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ORIGINAL RESEARCH

Assessment of the toes flexor musculature in institutionalized and community-dwelling older adults: biomechanical aspects, mobility and falls

Avaliação da musculatura flexora dos artelhos de idosos institucionalizados e comunitários: aspectos biomecânicos, mobilidade e quedas

Evaluación de la musculatura flexora de los dedos del pie de personas mayores institucionalizadas y comunitarias: aspectos biomecánicos, movilidad y caídas

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ABSTRACT | Morphological, biomechanical and functional changes in the feet may increase the risk of fall in older adults. Institutionalized older adults have less mobility and greater risk of falling. The aim of this study is to check the relationship of the feet's characteristics with the mobility and falls of institutionalized or active community-dwelling older adults. A total of 15 institutionalized and 15 community-dwelling older adults participated in this study. They were assessed considering the incidence of falls and through the Timed Up and Go Test; presence of hallux valgus; and strength peak of the muscles of the hallux and toes measured by a pressure platform. The variance analysis was used to compare the groups. As a result, the community-dwelling older adults showed greater muscle strength of the toe flexor muscles than institutionalized older adults ($p<0.05$) and better functional mobility. We observed the risk of fall in institutionalized older adults. Hallux valgus of mild degree was the most common deformity. The Pearson's correlation coefficient showed no correlation between the analyzed variables and incidence of falls. We concluded that the strength of toe flexor muscles is greater in community-dwelling older adults, as well as the functional mobility, when compared with institutionalized older adults.

Keywords | Aging; Muscle Strength; Foot; Accidents by Falls; Hallux Valgus.

RESUMO | As mudanças morfológicas, biomecânicas e funcionais nos pés podem aumentar o risco de queda nos idosos. Os idosos institucionalizados apresentam menor mobilidade e maior risco de queda. O objetivo deste trabalho é verificar as relações das características dos pés com a mobilidade e quedas de idosos institucionalizados e ativos da comunidade. Participaram deste estudo 15 idosos institucionalizados e 15 idosos ativos da comunidade, que foram avaliados quanto à incidência de quedas e por meio do *Timed Up and Go Test*; presença de hálux valgo e pico de força muscular de flexores do hálux e dos artelhos pela plataforma de pressão. utilizou-se a análise de variância para comparar os grupos. Como resultado, os idosos comunitários apresentaram maior força muscular de flexores dos artelhos que os idosos institucionalizados ($p<0,05$) e melhor mobilidade funcional. Observou-se risco de queda nos idosos institucionalizados. O hálux valgo grau leve foi a deformidade mais comum. O teste de Pearson não mostrou correlação entre as variáveis analisadas e a incidência de quedas. Conclui-se que a força muscular de flexores dos artelhos é maior nos idosos comunitários, assim como a mobilidade funcional, quando comparados com idosos institucionalizados.

Descritores | Envelhecimento; Força Muscular; Pé; Acidentes por Quedas; Hallux Valgus.

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RESUMEN | Las alteraciones morfológicas, biomecánicas y funcionales en los pies pueden aumentar el riesgo de caída en las personas mayores. Las que están institucionalizadas presentan menor movilidad y mayor riesgo de caída. El propósito de esta investigación es comprobar la relación entre las características de los pies con la movilidad y la caída de personas mayores institucionalizadas y activas en la comunidad. Del estudio, participaron 15 personas mayores institucionalizadas y 15 personas mayores activas en la comunidad, de las cuales se evaluaron la incidencia de caídas mediante el Timed Up and Go Test; la presencia de *Hallux valgus* y el punto máximo de fuerza muscular de los flexores del *Hallux* y de los dedos del pie mediante la plataforma de presión. Se utilizó el análisis de varianza para comparar los grupos. Los resultados demuestran que las personas mayores comunitarias presentaron una fuerza muscular de los flexores de los dedos del pie mayor que las institucionalizadas ($p<0,05$) y también una mejor movilidad funcional. En las personas mayores institucionalizadas se observó riesgo de caída. El *Hallux valgus* con deformidad leve fue la más común. El test de Pearson no demostró correlación entre las variables evaluadas y la incidencia de caídas. Se concluye que la fuerza muscular de los flexores de los dedos del pie es mayor en las personas mayores comunitarias, así como la movilidad funcional, en comparación a las institucionalizadas.

