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ORIGINAL RESEARCH

Relation of plantar pressure and range of movement of the lower limbs with the risk of falls in older women

Relação da pressão plantar e amplitude de movimento de membros inferiores com o risco de quedas em idosas

Relación entre la presión plantar y la amplitud de los movimientos de los miembros inferiores y el riesgo de caídas en adultos mayores

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ABSTRACT | The aim of this study was to verify the influence of plantar pressure and range of motion of hip, knee and ankle variables with the risk of falls in older women. Thirty-nine older women participated, for which Maximum and Medium Pressure were evaluated using the baropodometry platform. Then, we performed the Timed Up and Go (TUG) test and subsequently the range of motion (ROM) evaluation of hip and knee flexion and dorsal and plantar ankle flexion through the use of a goniometer. Baropodometric variables (Maximum Pressure and Medium Pressure) showed a tendency to influence the values of the TUG according to the value of the hypothesis test (P = 0.051), demonstrating a moderate correlation (R = 0.487), with emphasis on the Maximum Pressure showing significant correlation with the TUG (P<0.005). However, the joint range of motion of hip, knee and ankle showed no significant correlations in the baropodometric variables and in the risk of falls. Concerning the analysis of the association between the TUG classified with low and medium risk of falls with the falls, no differences were found (P=0.475). The increase in maximum pressure showed a relation with the risk of falls, though the range of motion of hip, knee and ankle showed no relation to the risk of falls and the baropodometric variables in the researched population.

Keywords | Foot. Postural Balance; Aged.

RESUMO | Objetivou-se verificar a influência das variáveis de pressão plantar e amplitude de movimento (ADM) de quadril, joelho e tornozelo sobre o risco de quedas em idosas. Participaram 39 idosas, avaliando-se a Pressão Máxima e Média sobre a plataforma de baropodometria. Em seguida, realizou-se o teste *Timed Up and Go* (TUG) e posteriormente a avaliação da ADM de flexão de quadril e joelho e flexão plantar e dorsal de tornozelo por meio de um goniômetro. As variáveis baropodométricas (Pressão Máxima e Pressão Média) tenderam a influenciar os valores do TUG conforme valor do teste de hipótese (p=0,051), demonstrando correlação moderada (r=0,487), com destaque para a Pressão Máxima, que apresentou correlação significativa com o TUG (p<0,005). Entretanto, a ADM articular de quadril, joelho e tornozelo não apresentaram correlações significativas entre as variáveis baropodométricas e risco de quedas. Sobre a análise da associação entre o TUG, categorizado em baixo e médio risco de quedas, e as quedas, não foram observadas diferenças (p=0,475). O aumento da pressão máxima apresentou relação com o risco de quedas, mas a ADM de quadril, joelho e tornozelo não apresentaram relação sobre o risco de quedas e as variáveis baropodométricas na população investigada.

Descritores | Pé; Equilíbrio Postural; Idoso.

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RESUMEN | Se buscó evaluar la influencia de las variables de la presión plantar y la amplitud de los movimientos (ADM) de la cadera, rodilla y del tobillo en el riesgo de caídas en adultos mayores. Han participado del estudio 39 adultos mayores, de los que se evaluaron su presión máxima y media a través de la baropodometría. Además, se empleó la prueba *Timed Up and Go* (TUG) y la evaluación de la ADM de flexión de cadera y rodilla, y flexión plantar y dorsal del tobillo a través de un goniómetro. Las variables baropodométricas (presión máxima y media) presentaron influencias en los valores del TUG según el valor de la prueba de hipótesis (p=0,051), lo que demostró una moderada correlación (r=0,487), destacándose la presión máxima, que presentó una significativa correlación con el TUG (p<0,005). La ADM articular de la cadera, rodilla y del tobillo no ha presentado significativa correlación entre las variables baropodométricas y el riesgo de caídas. Acerca del análisis entre el TUG, caracterizado de bajo y mediano riesgo de caídas, y las caídas no se han observado diferencias (p=0,475). El aumento de la presión máxima presentó relación con el riesgo de caídas, sin embargo la ADM de la cadera, rodilla y del tobillo no presentó relaciones entre el riesgo de caídas y las variables baropodométricas evaluadas en los participantes.

