Plantar cutaneous sensibility and dynamic balance in healthy elderly of the community: relational study

Sensibilidade cutânea plantar e equilíbrio dinâmico em idosos saudáveis da comunidade: estudo relacional

Sensibilidad cutánea plantar y balance dinámico en adultos mayores saludables de la comunidad: estudio relacional

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ABSTRACT | The skin somatosensation of lower extremities is relevant in the preservation of balance, whose interaction is compromised with aging. The purpose of this research was to determine the level of relationship between plantar cutaneous sensation with the dynamic balance in healthy elderly population. The study design was cross-sectional. A sample composed of 74 healthy elderly population between 60 and 75 years old, recruited from a Primary Care Center in the city of Talca, Chile. We measured the tactile discrimination of two points: first, second and third metatarsal, lateral border, arch and heel of both feet. Dynamic balance was assessed using the Biodex Balance System SD, recording the Overall Stability Index, the anterior-posterior, and the medial-lateral stability index. For the statistical analysis, we used Pearson's coefficient and the multiple linear regression. The results showed low correlation between the two-point discrimination of the right heel with the Overall Stability Index (r=0.244; p=0.018) and the medial-lateral stability index (r=0.267; p=0.011). The left heel was correlated with the Overall (r=0.268; p=0.011) and medial-lateral (r=0.285; p=0.007) stability indices. The multiple correlation analysis showed no influence of anthropometric and health factors, such as: age, body mass index, medicine number, diseases, and falls in the variance of the dynamic balance indexes. In conclusion, the reduced plantar cutaneous sensation in both heels was associated with slightly higher rates of total and medial lateral dynamic balance.

Keywords | Aging; Postural Balance; Accidental Falls; Sensation; Foot.

RESUMO | A sensação somática cutânea dos membros inferiores é relevante para a preservação do equilíbrio, cuja interação fica comprometida com o envelhecimento. O objetivo desta investigação foi determinar o nível de relação entre a sensibilidade cutânea plantar e o equilíbrio dinâmico em idosos saudáveis. O estudo é de tipo corte transversal. A amostra foi composta por 74 idosos entre 60 e 75 anos, advindos de um Centro de Saúde de Talca, no Chile. A discriminação tátil de dois pontos foi medida no primeiro, segundo e terceiro metatarsiano, na borda lateral, no arco plantar e no calcanhar de ambos os pés. O equilíbrio dinâmico foi medido por meio do *Biodex Balance System SD*, que registrou o Índice de Estabilidade Geral Bilateral, Anteroposterior e Médio Lateral. Para a análise estatística, utilizou-se o coeficiente de Pearson e a regressão linear múltipla. Os resultados mostraram uma baixa correlação entre a discriminação de dois pontos do calcanhar direito e o Índice de Estabilidade Geral Bilateral (r=0,244; p=0,018) e o Médio Lateral (r=0,267; p=0,011). O calcanhar esquerdo foi correlacionado com o Índice de Estabilidade Geral Bilateral (r=0,268; p=0,011) e o Médio Lateral (r=0,285; p=0,007). A análise de correlação múltipla não mostrou influência dos fatores antropométricos e de saúde, tais como: idade, índice de massa corpórea, número de medicamentos, doenças e quedas na variação dos índices de equilíbrio dinâmico. Em conclusão, a diminuição da sensibilidade cutânea plantar de ambos os calcanhares teve uma pequena associação com os maiores índices de equilíbrio dinâmico total e médio lateral.

Descritores | Envelhecimento; Equilíbrio Postural; Acidentes por Quedas; Sensação; Pé.

