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Association between flexibility of the glenohumeral and hip joints and functional performance in active elderly women

Correlação entre flexibilidade das articulações glenoumerais e coxofemorais e o desempenho funcional de idosas fisicamente ativas

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Abstract

Objective: To investigate the relationship between flexibility of flexion and extension of the glenohumeral and coxofemoral joints and functional performance among physically active and functionally independent elderly women. Methods: Six sets of range of motion (ROM) measurements relating to flexion and extension of the glenohumeral and coxofemoral joints were determined in 22 volunteers (age 70±6 years), using assisted-active goniometry. Functional performance was measured using the following tests: normal walking speed (NWS); maximum walking speed (MWS); sit-to-stand test (SST); timed up and go test (TUGT); putting on a blouse (PBL); going up stairs (GUS); rising from dorsal decubitus (RDD); picking up a coin from the floor (PCF); and 6-minute walk test (6WT). The relationships between the ROM variables and functional performance were tested using simple and multiple regression techniques. Results: There were significant correlations ($p<0.05$) between coxofemoral ROM and the SST (r=0.42 and r=0.45), GUS (r=0.52 and r=0.53) and 6WT (r=0.58 and r=0.59) (right and left sides, respectively). The multiple regression ratified the results ($r^2=0.51$; $p<0.05$), thus indicating that coxofemoral ROM accounted for 51% of the variance in the tests. There were no significant correlations between the glenohumeral ROMs and the functional performance tests. Conclusions: There was a significant association between assisted-active flexibility of the coxofemoral joint and some specific functional performance tests. No relationship involving glenohumeral ROM was identified. Additional studies are needed in order to elucidate the relationships between passive flexibility of different joint groups and functional performance in elderly people.

Key words: aging; physical activity; flexibility; goniometry; physical fitness.

Resumo

Objetivo: Investigar a relação entre a flexibilidade da flexão e extensão das articulações glenoumerais (GU) e coxofemorais (CF) e o desempenho funcional (DF) de idosas funcionalmente independentes e fisicamente ativas. Métodos: Determinou-se em 22 voluntárias (idade=70±6 anos) seis conjuntos de amplitudes de movimentos por goniometria ativo-assistida (ADM) na flexão e extensão das GU e CF. O DF foi determinado pelos testes: velocidade de caminhada habitual (VCH) e máxima (VCM); levantar e sentar em cadeira (LSC); Timed up and Go Test (TUGT); vestir blusa (VBL); subir degraus (SE); levantar do decúbito dorsal (LDD); pegar moeda no solo (PMS); teste de caminhada de seis minutos (TC6M). As associações entre as variáveis ADM e o DF foram testadas por técnicas de correlação simples e múltipla. Resultados: Houve correlações significantes ($p<0,05$) entre as ADM de CF e os testes LSC (r=0,42 e r=0,45), SE (r=0,52 e r=0,53) e TC6M (r=0,58 e r=0,59) (lados direito e esquerdo, respectivamente). A correlação múltipla ratificou esses resultados ($r^2=0,51$; $p<0,05$), indicando que 51% da variância nos testes deveu-se à ADM de CF. Não houve associações significantes entre as ADMs de GU e os testes de DF. Conclusões: Verificou-se associação significante entre a flexibilidade ativo-assistida de CF e alguns testes específicos de DF. Nenhuma relação foi identificada para ADM de GU. Estudos adicionais são necessários para elucidar as relações entre flexibilidade passiva de diferentes grupos articulares e a funcionalidade de idosos.

Palavras-chave: envelhecimento; atividade física; flexibilidade; goniometria; aptidão física.

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Introduction

Flexibility has been defined as the physical fitness component characterized by the capacity to move a joint, or a group of joints. This component is related to the capability of reaching the maximum possible joint range of motion (ROM), without compromising the muscle-tendon and joint integrity[1]. Because of the relationship observed between maximum physiological passive flexibility and joint ROM, many studies[1-3] have used ROM as a flexibility and mobility indicator[4,5]. In this context, joint goniometry has been considered to be the gold standard or gold criterion for measuring passive flexibility[5].

