A multivariate analysis of the correlation between step length-pacing and muscular fitness components in elder subjects*

Paulo de Tarso Veras Farinatti and Leonardo Nobre Codeceira Lopes

ABSTRACT

The objective of the study was to verify the association between step length and pacing during gait and muscular fitness components (MFC) (flexibility, strength and muscular endurance of the lower limbs) in 25 physically independent and apparently healthy women aged between 60 to 86 years old (mean = 79 ± 7 years) tests. The following variables were assessed: a) total and lower limbs height and body weight; b) step length and pacing (SL and SP); c) 2-minute step-in-place test (number of repetitions) (RESISR); d) maximal strength of knee extensors (load/body weight) (FORCAR); e) ankle and hip flexibility (FLEXA and FLEXH). Data were analyzed by simple and multivariate correlation techniques. The results suggested that: a) step length and pacing variables were directly associated to MFC, as suggested by the canonical analysis (r_{can} = .79; p < .05); b) the step length seemed to be more correlated with maximal strength and muscular endurance than with flexibility; c) the overall association of FLEXA, FLEXH, FORCAR and RESISR with SL and SP was stronger than the correlations found for any isolated variable. Based on these findings, a regression equation was proposed to estimate gait efficiency from MFC variables: EMB = 7.53 – .26 (FLEXH) + .29 (FLEXA) – 1.87 (FORCAR) – .05 (RESISR), and FGE = 7 (EMB) + 76, where *EMB = Raw Gait Score* and *FGE = Final Gait Score* (r^2 = .90; SEE = .35; p < .0001).

Key words: Aging. Physical fitness. Gait. Functional autonomy. Health.

INTRODUCTION

The capacity that elder subjects have of maintaining themselves independent seems to depend partly on the maintenance of flexibility, strength and muscular resistance, features that if analyzed as a whole could be considered as muscular fitness components (MFC)[1-4]. An example of the influence of these components on the physical-functional fitness in aging concerns the alteration on the gait normal standard. The aging process seems to be associated to unfavorable modifications in the way of walking, in the increase on the time required to travel a given distance and in the necessity of using support for the dislocation[5-7].

Therefore, a relation between the gait capacity maintenance and the functional independence level of elder subjects seems to exist. Guyatt *et al.*[8], for example, verified a positive correlation between the distance traveled in a six-minute gait test and the ability for the performance of many daily activities in 43 elder individuals considered as frail. Some authors suggest that the gait is a good – if not the best – risk indicative of autonomy loss with aging[9-12]. Even the self-appreciation of the functional state or the fear intensity of suffering falls seem to be associated to the maintenance of a gait model and effective speed[13-17].

Nagasaki *et al.*[18], for example, in a study involving 1,134 subjects older than 65 years, verified the step length trends to decrease and the step pacing trends to increase. The authors appreciated what they called as Walk Ratio, dividing the step length by its pacing, in comfort and maximal speeds. The results indicated this ratio would decline in any speed observed, but the step pacing trended to be even higher in high speeds in an attempt of compensating the step length limitation. Lockhart *et al.*[19] reported that, in comparison to young individuals, elder subjects would have a shorter phase of contact of the heels with the ground, shorter step length and thus, lower horizontal acceleration of the center of mass. Comparing subjects who fell more or less when walking on slippery surface, they came to the conclusion that a shorter phase of contact of the heels with the ground would be associated to the higher fall frequency, regardless the dislocation speed. It may also be concluded that the gait standard alterations associated to the loss of balance in general trend to multiply the occurrence of falls in elder subjects, which consequences may be harmful[20-22].

The reasons for the modifications on the gait standard in elder subjects are multifactor – maybe that is why they are not yet fully cleared. Some studies, however, search to enlighten this question and many of them consider the muscular fitness as the center of the discussion. Daniels and Worthingham[23], for example, included the muscular weakness and the articular movement limitation among the five main factors that could cause gait deficiencies. The same was performed by Hausdorff *et al.*[5], who analyzed, in a controlled randomized study, the etiology of the gait instability with aging. The muscular weakness and the articular movement limitation would be associated to a *wider support phase and to reduced steps* during gait as well as to the balance difficulties. Finally, Bassey *et al.*[24] demonstrated in very old and institutionalized subjects, that the support necessity to walk was strongly associated to a reduced power of knee extension. Indeed, over than 86% of the gait speed variations in the sample observed could be explained by the loss of muscular power in lower limbs.

With regard to the flexibility, Williams and Bird[25] emphasized the importance of the loss of flexibility, suggesting that this could be associated to alterations on the gait standard both in the step length and in the step balance. Vandervoort *et al.*[26], in a study in which the ankle articular complex was analyzed, verified that a decrease on the articular length with aging would occur as well as a decline on the maximal strength for the dorsiflexion, thus contributing to increase the gait difficulty. In his explanatory model for the etiology of the gait instability in elder subjects, Hausdorff *et al.*[5] also included the decrease on the movement length as independent determinant factor.

The literature, however, reveals the relations between the muscular fitness components; the step pacing and length have not been fully investigated. Despite knowing that the muscular strength and flexibility are important gait components, one may speculate that their values analyzed independently are not sufficient to explain

* Physical Activity and Health Promotion Laboratory, Sports and Physical Education Institute, Rio de Janeiro State University.

Received in 26/5/04. 2nd version received in 20/9/04. Approved in21/9/04.