Palabras clave | Envejecimiento; Fuerza Muscular; Pie; Accidentes por Caídas; Hallux Valgus.

INTRODUCTION

The risk of fall increases with age, hospitalization and institutionalization.[1,2] One third of community-dwelling older adults falls at least once a year. Of these, 30% lose mobility and independence because of falls. Half of the institutionalized older adults aged over 75 years fall in the same period[3]. Fall is a risk to the older adult's health and may have fatal consequences[4]. To understand the risk factors and develop preventive programs is a reality in long-term care institutions for older people; however, few studies have focused on this population[5]. To prevent falls, health professionals should investigate the musculoskeletal repercussions in older adults.

Physical activity is a protection factor to older adults[6]. Functional mobility depends on cardiorespiratory conditions, posture and gait[7], and it is essential for maintaining independence and active social life of the older adult. Community-dwelling older adults have better functional mobility compared to institutionalized older adults[8], suggesting that this is a risk factor for fall to be investigated in older adults in long-term care institutions.

The foot is important for stability, mechanical support and postural control of older adults[9]. With the aging process, the foot undergoes morphological, biomechanical and functional changes. About 80% of the population have foot problems, being hallux valgus the most common deformity[10]. In older adults, hallux valgus has been related to damages in the gait, postural stability and risk of falls[11]. It is important to investigate the mechanical parameters of the older adults' feet, because aging may alter the balance and increase the risk of falls[12,13]. The aging of the feet reduces mobility, increases the risks of falls and decreases the quality of life of older adults[11]. However, the relationship between the muscle strength of toes and presence of hallux valgus with functional mobility, balance and falls in institutionalized and community-dwelling older adults is not clear.

It is important to understand the role of the muscle groups of the foot to develop health promotion, fall prevention and older adults' rehabilitation programs, especially for the institutionalized ones, who have more risk of falls. Based on these assumptions, the following questions emerged: 1) what is the influence of the muscle strength of flexors of the hallux, toes and hallux valgus in functional mobility and fall incidence of institutionalized and community-dwelling older adults? The aim of this study was to verify the relationship of biomechanical characteristics of the older adults' feet (muscle strength, pressure and presence of hallux valgus) with the mobility and falls of institutionalized and community-dwelling older adults. It is believed that the reduction of the muscle strength of the toe flexor muscles and the presence of hallux valgus would be associated with more falls.

METHODOLOGY

This is a cross-sectional and descriptive study with sample selection performed using nonprobability sampling. Eight institutions of Florianópolis were contacted. Three philanthropic institutions and two private institutions

participated in this study. The institutions signed the declaration of knowledge and agreement to participate in this research.

With an initial sample of 159 institutionalized older adults, independent-in-gait older adults (n=27) were preselected, and community-dwelling older adults were randomly selected, through invitation, based on study groups on older adults of the Center of Health Sciences and Sports (Cefid) at Universidade do Estado de Santa Catarina (Udesc), Florianópolis (n=250). All participants accepted the invitation to participate in this study.

Subsequently, the Mini-Mental State Examination (MMSE) was held with a minimum score of 20 points, according to Brucki et al.[14] Then, anthropometric information on weight, height were collected, and body mass index (IMC) calculated. Moreover, the informed consent form was signed in duplicate. This study was approved by the Ethics and Research Committee on Human Subjects of the Universidade do Estado de Santa Catarina by the opinion no. 1,472,712. Figure 1 represents the flowchart of the selection of older adults at the ILPI.