Flexibility depends on the resistance that is offered to joint motion by different tissues or body structures, such as the joint capsule, muscles, tendons and skin[5,6]. With advancing age, these structures go through changes that reduce their elasticity[7-9]. Thus, aging is considered one of the main agents responsible for mobility reduction and, consequently, reduction in quality of life. However, the alterations observed in body structures also relate to the level of physical activity[4,10]. The skeletal muscles seem to be the most responsive body tissues, and this can explain the great loss of muscle fitness that is observed during aging and attributed to disuse[7,11-13]. Therefore, physical inactivity, whether voluntary or caused by the presence of diseases[5], has been considered to be a determining factor for flexibility changes in elderly populations, which may affect their functionality, mobility and quality of life.

It has been suggested that physically active subjects present greater ROM than do sedentary individuals[4,10]. Investigating this notion, Cunningham et al.[14] compared strength and flexibility levels (represented by the ROM of shoulder, hip, elbow and wrist joints) and cardiorespiratory fitness among independent elderly individuals, with those of elderly individuals living in permanent care institutions, and observed significant correlations between passive flexibility and levels of physical activity. They also observed that physically active elderly people (regardless of the type of activity that was carried out on a daily basis) not only lived autonomously but also presented higher levels of general flexibility, higher walking speed and better cardiorespiratory fitness, and reported better life quality, when compared with the institutionalized elderly people[14].

In this context, it is of interest to note that although flexibility exercises are included in physical training programs with the objectives of minimizing the risk of lesions and improving physical and functional fitness[4,10,15], the relationship with and, especially, the predictive capacity of flexibility for functional performance, have been little studied. The vast majority of studies directed towards observing the relationship between flexibility and functional performance have been aimed at the relationship between flexibility and changes in gait pattern[16], balance[17] or the risk of falls[16,17].

Some studies have proposed that, among functionally independent elderly people, the relationship between flexibility and performance in daily activities would not be evident[18,19]. However, these studies emphasized the lower limbs. One of the reasons for this could come from the fact that the decline in joint flexibility in the upper limbs is less than what is observed in other joints[20]. Moreover, elderly people's complaints relating to upper limb flexibility limitations are relatively less frequent than those that concern the lower limbs[21]. On the other hand, it is undeniable that upper limb mobility is necessary for many daily activities, such as moving objects from shelves, getting dressed or having a bath. Thus, it would be important to observe the nature of the relationship between flexibility and functionality in different activities. It is also observed that there are few studies investigating correlations between flexibility and functional performance among elderly people who are not absolutely frail and who are physically active. In fact, most studies suggesting that flexibility has an important correlation with functional performance have observed elderly people who were well advanced in years, institutionalized or with low levels of physical fitness[14,17,21,22].

Therefore, there are gaps regarding the possibility of using flexibility as a predictive variable for functional performance in samples formed by physically active elderly subjects. Thus, the present study had the objective of investigating the relationships between six ROM combinations, formed by associations of flexion and extension movements of the glenohumeral and coxofemoral joints, and functional performance among physically active and functionally independent elderly individuals, assessed by performing motor tasks relating to daily activities.

Materials and methods

Subjects

To participate in the study, the subjects had to be aged 60 years or over and be independent in performing basic activities of daily living (ADLs) and instrumental activities of daily living (IADLs). Twenty-two women offered to be volunteers and met the inclusion criteria for the study (age: 70±6 years, height: 1.53±0.07m, body weight: 62.5±8.6kg and body mass index: 26.9±3.3kg/m^2).

The inclusion criteria were established by means of two questionnaires. The first sought to gather general data (age, date of birth and marital status, among others) and information regarding medications, reports of existing diseases and regular practice of physical activity (type, frequency and intensity), during the month prior to the study. To classify the individuals' levels of physical activity, the strategy proposed by the Behavioral Risk Factor Surveillance System Survey[23] was used. The level of physical activity was established through the subjects' answers regarding their physical activity practices during leisure time, such as: jogging, walking, parlor games, ballroom dancing, folk dancing and gardening, among others.

After attending consultations with their own doctors and presenting document certifying their capability to participate in the proposed tests, all subjects signed a free and informed consent statement, in accordance with the recommendations of the Declaration of Helsinki and Resolution 196/96 of the Brazilian National Health Board regarding research involving human beings. The study was approved by the Research Ethics Committee of the Universidade Federal de Alagoas (report number 006119/2005-50).