Palabras clave | Pie; Balance Postural; Adulto mayor.

INTRODUCTION

As a result of the aging of the Brazilian population, 13% of the general population will consist of older people by the year of 2020[1], increasing the risks of chronic degenerative diseases[2] and physical disabilities such as decreased range of motion (ROM) and plantar pressure distribution alterations, which alter the proprioception leading older adults to insecurity, postural instability and falls[3].

Due to the aging process, structural and functional alterations occur, varying from an individual to another[4], being a complex and multifactorial process[5]. Such alterations affect the musculoskeletal system, accompanied by a loss of muscle mass, decrease of strength and ROM of lower limbs (LL), of endurance[6-8] and alterations in bone structure, such as alterations in the feet, influencing plantar pressure distribution, affecting the somatosensory information and therefore, balance[9-12].

Since older adults go through alterations in balance, they reduce their daily life activities, due to fear of falls, injuries and functional immobility, causing them to have less autonomy and dependence, important indicators of quality of life for this population[2].

Various methods have been developed to evaluate balance, plantar pressure and ROM, which include simple observations, clinical tests, scales and posturographic measures. All of these methods have advantages and limitations and can provide different results with multiple interpretations[13].

Some functional tests like the Timed Up and Go (TUG) and Goniometry, respectively used to evaluate the risk of falls and articular freedom of movement, are widely employed due to easy applicability and low cost, allowing professionals to make an analysis of the propaedeutics, the evolution of the treatment and a quantitative model-based prognosis. On the other hand, baropodometry explores variations in the bases of support, to measure and compare the distribution of pressure on the feet, providing qualitative data on step morphology, and displacement of the center of gravity[14-17].

The importance of plantar pressure distribution evaluation and ROM of LL are due to the fact that by identifying possible relations between these variables, preventive measures could be adopted to prevent falls. Moreover, research on plantar support is still scarce, but has need for a greater number of approaches, since the analysis of this segment can identify instability in the walking of the individual. The importance of using more accessible tools for clinical practice which may assist in the evaluations and therapeutics involving alterations in plantar pressure distribution also stands out.

All of this considered, it is believed that plantar pressure variations and ROM of LL influence the risk of falls. The aim of this study was to verify the relation of plantar pressure variables and the ROMs of hip, knee and ankle with the risk of falls in older women.

METHODOLOGY

This is a cross-sectional and descriptive study with a quantitative approach. Older women were recruited in Senior Living Centers and Basic Health Units in the city of Londrina, Paraná, Brazil, from June to July, 2014. Inclusion criteria were age ≥ 60 years old, being

physically independent and cognitive state preserved, cutting note ≥ 19, depending on their education level, according to the Mini Mental State Examination (MMSE)[18].

For the exclusion criteria, the older women could not have any disabling injury and lower limb fracture, use of orthotics and prosthetics on the lower limbs, visual, vestibular and neurological disorders and being unable to perform some of the tests.

The sample was determined through the program BioEstat 5.0, used as a parameter of mean value and standard deviation. Considering the confidence interval of 95%, 5% alpha level and 80% power test, it was determined that the minimal sample would be 39 individuals. Considering the losses, 45 individuals were evaluated.

This study was approved by the Research Ethics Committee of UNOPAR, as stated in opinion 276.702. After being oriented regarding the study, the older women signed an informed consent form, answered the MMSE and were questioned about the occurrence of falls, with simple answers, yes or no, and the time of the falls (being these in the last 12 months). Then, after familiarization with all instruments, the plantar pressure distribution analysis, the TUG and finally the ROM in LL analysis were made.

For the plantar pressure distribution analysis the electronic baropodometric platform (Footwork, Arkipelago®) was used. The women stood on it, barefoot, with eyes open, in a relaxed posture and with arms on the sides of the body. They were oriented to stare at a fixed point marked on the wall 2 meters away from the platform and at eye height. The static evaluation was made with bipedal support, and the images were captured in a time frame of 30 seconds and recorded in a microcomputer with specific software. The analyzed variables were maximum pressure (Max_P) and medium pressure (Med_P). Then the TUG was applied, which was measured in seconds to estimate the time taken to get up from a chair, walk a distance of three meters, rotate 180°, walk toward the chair and sit down again. No help is given during the test and after it, the women were classified according to the time spent: less than 10 seconds: low risk of falls; 10 to 20 seconds: medium risk of falls and over 20 seconds: high risk of falls[19].