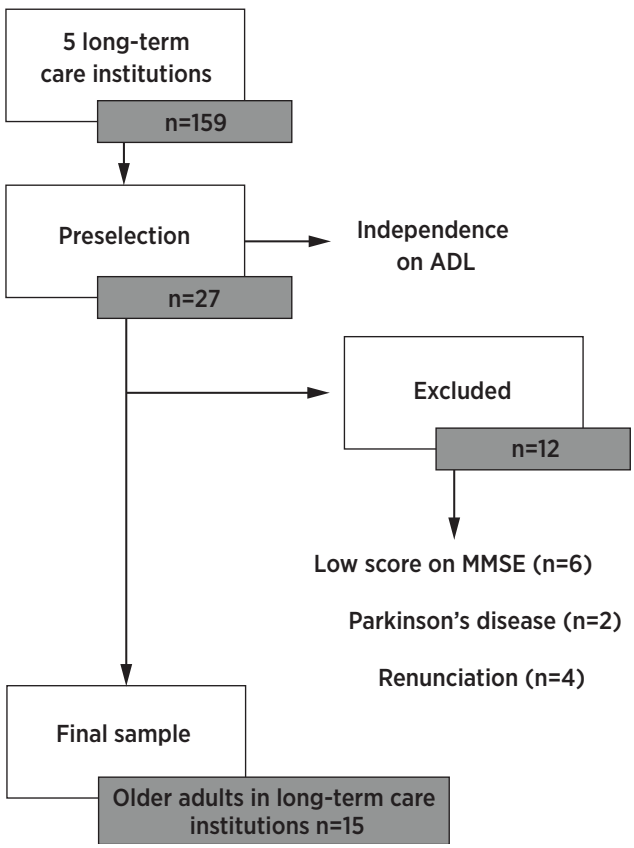

Figure 1. Flowchart of the selection of the older adults in long-term care institutions
ADL: activities of daily living; MMSE: mini-mental state examination.

Participants were divided into two groups: Group ILPI, consisting of 15 institutionalized older adults and Group Community, consisting of 15 active community-dwelling older adults.[15] Inclusion criteria were: to be at least 60 years old, to be independent on everyday life activities and on gait, and to be residing for at least for 6 months in an ILPI (only for Group ILPI). Exclusion criteria were: physical incapacity to carry out the study assessments, uncorrected visual alteration, uncontrolled hyperglycemia, foot pain, neurological disorders and lower-extremity amputation.

The number of falls in the past year was determined by self-report. A fall was considered as "an unexpected event in which the subject was positioned on the ground or in a lower level"[16].

The functional mobility was assessed with Timed Up and Go Test (TUG).[17] The cutoff point for the risk of falls was 12.4 seconds for Brazilian adults.[18]

The presence of hallux valgus was assessed using the Manchester Scale, which involves standardized photographs with real cases of hallux valgus. The photos represent the severity degree (score) of hallux valgus (none 0, mild 1, moderate 2 and severe 3).[19]

A portable pressure platform (Emed/AT, Novel) was used to check the muscle strength of hallux and toe flexor muscles. It was adapted to the assessment protocol of maximum muscle strength peak by Mickle et al.[20] This protocol has excellent intraclass correlation coefficient for hallux (ICC=0.93) and toe (ICC=0.92) flexor musculature[20] and it was carried out after demonstration and training. The group of older adults living in long-term care institutions (Group Institutions) was assessed in institutions, and Group Community, at the Cefid Biomechanics Laboratory. The sequence of assessments was random.

The adaptation consisted of requesting the older adults to press once the hallux with the greatest strength possible and once all toes against the pressure platform instead of three times. During the test, three verbal commands were conducted through the word: "press it!".

The data analysis software allowed the determination of variables of maximum muscle strength (N) and distribution of plantar pressure (kPa). Magnitude determination of plantar pressure occurred individually in the moment of maximum strength peak. The normalized maximum muscle strength (% body weight) was calculated using the body mass of every individual.