The functional performance evaluation was carried out by means of self-reporting of performance capability in carrying out ADLs and IADLs. For this, two scales were used: Katz[24] for assessing the ADL performance and Lawton[25], for the IADL. Thus, the subjects who were considered completely independent were the ones that could perform all the ADLs and IADLs without human assistance or the use of supports or accessories. Therefore, the elderly individuals who were included in the sample were those classified as functionally independent (those that, as well as being able to perform domestic chores, practiced at least one leisure physical activity, in sessions lasting at least 30 minutes and at a frequency of three or more sessions per week). Subjects were excluded from the sample if they were practicing formal physical exercise programs (for example: gymnastic classes, stretching or muscle workouts, among others) or if they presented physical or mental problems (amputations, dementia, vision and hearing problems, among others) that could stop the individual from participating in the proposed tests.

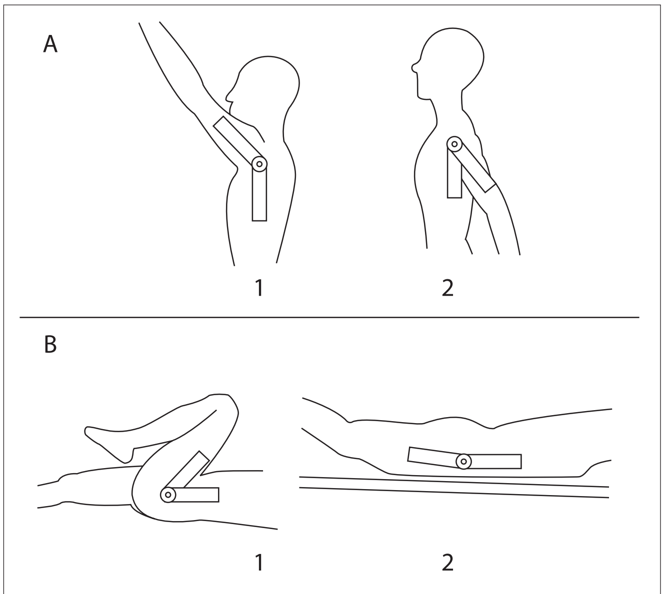

Figure 1. A – positioning of the goniometer for measurements of flexion ROM (1) and extension ROM (2) of the glenohumeral joint; B – positioning of the goniometer for measurements of flexion ROM (1) and extension ROM (2) of the coxofemoral joint.

Measurement of flexibility

The ROMs were measured using a standard universal goniometer (International Standard SFTR Goniometer, Orthopedic Equipment Co. Bourbon, Indiana, USA), on two different days, by two trained researchers. The measurements were carried out in an actively assisted manner. While the subject was asked to perform a movement, one of the evaluators directed the movements and took care of adequate postural alignment. The second evaluator manually positioned and attached the goniometer. To carry out the measurements, the techniques described by the American Academy of Orthopedic Surgeons[26] were respected.

The ROM measurements on the glenohumeral joints were performed while the subjects were seated. In this position, the goniometer axis was positioned over the acromion, such that the fixed arm was positioned along the midaxillary line of the trunk (pointing towards the greater trochanter of the femur), while the movable arm was resting on the lateral surface of the shaft of the humerus (facing the lateral epicondyle). The ROMs of the coxofemoral joints were measured while the subjects were in dorsal decubitus (flexion measurement) and ventral decubitus (extension measurement). For both measurements, the goniometer was positioned in the same way: on the lateral surface of the coxofemoral joint, such that the axis was positioned at the level of the greater trochanter. The fixed arm of the goniometer needed to be positioned on the midaxillary line of the trunk and the movable arm, over the lateral surface of the thigh, pointing towards the lateral condyle of the femur. The goniometer positioning can be seen in Figure 1.

It is emphasized that although all the movements allowed by the joints that were studied are important for functional performance, it was decided for operational reasons only to measure the possible arcs of movement composed by flexion and extension movements. Thus, the following combinations of ROMs were used as flexibility measurements: 1) Sum of glenohumeral joint ROMs – right and left shoulder flexion (RSF+LSF) and right and left shoulder extension (RSE+LSE); 2) Sum of coxofemoral joint ROMs – right and left hip flexion (RHF+LHF) and right and left hip extension (RHE+LHE); 3) Sum of flexion and extension of both glenohumeral joint ROMs – flexion and extension of right and left shoulder (ΣROMS); 4)

Sum of flexion and extension of both coxofemoral joint ROMs – flexion and extension of right and left hip (∑ROMH).