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RESUMEN | La somatosensación cutánea de los miembros inferiores es relevante para la preservación del balance, cuya interacción se compromete con el envejecimiento. El propósito de ésta investigación fue determinar el nivel de relación entre la sensación cutánea plantar y el balance dinámico en adultos mayores saludables. El diseño de estudio fue de corte transversal. La muestra fue conformada por 74 adultos mayores entre 60 y 75 años, incorporados desde un Centro de Salud de Talca, Chile. Se midió la discriminación táctil de dos puntos en: primer, segundo, tercer metatarsiano, borde lateral, arco plantar y talón de ambos pies. El balance dinámico fue valorado con el *Biodex Balance System SD*, registrando el Índice de Estabilidad General Bilateral, Antero Posterior y Medio Lateral. Para el análisis estadístico se utilizó el coeficiente de Pearson y la regresión lineal múltiple. Los resultados mostraron una correlación baja entre la discriminación de dos puntos del talón derecho con el Índice de Estabilidad General Bilateral (r=0,244; p=0,018) y con el Medio Lateral (r=0,267; p=0,011). El talón izquierdo se correlacionó con el Índice de Estabilidad General Bilateral (r=0,268; p=0,011) y el Medio Lateral (r=0,285; p=0,007). El análisis de correlación múltiple no mostró influencia de los factores antropométricos y de salud, tales como: edad, índice de masa corporal, número de medicamentos, enfermedades y caídas en la varianza de los índices de balance dinámico. En conclusión, la disminución de la sensación cutánea plantar de ambos talones se asoció levemente con mayores índices de balance dinámico total y medio lateral.

Descriptores | Envejecimiento; Balance Postural; Accidentes por Caídas; Sensación; Pie.

INTRODUCTION

One of the skills that are frequently compromised among the elderly is the control of postural balance[1-3], which is considered to be essential for functional independence, health status and quality of life, and its alteration constitutes a primary risk factor for fall-related accidents in this age group[3-5]. The fall is a common phenomenon that affects most of the elderly population. It is estimated that 35% of the elderly people aged more than 65 years old falls annually, and such number increases to 42% among subjects aged 70 years old or more[6]. Such falls can lead to severe injuries, and therefore they are considered as a public health issue[7].

The mechanisms that are subjacent to the increasing balance with aging and the higher incidence of falls are not in agreement. Nonetheless, it is demonstrated that the maintenance of balance depends on the skills of the sensory systems to inform about position, orientation and movement of the body, as well as on the capacity of the central nervous system (CNS) to integrate this information and generate the appropriate motor response[1,8,9].

The plantar cutaneous sensitivity is closely associated with balance control, and its compromise can contribute to falls[10,11]. Therefore, for instance, it has been demonstrated that the partial and total loss of the sensory function experimentally induced in the foot sole results in the increased balance proportional to sensory loss[12]. On the other hand, the two-point tactile discrimination (2PTD) in the plantar zone of the first toe among the elderly was proven to be significantly higher among those who fall frequently[10].

The investigations that analyzed the effects of age over plantar cutaneous receptors mostly considered the ones that adapt fast, like the Pacinian and Meissner's corpuscles in the feet toes, which decreased in number with age and were associated with the decreased tactile sensitivity, perception of vibration and increased medial-lateral static balance[10].

In this sense, the sensitivity of the foot sole is essential to preserve the balance in all of the ages and is compromised among the elderly. Most investigations that analyzed the relationship between plantar cutaneous sensitivity and balance mainly refer to static postural control[11]. Such relations are difficult to extrapolate most of the activities that take place in daily activities and require the ability to keep balance for dynamic tasks. In this context, the purpose of this investigation was to determine the level of relation between plantar cutaneous sensitivity and dynamic balance among healthy elderly in the community.

METHODOLOGY

Design

Cross-sectional relational study

Participants

A sample of 74 elderly people was used, according to calculations to correlate the variables with unilateral analysis; Pearson's rho of 0.3; 95% confidence interval (95%CI) and 80% statistical power; incorporated by convenience from the Health Family Center (CESFAM) Carlos Trupp, in the city of Talca, Chile.

Inclusion criteria were: elderly people aged between 60 and 75 years old, of both genders, controlled and compensated in morbidity, mini-Mental ≥12 and absence of acute conditions. Exclusion criteria were: diabetes mellitus, body mass index (BMI) ≥40 kg/cm^2, conditions of the central or peripheral nervous system, untreated hearing or visual changes, musculoskeletal changes in the lower, orthostatic hypertension, vertiginous syndrome and ankle instability.