The software SPSS 20.0 was used for data processing. Normality of data was tested using the Shapiro-Wilk test. The Pearson's correlation coefficient and multifactorial analysis of variance (ANOVA) with *post hoc* Tukey's test

were used for TUG, presence of hallux valgus, maximum strength, normalized maximum strength and pressure variables. This study accepted $p<0.05$ for significance.

RESULTS

Sample characterization data and data related to the mean and standard deviation of age, BMI, MMSE and TUG are described in Table 1. Group ILPI had 8 female older adults and 7 male older adults. Considering the history of falls, only 13% of older adults had fallen in the year before the assessment. Group Community had 10 female older adults and 5 male older adults, 40% had fallen in the past year.

Table 1. Mean and standard deviation of age, BMI, MMSE and TUG of the Group Institutions and Group Community

	Group ILPI (n=15)	Group Community (n=15)
Age (years)	77.4±9.8	76.2±8.5
BMI (kg/m^2)	26.4±4.5	28.7±4.4
MMSE (points)	23±2.6	27±2.5
TUG (seconds)	17.1±5.6	12±3.9

BMI: body mass index; MMSE: mini-mental state examination; TUG: Time Up and Go test.

In the Group Institutions, 44% showed mild degree of hallux valgus and 20% showed moderate or severe degree. In the Group Community, hallux valgus of mild degree was observed in 20% of older adults and 16% showed moderate or severe degree.

Maximum strength and normalized maximum strength were investigated considering the groups, hallux and toes (mean values are shown in Table 2). Maximum strength was affected by the characteristic of the group, i.e., we found difference was ($F=4.2$, $p=0.04$, $\eta^2=0.03$, power=0.53) between groups for this variable. The comparison between the means showed that the Group Community had greater strength than Group Institutions ($p=0.005$).

Table 2. Mean and Standard Deviation of pressure, maximum strength and normalized maximum strength

	Pressure (kPa)	Maximum strength (N)	Normalized maximum strength (%)
Group Community	48.1±13.8	143.8±64.2*	41.3±18.6
Group Institutions	42.7±20.8	105.6±84.1*	36.4±24.2
Hallux	51.1±18.4*	130.1±85.1	33.5±14.8*
Digits II_V	39.7±15.3*	119.3±68.2	44.2±25.9*

*p<0.05

The toe affected the pressure ($F=8.0$, $p=0.005$, $\eta^2=0.07$, power=0.80) and the normalized maximum strength ($F=4.5$, $P=0.03$, $\eta^2=0.04$, power=0.56). Comparison of means showed that Group Community shows greater pressure at the hallux than at the toes ($p=0.001$) and greater normalized strength on the toes than the hallux ($p=0.004$).

The correlations were investigated considering pressure, maximum strength, normalized maximum strength and TUG variables in Groups Community and Institutions, and no correlations between them were observed ($p>0.05$).

DISCUSSION

Institutionalized older adults showed lower muscle strength and pressure of the hallux and toe flexor muscles and higher incidence of hallux valgus than active community-dwelling, according to our initial hypotheses. We found no relationship between muscle strength of hallux and toe flexor muscles and the functional mobility and incidence of falls in the older adults.

Aging makes the foot more favorable to develop valgus deformities in the hallux and reduces the muscle strength of the foot flexor muscles, affecting the postural control and gait[21,22]. The weakness of the toe flexor muscles reduced the ability of community-dwelling older adults on controlling the changes of body weight and on the impulse of the body forward during gait[23]. Menz et al.[9] evaluated the older adults' foot and observed the reduction of muscle strength on functional performance. However, as well as in our study, muscle strength of the toe flexor muscles was not associated with the incidence of falls.[9]

The Group Community had greater strength in the toe flexor muscles and better results for TUG. Other studies state that the maintenance of the strength of muscles intrinsic to the foot is efficient in carrying out everyday life activities[24]. The low frequency of physical activities and low fitness among institutionalized older adults seem to be associated with less strength of Group Institutions[25]. Strengthening exercises that include the toe flexor musculature may contribute for older adults to be more active, participative in institutions and in the society – however, this statement requires further investigation.