With the aim of minimizing possible differences that occur due to natural handedness, the strategy used was to represent the flexibility through the sum of the ROMs of both halves of the body. The intra-evaluator reproducibility (reliability) was determined by means of the intra-class correlation coefficient (ICC; $p<0.05$). The values presented demonstrated high reliability: 0.92, 0.90, 0.93 and 0.90 ($p<0.05$), respectively, for SF, SE, HF and HE.

Measurement of functional performance

To assess functional performance, eight moving tasks that are considered important for functional independence were used. With the exception of the 6WT, for which the measurement criterion was the distance walked, the minimum time spent to perform each of the following tasks was used as the measurement[27-30]:

- Six-minute walking test (6WT*)*: with the aim of evaluating the subjects' aerobic capacity, this test required the subjects to cover the greatest possible distance, in six minutes[30,31]. If necessary, because of tiredness or any other reason, the subject under evaluation could stop the test and, after the required rest period, restart it. In a recent study, Andersson et al.[31] showed that this test presented high test-retest reproducibility (ICC=0.98);
- Normal (NWS) and maximum (MWS) walking speed: in this test, the subject was required to walk a distance of four meters at two different speeds (normal and as quickly as possible), without running[29]. Time was measured using a digital chronometer that was triggered and interrupted by a device called a laser gate. The laser gate is composed of two laser beam lamps (model EQ014) and two photoelectric cells (model EQ012B). Blocking the reception of the two light beams caused the chronometer to be started or stopped (Wackerrit®, model EQ018D). All the equipment that composed the laser gate was manufactured by the same company: Industrial Center for Teaching and Research Equipment (Centro Industrial de Equipamentos de Ensino e Pesquisa, CIDEPE®, Canoas, RS, Brazil). To mark out the distance, two strips of adhesive tape of 0.5m in length were attached to the ground. As a strategy to minimize the effects of acceleration and deceleration, the subject began the walk one meter before the starting line and only started to decelerate one meter after the finishing line. The subjects did the walking test three times: twice at normal speed and the third time as quickly as possible. Van Loo et al.[32] reported a mean ICC of 0.95 for this test;
- Sit-to-stand test (SST): with the aim of testing the ability to stand up and sit down on a chair, the subjects were asked to stand up from a seated position on a bench at a height of 43cm, with their backs against a wall and their arms crossed at chest height. After performing the task successfully, the subject was required to start the test, which consisted of standing up and sitting down five times on the bench. The test was started while the subject was sitting down and finished at the fifth (last) standing up. According to Bohannon[28] this test presents moderate ICC (ICC=0.77). The test was attempted once only;
- Timed up and go test (TUGT): this test considered the time taken for the subjects to stand up from a bench at a height of 43cm, with their arms crossed in front of their chest, walk in a straight line for three meters and, after going around a cone that marked this distance, go back and sit down. According to its proposers[33], the test presents high reproducibility coefficients (ICC=0.99). After familiarization, the test was carried out in a single attempt;
- Putting on a blouse (PBL): the test consisted of putting on and buttoning up a blouse that had previously chosen according to each subject's physique (small, medium and large). In this test, the time started to be counted when the subjects touched the blouse, which was offered by the evaluator, and finished when all the buttons had been done up correctly[21]. After familiarization, the test was carried out in a single attempt;
- Going up stairs (GUS): for this test, a portable structure of 49cm in height and three steps was used. The first step was 13cm high, 24cm deep and 68cm wide; the second step was the same depth and width as the first step, but was 18cm high. The third and last step (the platform), was the same height and depth as the second step, but was 67cm wide. The test began with the subject standing, as near as possible to the first step. At the "go" signal, the subject had to go up the three steps as quickly as possible. The time started to be counted when the subject's foot moved, and was stopped when the subject was standing, with balance completely recovered, with both feet on the platform[34]. After familiarization, two attempts to perform the test were made. The best time was recorded as the result;
- Rising from dorsal decubitus (RDD): this test was proposed by Alexander et al.[27]. It started with the subject lying down on a small mattress, in the dorsal decubitus position. At the starting signal, the subject was required to get up and stand up. The chronometer was triggered when the subject started moving and was stopped when the subject had completely regained balance in the standing position. Three attempts were allowed. The best time was taken to be the result;