Procedure

Subjects were selected when they attended the examination of preventive health care of the elderly (EMPAM)[13], which is annually applied by the Primary Health Care System in Chile. It includes the valuation of vital signs, anthropometric situation, morbidity, intake of medicines, biopsychosocial functional condition, cognitive status according to the mini-mental modified for the Chilean population[14], the risk of falls with the Unipodal Support Test[15] and Timed Up and Go[16]. The objectives of the study were explained to those who met the eligibility criteria, who were invited to go to the Laboratory of Aging at Universidad Católica del Maule, where they signed the informed consent form. The study was approved by the Bioethics Committee of Universidade Católica del Maule and the Health Service of Maule, Talca, Chile (INT.B-ET: 021/2010).

Plantar cutaneous sensitivity was evaluated with the two-point tactile discrimination (2PTD), which aims to determine the distance in millimeters to detect the tactile stimulus of two points on a cutaneous surface. This proof contemplated six areas of the foot sole: head of the three first metatarsals (MT), lateral border of the foot, plantar arch and heel. A longitudinal esthesiometer was used with an adapted vernier caliper (Mitutoyo 4296907), calibrated for the minimum unit of 1 mm, and the limit was 50 mm of amplitude. The test was conducted by two experienced evaluators: one explained the test and performed the evaluations, and the other watched the contact of the esthesiometer with the skin and registered the results. The subject was placed on a recliner stretcher, in the sitting position, with the trunk supported in a 110º flexion of the hip. Knees were relaxed and extended, and patients were barefoot and with covered eyes.

The central point of the first, second and third MT was marked, as well as the lateral border, the plantar arch and the ankle, for both feet (Figure 1). Afterwards, the evaluator touched the different points with perceptible pressure, starting with 0 mm and increasing the distance between the extremities 1 mm at a time, being equidistant to the central point, until the subject mentioned feeling two contact points, which were ratified by contacting one or two points, randomly, in the area evaluated twice.

Dynamic balance was measured with the Biodex Balance System (BBS SD), a reliable and widely used system used in the past few years to assess postural balance[17,18]. It has a mobile and circular platform that allows up to 20º of inclination in the anterior-posterior and medial-lateral line, simultaneously. It measures the ability to control the angle of inclination of the platform, and it is quantified by the system as a variance from the center. Values are expressed as the Index of Bilateral General Stability (IEGB), Index of Medial-Lateral Stability (IEML) and Index of Anterior-Posterior Stability (IEAP), and the highest variance would indicate poor neuromuscular control[18,19]. Besides, this system measures the percentages of time used for the four concentric zones: A (0-5°); B (6-10°); C (11-15°) and D (16-20°), as observed in Figure 2; the longest permanence in more peripheral zones would reveal dynamic balance deficit[18].

In order to perform the test, the elderly participants were placed in the biped position, barefoot on top of the platform of BBS SD (Model 950-302, serial 09031224 NY) with the support of their hands. The examination consisted of three 20 second tests and 20 seconds of rest, considering the third one as a register, using the level eight of stability and

Figure 1. Image of the zones and measurement direction of the two-point tactile discrimination for the right and left feet (head of the 1st, 2nd and 3rd metatarsal, lateral border of the foot, medial and central border of the heel)

following the protocol recommended by the manufacturer. Results were filed in the BBS memory and inserted into a computer.

Statistical analysis

Data were revised and inserted into the software Microsoft Excel 2007 for Windows. The analysis was conducted with the software SPSS 18.0 (License 192.168.100.221). Descriptive statistics was used, with measures of central tendency (mean and standard deviation) of the anthropometric and health parameters that characterized the sample, such as tests of 2PTD and dynamic balance. For the correlation analysis between the IEGB, IEAP and IEML variables with the 2PTD test, Pearson's correlation coefficient was used, considering a 95% significance level, and a very high relation was estimated as higher than 0.8; high, between 0.6 and 0.6; moderate, between 0.4 and 0.6; low, between 0.2 and 0.8; and very low, 0.0 to 0.2[20]. In order to rule out the effect of other variables (age, BMI, number of medicines, diseases and falls), a multiple regression analysis was conducted.

RESULTS

The descriptive results of the sample are demonstrated in Table 1. The correlation analysis between 2PTD with dynamic balance indicators indicated a low positive relation, however, statistically significant between the sensitivity of the right heel with IEGB (r=0.244; p=0.018), IEML (r=0.267; p=0.011) and zone D (r=0.243; p=0.018), and negative with zone A (r=0.202; p=0.042). On the other hand, the left heel was positively correlated with IEGB (r=0.268; p<0.011), IEML (r=0.285; p=0.007), and zone D (r=0.290; p=0.006); and negatively correlated with zone A (r=-0.193; p=0.05), as observed in Table 2.