We found no association between the muscle strength of toes flexors with the hallux valgus, functional mobility and falls in both studied groups. The results suggest that active and in-community life is a factor of protection for older adults' motor and functional independence and cognition, and it must be preserved. However, most of the cases of

hallux valgus were in mild degree, and this fact can justify the non-relationship with falls of older adults. Studies with larger samples should be carried out to confirm this fact. The pressure was found in greater magnitude at the hallux and the normalized maximum strength was greater on the toes of older adults. The severer the valgus deformity, the lower the pressure under the hallux region[21]. Hallux valgus changes the function of the first toe, resulting in the lateral redistribution of the feet load.

Curiously, the Group Community fell more times than the Group Institutions, contradicting the fact that institutionalized older adults suffer more falls than community-dwelling older adults[26]. Couto and Perracini[27] report that active older adults in the community are more exposed to the risk of falls. A study on the profile of institutionalized older adults observed that independent or totally-dependent older adults have lower risk of falls, when compared with moderately-dependent older adults[28]. The stratified profile of institutionalized older adults may help to solve this doubt in future studies.

The sample of this study included only institutionalized older adults who were independent in relation everyday activities and gait. This fact may have reduced the accidental falls observed. These older adults lived in restricted environment with full-time assistance. As expected, functional mobility was better for the Group Community. Lima et al.[29] and Macedo et al.[30] assessed older adults of the community with high cognitive level and obtained great performance on TUG, indicating low risk of fall. Policies that promote and encourage the community experience, in addition to the practice of physical activities, must be more present in a society going through a population aging process, since several studies indicate that remaining active favors the older adult's functional mobility and cognition. To encourage physical activities for muscle strengthening is important to maintain the older adults' independence and mobility. More studies must be developed with follow-up programs, and functional and cognitive assessment, to detect and reverse the risk of falls in older adults.

A physical exercise program was applied for older adults with cognitive alteration in a long-term care institution. The authors observed that exercises improved physical fitness and reduced the falls, but there was no improvement on the cognitive clinical condition[31]. A study conducted with 472 institutionalized older adults showed the high prevalence of cognitive disfunction and physical limitation[28]. To preserve the cognitive state in life is important for a good performance of motor tasks[32]. The Mini-Mental State Examination is a simple test with quick application, which must be included in the monitoring of older adults. In our study, institutionalized older adults showed risk of falls detected by TUG. We suggest that the inclusion of TUG into the routine assessments in long-term care institutions may be beneficial to identify older adults in risk of fall.

Programs or supervision of physical activities must be included in long-term care institutions as a strategy to improve muscle strength, functional mobility and preserve the mental state of older adults. A 12-week exercise program was applied for longevous older adults in long-term care institutions. We observed improvement of balance, mobility, muscle strength of lower extremities and reduction of falls for older adults under intervention, while the functional clinical condition of the older adult in the control group deteriorated[33]. In long-term care institutions, the practice physical exercises is not rarely encouraged, creating the vicious circle of aging, sedentary lifestyle, loss of functional ability, social isolation and reduction of quality of life[26].

This study is the first to analyze biomechanical variables related to the foot in older adults in long-term care institutions in Brazil. The recruitment of people in these institutions is hard, however we have established inclusion criteria that have not been applied before, with cutoff score at 20 points for MSEM[14] and independence at gait, which show the clear influence on the results and have restricted the sample size. The limitations of these study include small sample and absence of a control group.

CONCLUSION

Institutionalized older adults showed lower muscle strength and lower pressure on the hallux and toe flexor muscles, greater incidence of hallux valgus and lower performance on functional mobility, when compared with older people in community. Muscle strength of hallux and toe flexor muscles and presence of hallux valgus were not associated with functional mobility and falls of the investigated older adults.

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