The last test was the ROM in LL analysis, using the Universal Goniometer (Carci®). During the ROM analysis of hip flexion, the individual remained in supine position, the stationary arm of the goniometer was positioned on the axillary line of the trunk, the moving arm on the lateral surface of the thigh and the central axis was positioned on the greater trochanter. Then, the hip flexion with the knee extended was performed, up to the maximum point of pain sensation to obtain this degree of range. Then, the women remained in prone position with knees out of the stretcher, to evaluate the knee's ROM. The stationary arm of the goniometer was placed on the lateral surface of the thigh, the moving arm on the lateral surface of the leg and the central axis over the joint line of the knee joint. Then the flexion movement was requested to obtain the ROM of this joint. For the evaluation of the ROM of the ankle the individual.remained sitting on the stretcher, knees out and suspended, flexed at 90 degrees. The stationary arm of the goniometer was placed on the lateral surface of the leg, the moving arm on the lateral surface of the foot, with the central line on top of the last metatarsal and the central axis over the lateral malleolus; the dorsal flexion movement followed by plantar flexion in order to obtain the total ROM of this joint[20,21] was then made. Three evaluations were carried out in order to extract the largest angulation of the ROM (of the 3 joints), the largest measure found between the two limbs[22] being the one used.

The statistical data is displayed in mean value and standard deviation. The normality of the data was verified through the Shapiro-Wilk test. To observe whether there is correlation between the baropodometry and ROM with the TUG and ROM with the baropodometry's variables, a Simple Linear Regression and the Chi-Square test were applied in order to verify the relation between ROM and the falls. The statistical package used was SPSS version 20. The significance adopted for this study was of 5% ($P < 0.05$).

RESULTS

We evaluated 39 older women, aged 70.94 (DP 5.46) years, weight of 61.91 kg (DP 11.67), height of 1.53m (DP 0.058) and BMI of 26.36kg/m^2 (DP 3.94). They had a ROM of 88.05° for the hip (DP 11.00), 111.87° for the knee (DP 13.84) and 43.95° for the ankle (DP 8.36). Regarding the TUG they were classified with low and medium risk (10.00; DP 2.77). The association between low and medium risk of falls, based on the TUG with the falls in the last year (Chi-Square=0509, p=0.475) has not been verified.

Table 1. Analysis of the association of the TUG and the falls

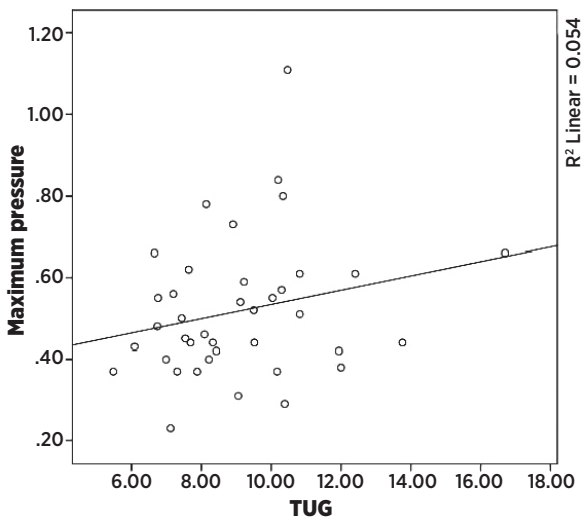
Falls		TUG		Total
		Low risk	Medium risk	
Yes	n %	10 71.4%	4 28.6%	14 100.0%
No	n %	15 6.0%	10 40.0%	25 100.0%
Total	n %	25 64.1%	14 35.9%	39 100.0%

Chi-square=0.509, p=0.475

In the analysis of the influence of the baropodometric variables (Med_P; Max_P), we observed a tendency to influence the values of the TUG (Linear Regression, f=2.636; p=0.051), with moderate correlation (r=0.487). Thus, it is possible to conclude that these variables account for 23.7% of the total variance of the TUG in the studied sample, with emphasis on the Max_P which obtained statistical significance compared to the TUG (p<0.005).