Finally, the multiple linear regression analysis showed no significant relation between the anthropometric and health characteristics, with the variables IEGB, IEAP and IEML (Table 3).

DISCUSSION

This study represents the first report of the relationship between 2PTD in different zones of the foot sole, with dynamic balance indicators measured with BBS SD.

Table 1. Characteristics of the sample (n=74)

Characteristic	Mean	SD
Age (years)	67.3	4.8
BMI (kg/cm^2)	28.4	3.5
Number of falls	1	1.9
Number of diseases	2.9	1.2
Number of medicines	2.8	1.5
MMSE	17.4	1.8
Right TAU (seconds)	17.2	11.8
Left TAU (seconds)	16.4	12.2
TUG (seconds)	7.1	1.4

BMI: body mass index; MMSE: mini-mental status examination; TAU: unipodal supporting test; TUG: timed up and go; SD: standard deviation.

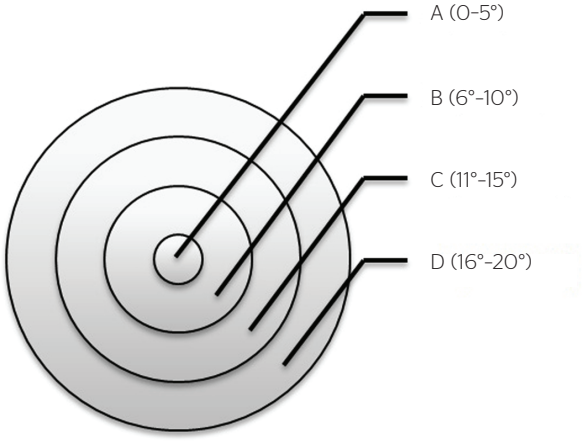

Figure 2. Concentric balance zones of the Biodex Balance System SD to calculate the percentage of permanence time

Table 2. Statistically significant Pearson's rho between the two-point tactile discrimination of the right and left plantar cutaneous points, with indicators of bilateral dynamic balance

2PTD of the right and left heel	IEGB	IEML	Time Zone A (%)	Time Zone D (%)
2PTD right heel	0.244*	0.267*	-0.202*	0.243*
Significance level (unilateral)	0.018	0.011	0.042	0.018
2PTD left heel	0.268*	0.285**	-0.193*	0.290**
Significance level (unilateral)	0.011	0.007	0.050	0.006

IEGB: Index of Bilateral General Stability; IEML: Index of Medial-Lateral Stability; 2PTD: Two-point tactile discrimination; *correlation is significant at the level of 0.05 (unilateral); **correlation is significant at the level of 0.01 (unilateral)

Table 3. Analysis of variance of multiple regression and R^2 among the independent variables: age, body mass index, number of falls, number of medicines, number of diseases and dependent variables IEGB, IEAP, IEML

ANOVA							
Balance indexes		Sum of squares	gL	Squared average	F	p-value*	R^2
IEGB	Regression	14.207	5	2.841			
	Residual	516.184	68	7.591	0.374	0.865	0.027
	Total	530.391	73				
IEAP	Regression	8.039	5	1.608			
	Residual	405.416	68	5.962	0.270	0.928	0.019
	Total	413.455	73				
IEML	Regression	3.260	5	0.652			
	Residual	244.627	68	3.597	0.181	0.969	0.013
	Total	247.887	73				

* Predictive variables: number of medicines, age (years), body mass index, number of falls, number of diseases; Dependent variables: IEGB: Index of Bilateral General Stability; IEAP: Index of Anterior-Posterior Stability; IEML: Index of Medial-Lateral Stability

Aging is associated with significant changes regarding dynamic postural control, which is a key factor for the risk of falls[21]. Consequently, knowing the influence of somatosensory changes associated to normal aging is relevant. The results show low correlation, however, statistically significant, between the studied variables. Even when our results showed low associations, these are in accordance with previous studies, which showed significant correlations between sensory deterioration and postural balance[21-24]. Specifically, 2PTD proved to be affected by aging, with an average decline of 91% in the foot. Its deterioration in the plantar zone of the first toe is higher among people who fall in relation to those who do not fall, and is associated with the increased medial-lateral static balance[5,10].