- Picking up a coin from the floor (PCF): for this test, which aimed to assess the mobility and flexibility of the vertebral column and coxofemoral joints[35], an adhesive tape measuring 30cm in length was attached to the floor. A coin was positioned 30cm from the tape. To perform the test, the subject was required to stand beside the tape and the coin and, at the "go" command, should stoop down and, as quickly as possible, pick up the coin. The chronometer was triggered at the starting signal and stopped when the subject was standing again, with completely recovered balance. According to its protocol, only two attempts were allowed for this test. The shortest time between the two attempts was used as the measurement.

Since there is no data in the literature on the reliability of the latter four functional performance tests (PBL, GUS, RDD and PCF), they were applied on two different days, with a 24-hour interval between them. After obtaining the results from the first test day, the subjects returned to the lab for a reevaluation. The times established in the two tests were considered and, if the difference between the two was less than 5%, the smaller value was accepted as the final result[36]. If the difference was greater than 5%, the subject needed to be evaluated a third time. Thus, as proposed by Suzuki et al.[36], the reproducibility coefficients of the observed measurements in our study, as calculated by means of the intra-class coefficient correlation (ICC), were classified as excellent, because they were greater than or equal to 0.85 (PBL, ICC=0.87; GUS, ICC=0.90; RDD, ICC=0.85; PCF, ICC=0.92).

Statistical analysis

The number of subjects for the sample was calculated using the Primer of Biostatistics 4.0 software (McGraw-Hill Inc., New York, NY, USA), after a pilot study, taking a cutoff of 0.85 for the standard deviation of the residuals. The statistical power was taken to be 80% and the significance level was taken to be 5% ($p<0.05$). Thus, it was determined that a minimum of 16 individuals was needed to make up the sample. The homogeneity of the variance in the data that were collected was confirmed using the Levene test and the normality of the data was confirmed using the Shapiro-Wilks test. While the six ROM combinations (RSE+LSE; RSF+LSF; ΣROMS; RHE+LHE; RHF+LHF; ΣROMH) were independent variables, the eight functional tests were dependent variables. The correlations between the flexibility measurements and the functional performance tests were calculated by means of simple correlation techniques (Pearson r) and the association between the ROM combination interactions and the functional performance tests was calculated through multiple correlation techniques[14,37]. All the statistical calculations were done using the Statistica 6.0® for Windows software (Statsoft, Tulsa, OK, USA).

Results

The results from the tests that were used in the functional performance assessment on the subjects can be seen in Table 1.

The ROM results (expressed in degrees) from the glenohumeral and coxofemoral joints, measured through goniometry, can be seen in Table 2.

Table 3 shows the results from the simple correlation. It can be seen that three out of the eight functional performance tests (SST, GUS and 6WT) presented significant correlations with coxofemoral joint flexibility, ranging from 0.45 to 0.59.

The multiple correlation confirmed the data from the simple correlation, thus indicating that only the coxofemoral joint ROM was significantly associated with functional performance (Table 4). The ROM that presented the highest predictive capacity for functional performance was RHF+LHF. This

Table 1. Results from the functional performance tests (n=22).

Variables	Range	Mean±sd	95%CI
NWS (sec)	2.62-5.15	3.6±0.8	3.3-3.9
MWS (sec)	1.79-3.87	2.6±0.5	2.4-2.8
SST (sec)	4.75-10.40	6.6±1.4	6.1-7.2
TUGT (sec)	5.0-7.1	6.1±0.6	5.8-6.4
PBL (sec)	14.8-46.0	31.1±9.0	27.6-35.3
GUS (sec)	0.9-1.7	1.3±0.2	1.2-1.4
RDD (sec)	1.8-8.7	3.9±1.5	3.3-4.5
PCF (sec)	1.4-5.1	2.3±0.7	1.9-2.6
6WT (m)	362.1-710.9	501.1±75.1	469.3-532.8

95%CI=95% confidence interval; mean=arithmetical mean, SD=standard deviation; NWS=normal walking speed; MWS=maximum walking speed; SST=sit-to-stand test (five times); TUGT=timed up and go test; PBL=putting on a blouse; GUS=going up stairs; RDD=rising from dorsal decubitus; PCF=picking up a coin from the floor; 6WT=6-minute walking test.