Table 2. Analysis of the influence of baropodometry with the TUG

Dependent variable	Predictive variables	Standardized coefficient	95%CI	Value of p
TUG	Max_P	1.597	6.715/35.454	0.005*
p<0.05= significance	Med_P	−1.078	−8.073/0.210	0.062



Graph 1. Relation of influence of Maximum Pressure with the TUG

In the analysis of the relation of the ROM of LL with the TUG a significative influence (Linear Regression, f=1,743; p=0.176), in which there was weak correlation (r=0.361), representing only 13.0% of the total variance of the TUG was not observed. The same was found in the analysis of the relation between ROM of LL and the Max_P (Linear Regression, f=0.119; p=0.948), a weak correlation (r=0.100) having been found, representing only 10.0% of the total variance of the Max_P.

DISCUSSION

The increase of plantar pressure can influence falls, due to the fact that proprioception and sensory information of the plantar surface are the most important factors for the maintenance of postural balance in normal conditions[23], considering that, when walking, the foot is the only structure of the human body in contact with the ground , and any factor that can interfere with the normal function, as is the case of plantar pressure, could harm the stability and corporal balance[24].

In addition, Menz and Lord[25] investigated the alterations in the foot and their direct relation with the performance in tests of coordinated stability and in functional tests, and found that these alterations had direct relation to the performance in these tests because broader body movements interfere with a greater function of the base, and that would cause a deficiency in the response of stability for individuals who have foot problems such as plantar pressure increase.

Therefore, Alfieri et al.[11] examined the influence of a physiotherapeutic intervention program focused on proprioceptive stimulation over postural stability in older adults; they demonstrated a significant increase in plantar contact area in bipedal stances through baropodometry, as well as a significant decrease of the contact pressure peak on the plantar surface, facilitating the control of movements, since the number of plantar sensory receptors touching the surface also increases, supplying the nervous system with more precise information from the periphery, favoring a better distribution of pressure peaks facilitating motor control and postural stability[26], demonstrating that the increase of plantar pressure can influence the risk of falling.

Consequently the plantar cutaneous sensory stimulus represents an important role in the regulation of human walking, contributing to postural control in conditions of multidirectional postural alterations that occur unpredictably during walking, considering that the inputs of the plantar mechanoreceptors

provide detailed information which facilitate compensatory reactions[27].

Regarding the analysis of the relation of the TUG test with the falls, an association has not been verified since the studied population was classified with low and medium risk of falls, considering that all of the older women are physically active and do not show any alterations in muscles and joints, which could contribute to the risk of falls. The time taken to perform the TUG test is directly associated with the level of functional mobility[28]; therefore a good TUG test performance in this study can be attributed to the benefits from the neuromuscular and morphological adaptations that come from daily work activities, which may be responsible for a not as steep decline of these motor skills.

Regarding the relation of the ROM with the TUG test, some authors report that the decrease of ROM caused by aging affects the coordination and balance, what predisposes the individual to falls[7], which was not found in the investigated population, demonstrating that the etiology of the falls is usually multifactorial[29,30] and results from the interaction between intrinsic and extrinsic factors[31].

However, Carvalho et al.[12] demonstrated the relation of low mobility of the hallux with plantar pressure increase in older adults when compared to young adults. The fact this joint has not been investigated by this study justifies the absence of the relation between the ROM of LL with plantar pressure increase.

Although it was possible to consider the contribution of high plantar pressures to falls, other variables like type of feet can also play an important role[25], and may influence plantar pressure distribution. However, the importance of evaluating muscular strength and endurance, once weakness and limitation of ROM in LL would be associated with alterations of walking pattern, as well as with difficulty of balance[21,32], should be considered.

CONCLUSION

The inflection of hip and knee variables and plantar and dorsal ankle flexion did not influence the risk of falls and the baropodometric variables, though the increase in maximum pressure influenced this risk in the studied population. These results demonstrate the importance of investigating the alterations in plantar pressure distribution in older women, because alterations in the feet can increase the risk of falls, leaving these individuals more susceptible to these events and their consequences, affecting their autonomy, an important indicator of quality of life for this population.

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