On the other hand, individuals who presented more distance in the 2PTD in both heels tended to show more variance in IEGB and IEML, which could indicate more difficulties to stabilize the platform in specific directions. Since IEGB is composed by IEAP and IEML, the greatest magnitude in the medial-lateral direction would generate the increment of this index[18]. From the biomechanical point of view, when the subject is on a bilateral support, the support area in the medial-lateral direction is higher than the one of the anterior-posterior direction, being consistently higher than the unipodal support base. If we add the permanence on a unstable platform like the BBS, the prevalent strategy would be in accordance with the medial-lateral balance control through a mechanism of load and unload the hip level.

On the other hand, from the sensory motor approximation, there is evidence that the elderly people exhibit proprioceptive deficit in the sensation of position and movement of the distal lower limb zones, which has an impact on tasks related to dynamic postural balance[11]. In that regard, according to Takacs *et al.*[21], the proprioceptive changes of lower limbs directly affect the postural response to the disturbance. Even if cutaneous receptors are not typically considered to be proprioceptors, they provide complementary information to the sensation of position and joint movement[10]. In this sense, it is likely that the loss of sensitivity in load zones in the foot sole, added to the decreased proprioception of the ankle, leads to the use of proximal joints, like the hip, for balance control. According to Horak *et al.*[25], the hypoxia anesthesia of the foot and the ankle led to the increased dependence of the hip strategy to compensate for the posterior acceleration of the support surface, which normally requires an ankle strategy.

On the other hand, there is no evidence that valued the stability standards inside the concentric zones of BBS among the elderly. Arnold and Schmitz[18] proposed that the percentage of time of stay in peripheral zones could reveal proprioceptive dysfunctions associated with ankle or lower limb pathologies. Therefore, they reported that individuals without ankle conditions tend to stay longer inside zone A (0-5º). According to our investigation, the elderly people with more distance in the 2PTD in both heels tended to stay longer in the peripheral zone (zone D, 16-20º), and less time in the central zone (zone A; 0-5º). According to that, it is reasonable to expect that one individual with decreased plantar somatosensation can have difficulties to remain stable on the mobile platform, dislocating their mass center to peripheral zones.

According to Kennedy and Inglis[26], 70% of the foot sole receptors are rapidly adapting, which suggests more sensitivity for dynamic balance control, with preferential distribution in the anterior foot zone, lateral border and heel, which could correspond to the critical zones that support the weight of the body under load conditions. In this sense, in our study, the sensitivity of the heel is a key zone related to dynamic balance.

The multiple linear regression analysis did not show statistically significant relation between the anthropometric and health parameters and the dynamic balance indicators, therefore, these factors did not significantly influenced the analyzed variables. This does not mean that these parameters do not influence dynamic balance; since that given the required characteristics for the selection of the sample, there may

have been an insufficient variation of these variables, and sensory loss could be attributed to the aging process, and not to other factors.

Finally, it was considered that the procedures used in this investigation were adequate; nonetheless, there are some limiting factors: the incorporation of a lower proportion of elderly participants with risk of falling prevented us from determining if there are more associations among these subjects. That is why it would be important to consider this variable and the incorporation of other age groups for further investigations. This narrow age rank could lead to less variability of plantar cutaneous sensitivity and balance. However, it was observed that all of the participants included in the study did not present with health conditions that could have influenced sensory and balance measures, since they were mostly healthy or compensated in terms of morbidity. On the other hand, since the BBS SD registers the dynamic balance of a subject and needs the proprioceptive system of the ankle to keep balance, it would be relevant to include proprioceptive measures of distal joints, and probably then the magnitudes of relation would be greater.

Finally, the decreased plantar cutaneous sensitivity in the heels of the healthy elderly people was slightly associated with higher rates of total dynamic and medial-lateral balance. It is expected that these findings can contribute with the generation of further studies, oriented to understand the influence of somatosensory loss in the lower limbs among the elderly for the control of dynamic balance.

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