and left sides, confirming asymmetry and falls risk for the women in the research, similar to Patterson et al.[26]. These differences could have been caused by the oscillation of the center of mass or by the direction of the dominant foot during the swing phase[27].

The base width measure showed a significant statistical difference between young women and adult/older adults in the study, which is compatible with Muir et al.[28]. Base width affects balance and gait, regulating the positioning of the center of mass[29] and revealing the difference between the gait of the falling and the non-falling elderly person[4].

The average gait velocity is a functional marker that indicates falls risk for the older adult[30], especially after the seventh decade of life[11]. In the study, with an average age of 42, the gait velocity of the young women was 1.26 m/s, while for adults and older adults it was 1.12 m/s. These values are compatible with other studies[(31,32]. Then, the effect of age variation on the velocity was considered. Linear regression showed that for every year added the gait velocity of the woman undergoes a 20% change. The decrease of the gait velocity can be used as a marker of frailness[33]. The sooner the alteration of gait velocity is identified, the better the therapy to decrease falls risk.

The step and stride lengths presented a significant difference bilaterally. The decrease of the stride length is associated with falls in men aged above 74 years, but not in women in that same age range, nor in men and women aged between 65-74 years[4].

In the present study, the functional measures of step length, stride length and velocity decreased with age, while the measures of stability (stance, double support and pre-swing time) increased with age, aiming at stability to reduce falls risk[34,35].

The double support measure was directly related to age after 50 years (R = 0.48 and p = 0/010 to the right and R = 0.60 and p<0.001 to the left), which is compatible with LaRoche et al.[36].

Physical therapy programs[37] lead to changes in the parameters of velocity, stride period and stride length, which are measures of falls risk.

The spatiotemporal measures present subtle changes, and the tridimensional motion analysis equipment detect minimal differences in gait caused by age.

CONCLUSION

The measures of step length, stride and velocity decrease, while the measures of stance period, double support and pre-swing increase. When comparing both age groups, the alterations that indicate falls risk occur between the ages of 50 and 70. Our findings add to the knowledge on gait alterations for an age group not considered a risk group.

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