Table 2. Goniometry results from the different movements analyzed (n=22).

Variables	Range	Mean±sd	95%CI
RSF+LSF (degrees)	200-338	277.3±32.1	263.8-290.9
RSE+LSE (degrees)	60-150	96.1±21.6	87.0-105.0
ΣROMS (degrees)	286-470	373.1±46.2	353.9-393.0
RHF+LHF (degrees)	126-246	197.3±25.6	186.5-208.1
RHE+LHE (degrees)	6-42	15.8±8.5	12.2-19.3
ΣROMH (degrees)	140-281	213.1±29.7	200.5-225.6

RSF+LSF=sum of right and left shoulder flexion ROM; RSE+LSE=sum of right and left shoulder extension ROM; ΣROMS=sum of the flexion and extension ROM in both glenohumeral joints (RSF+LSF + RSE+LSE); RHF+LHF=sum of right and left hip flexion ROM; RHE+LHE=sum of right and left hip extension ROM; ΣROMH=sum of the flexion and extension ROM in both coxofemoral joints (RHF+LHF + RHE+LHE).

Table 3. Pearson correlation coefficients between the different range of motion indexes and the functional performance tests (n=22).

Variables	RHF+LHF	RHE+LHE	∑ROMH	RSF+LSF	RSE+LSE	∑ROMS
NWS	-0.29	-0.40	-0.36	-0.10	-0.13	-0.00
MWS	-0.31	-0.38	-0.37	-0.25	-0.20	-0.27
SST	-0.45*	-0.11	-0.42*	-0.08	-0.00	-0.06
TUGT	0.16	-0.33	0.04	0.20	0.34	0.30
PBL	-0.40	-0.16	-0.39	-0.33	-0.21	-0.32
GUS	-0.52**	-0.28	-0.53**	-0.32	-0.21	-0.32
RDD	-0.35	-0.30	-0.39	-0.25	-0.12	-0.11
PCF	0.02	-0.09	-0.01	-0.08	0.13	0.11
6WT	0.58**	0.31	0.59**	0.37	0.07	0.29

**significant correlation ($p<0.01$); *significant correlation ($p<0.05$).

was responsible for 51% of the test variance. The ∑ROMH also presented significant functional performance correlation, responsible for 44% of the test variance.

Table 4. Multiple correlation results between the combinations of different ranges of motion and the set of functional tests (n=22).

Variables	r	r²	r² adjust.	F (10,13)	SEE	p
RSF+LSF	0.59	0.36	-	0.72	34.3	0.70
RSE+LSE	0.64	0.42	-	0.93	21.9	0.54
RHF+LHF	0.85	0.72	0.51	3.40	17.9	0.02*
RHE+LHE	0.63	0.40	-	0.86	8.8	0.59
∑ROMS	0.64	0.38	-	0.8	48.5	0.64
∑ROMH	0.83	0.68	0.44	2.8	22.3	0.04*

r=multiple correlation coefficient; r²=determination coefficient; r² adjust.=adjusted determination coefficient; F=variance between groups; p=significance level; SEE=standard error of estimation; *statistically significant ($p<0.05$).

Discussion

With aging, it is expected that there will be general reductions in flexibility and functional repercussions relating to increased energy expenditure, along with capacity limitations relating to performing daily activities[6,7,11,13,14,21]. As expected, the observed subjects presented angular values that were 21 to 28% smaller than the normal values obtained in younger populations[26]. On the other hand, when comparing the flexibility that was found with data from studies carried out among elderly individuals with high levels of functionality[6,13], the present results were equivalent to or slightly higher than the reference values. For example, Cunningham et al.[14] measured the flexibility of 44 active and independent elderly women and found mean values of 138º (±20º) and 108º (±24º) for ΣROMS and ΣROMH, respectively, while in the present study, the subjects reached 187 and 107º in the same movements.

It can be seen that, when compared with the flexibility values of young subjects, the differences were smaller for the glenohumeral joints than for the coxofemoral joints. This finding reinforces the observations by Bell and Hoshizaki[20], who found that the decline in ROM levels in the joints of the upper limbs was smaller than the decline in other body segments, among 190 men and women of ages ranging from 18 to 88 years. According to Lung et al.[9], this difference in mobility loss could be partially explained by the fact that the upper limbs would be continuously used during all stages of life, while the lower limbs would be decreasingly used due to physical inactivity. The results from Bergstrom et al.[22] further reinforce this position: in a longitudinal study with a duration of nine years (subjects with ages ranging from 70 to 79 years), it was found than only 32% of the subjects presented complaints regarding shoulder mobility limitation.

The main contribution of the present study lies in the fact that the relationship between functional performance and flexibility was analyzed, taking into account the interactions of these variables with regard to producing effects on functional situations. The results obtained partially confirm the little evidence available[22] regarding the possible relationship between flexibility and functional performance among healthy elderly people. Unlike other investigations, no correlations between glenohumeral joint mobility and performance was observed in the present study, even when considering the low statistical power. The few associations observed were in relation to the flexion range of the coxofemoral joints. Such findings can be explained through the fact that, with the exception of the PBL and PCF tasks, the other tasks did not demand any notable participation from the glenohumeral joints. A second possible explanation for the finding relates to the relatively high levels of physical fitness of our subjects, when compared to older and institutionalized elderly people. It is emphasized that, in a population of physically active elderly individuals, other physical qualities can be more determinant, such as muscle strength[18,27].

Only three of the eight functional tests (SST, GUS and 6WT) presented significant correlations with coxofemoral joint flexibility. It is important to note that the observed associations were concentrated in the flexion ROM (RHF+LHF), and not in extension. This contradicts the findings of classical studies such as the one by Roach and Miles[38], which showed that, among elderly subjects, the extension ROM of the coxofemoral joints would be the most impaired, which would be reflected in step length reduction. However, it is important to note that one of the main limiting factors on ROM is what Gajdosik et al.[39] called passive resistive torque (PRT). The PRT is a force that tends to offer resistance to any attempt to change the length of the conjunctive tissue situated in the tendons and tissues around the joint complex[39]. Therefore, considering that PRT is sensitive to alterations that occur in the tissues and to levels of muscle force and physical activity, and that these variables are influenced by different levels and types of physical activities that are practiced, it is coherent to suppose that the high level of physical fitness of the subjects in our sample was the main factor responsible for these differences that were found.

The associations between the SST and GUS tasks and the flexibility of the coxofemoral joints were also observed by Bergstrom et al.[22]. With regard to the relationship between 6WT and the coxofemoral joint ROM, it is of interest to note that, although the association was significant (RHF+LHF, $r=0.59$, $p=0.003$; ∑ROMH, $r=0.59$, $p=0.002$), other studies have not been capable of demonstrating high coefficients of correlation between the same variables[16,40]. From what it seems, regarding the relationship between flexibility and gait pattern, the ankle joints would be more important than the hip or knee joints[16,40]. However, it is emphasized that these studies have important methodological differences, in relation to ours. While Farinatti and Lopes[16] examined the gait quality, by measuring the range and frequency of the step, Judge Davis and Ounpuu[40] worked with elderly individuals who were in a physical and functional condition that was much worse than that of the subjects in the present study. In the first case, the gait speed was not assessed, and only 32 steps were monitored. In the second, the ROM reduction in the ankles and changes to the gait pattern could have been greater than what was shown by the sample of the present study. In fact, the importance of the ankle joint increases with the elderly individual's increasing level of frailness, with dramatic reductions in the mobility of this joint. On the other hand, it is undeniable than greater coxofemoral joint ROM can favorably influence step amplitude, with a probable impact on movement speed over longer distances, as is the case of the 6WT.

Although the performance in the SLC test theoretically requires good hip flexion and extension ROM[41], the correlations observed between the ROM of these joints and the test performance were relatively weak, although significant. It can be speculated that this relationship may have been influenced by the sample characteristics: physically active elderly individuals present greater muscle strength. Since one of the determining factors for the performance in this test is the strength of the extensor knee muscles[41,42], the possible influences of flexibility could have been left behind. The same argument could, at least partially, explain the reduced correlations between the hip ROM and the performance in the GUS test.

Cunningham et al.[14] observed associations between the functional independence of elderly individuals and the variables of knee extensor muscle strength, normal walking speed, shoulder, hip and ankle flexibility, level of physical activity and the score obtained in the inventory for assessing the level of functional incapacity. It was observed that although the correlations between glenohumeral and coxofemoral joint flexibility and functional independence were significant, they were small (-0.27 and 0.34, respectively). On the other hand, it was observed that 40% of the variance in the functional limitations was associated with participation in physical activities and with shoulder joint ROM. In the present study, the ∑ROMH was responsible for 44% of the overall functional performance variance, which, in a way, is in agreement with the results found by Cunningham et al.[14]. This is of interest, since the kinds of instrument used for ROM measurements and, especially, the sample characteristics were different in the two studies. In the study by Cunningham et al.[14], not only was ROM measured using a Leighton flexometer, but also the sample was composed of institutionalized individuals, who therefore presented reduced physical fitness and activity levels.

In this respect, Beissner Collins and Holmes[37] observed 80 subjects (age 81±7 years; 58 women and 22 men) who were divided in two groups: institutionalized with functional limitations and functionally independent subjects. The level of association shown by the variables of muscle strength and lower limb joint ROM in relation to functional performance was significant and moderate (respectively, $r^2=0.71$ and 0.77). These correlations were slightly higher than the ones from the present study. When the data from Beissner Collins and Holmes[37] were analyzed using multiple correlations, once again the lower limb muscle strength and flexibility were the variables that were most associated with performance. When observed alone, the lower limb ROM was responsible for 59% of the variance. However, when associated with lower limb strength, the r^2 was of the order of 0.77.

It is of interest to note that, in the study by Beissner Collins and Holmes[37], the variables were associated differently with the two functionality groups. For the subjects with functional limitations, the set of variables that most related to functional performance was represented by the combination formed by the ROM and muscle strength of the lower limb muscles. However, for the functionally independent elderly individuals, the strongest association with performance was with the upper limb muscle strength. These results can, at least partly, help to explain the difficulty in identifying significant associations between flexibility and the motor functional tests. Similar results were observed in the study by Geraldes et al.[19], in which, with the exception of the tasks that were strictly related to certain measurements, notably trunk movements, no significant relationship between multi-joint flexibility and functional performance among physically active elderly women was identified. There is the possibility that the absence of statistical significance for the shoulder and hips joint ROM correlations was due to the fact that the tests did not involve the direct and effective participation of these joints.

It is important to mention two possible methodological limitations. The first is with regard to the fact that the sample selection was not carried out probabilistically and the second relates to the number of subjects in the sample, because in multivariate statistics, the number used represents the minimum generally accepted for the use of this statistical resource[43]. Therefore, even though the sample size was within the accepted limits for previously performed sample calculations, it must be recognized that the risk of type I error cannot be neglected. The results of the multiple correlation confirmed that the coxofemoral ROM was significantly associated significantly with functional performance, unlike the tasks that are more directed towards the upper limbs. According to the adjusted determination coefficient (r^2), the combination that presented greatest predictive capacity for performance in the tests was the sum of the coxofemoral joint flexion range (RHF+LHF). This combination was responsible for 51% of the variance in the results, a slightly higher value than what was obtained for the combination of flexibility measurements represented by ∑ROMH, with r^2=0.44. These results indicate, according to the literature available, that flexibility perhaps should not be used as the only predictive variable for functional performance. Other factors, such as muscle strength, should be used together with this.

Conclusions

With regard to the motor tasks that were used as tests, the results suggest that functional performance is more related to the sum of ROM measurements in a set of joints, than to the ROM alone. Moreover, the multivariate analysis demonstrated that, although significant, the correlations observed were concentrated only in the hip flexion movements. No significant association was identified for the glenohumeral joint ROM. Even when associations were identified, such as in the case of the coxofemoral joints, they were revealed to be very specific, appearing to be related strictly to the characteristics of the tests used. Thus, the practical recommendation that flexibility measurements can be used alone as a predictive variable for functional performance among healthy and physical active elderly individuals needs to be elucidated. Among the possibilities of future studies, the following can be mentioned: investigation of the correlation of flexibility and other variables of physical fitness, especially muscle strength, with functional performance; use and comparison of the effects of static and dynamic flexibility measurements and their relationship with functional performance; use of motor task tests that objectively and directly involve the target joints of the study and investigation of the differences between flexibility and functional performance in groups of different physical fitness levels.

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