Correspondence to: Paulo de Tarso Veras Farinatti, Rua São Francisco Xavier, 524, sala 8.133-F, Maracanã – 20550-013 – Rio de Janeiro, RJ – Brazil. E-mail: farinatt@uerj.br

the way they interact. In other words, gait is a functional situation to which strength and flexibility concur simultaneously – their isolate description, therefore, provides important information, however, incomplete for a better comprehension of their actual contribution for the stroll efficiency. With regard to this fact, no studies analyzing the gait components and the strength relative importance and flexibility considered simultaneously were found. Thus, the present study aimed at correlating the step length and pacing in aged women with the muscular fitness components of the lower limbs: muscular strength, muscular resistance and articular flexibility.

METHODOLOGY

Twenty-eight subjects physically independent participated in this study with ages ranging from 60 to 86 years (average = 79 ± 7 years) who participate in the Aged in Movement Project: Maintaining the Autonomy, from the Rio de Janeiro State University (UERJ). The Institution's Ethics Committee previously approved the procedures. All volunteers were informed of the activities to be performed and agreed in participating of this study by signing the consent form according to the resolution 196/96 from the Health National Council. The following factors were adopted as exclusion criteria: a) late infarct situation (less than two years) and unstable angina; b) systolic-diastolic hypertension response in exercise maximal test; c) ischemic response in exercise maximal test; d) neuropathological affections that would impair the gait standard; e) osseous-articular deformities that would contraindicate the test performance. Due to operational reasons, the subjects were randomly divided into three groups of five individuals, where each group was called in different days for the performance of the tests in the following order: step length and pacing, step-in-place test, hip and ankle flexibility and lower limbs maximal strength. Each tests session lasted about 30-45 minutes.

The step length and pacing were defined by test proposed by Nagasaki *et al.*[18]. Lines on the floor were demarcated with adhesive tape, two meters apart until at least 30 meters had been demarcated. The individual was positioned with heels on the first line, starting with the sign at maximal gait speed (running was not allowed) until the individuals performed a total of thirty-two steps. The total distance traveled (comprehended between the first line and the point in which his heel touched the floor at final of the last step execution) and the time spent on the way were recorded. The total and lower limbs height and body weight in bench with standardized measure (44 cm) for the calculation of the corrected step length and pacing were also measured. The test was applied three times and the values associated to the longest distance were adopted as final result.

For the calculation of the average step length (SL) the total distance traveled (DTP) was divided by the thirty-two steps executed by the subject (SL = DTP/32). Now, the step pacing (SP), consisted of the relation between the total number of steps performed and the time spent (in seconds) to perform the whole way (SP = number of steps/time). Once both the average step length and the step pacing are influenced by the subject's height, particularly by the lower limbs' height, both were corrected with the objective of allowing a comparison between the results obtained. The correction formulas are: SL_{corr} = SL/(LL Height/LL average height); SP_{corr} = SP x (LL Height/LL average height)$^{1/2}$, where LL Height = lower limbs' height and LL average height = Lower Limbs' average height. The lower limbs' height was obtained by subtracting the trunk's height by the total height. In order to determine the trunk's height, the subject was asked to sit on a bench with standardized height and measuring the distance between the floor and the vertex. Then, the bench's height was subtracted from this measure. The lower limbs' average height corresponded to the arithmetic average of all measures of the lower limbs obtained in the sample.

The lower limbs resistance was estimated from the 2-minute step-in-place test, according to standardization proposed by Rikli and Jones[27]. The test was selected due to its relationship with the peripheral fatigue level (muscular), despite some authors adopt it as cardiorespiratory endurance indicative in subjects very inactive[28]. The average point of the distance between the patella and the iliac crest of the subjects was initially obtained. This was the minimum height in which the knees should be elevated during the test. In order to control the correct knees height, two long sticks were placed side by side and tied by elastic at the correct height. The knees should touch the elastic during the test. At the command, the subject started the movement with the right lower limb by simulating the gait. The counting occurred every time the right knee reached or exceeded the minimum height established. In case the subject presented symptoms of fatigue and could no longer elevate the knee up to the minimum height, the counting should be interrupted and the subject was allowed to stop the activity and to return later, as long as he remained within the two minutes allowed. The subjects were informed when the test reached one minute and when 30 seconds were left until the end of the test. The final result consisted of the number of times the right knee reached the minimum height within the two minutes proposed. The subject was allowed to perform a few attempts before the test was actually started for familiarization. At the end of the test, the subjects were instructed to walk slowly for a few minutes for recovery.

The hip and ankle flexibility measures were performed at the sagittal plane and in the right limb with the aid of a protrator-type universal goniometer[29]. For the evaluation of the hip articulation, the subject had to lie down on padded bench in dorsal decubitus and with knees extended. The appraiser placed the goniometer with its central shaft on the trochanteric point, one of the staff fixed to side of the trunk (on the prolongation of the axillary line) and the other fixed to the external side of the thigh on its medium line in order to form an angle of 180°. Soon after, the hip flexion was performed with knee extended up to the maximal point in which the discomfort sensation was felt, recording the angle formed between the lower limb and the bench. If the subject started bending the knee, the limb should be lowered slightly to make the subject to extend it fully, then lifting the leg again. For the evaluation of the ankle articulation, the subject had to sit down on a high bench; barefoot in such way his feet would not touch the floor and remained relaxed. The goniometer was placed with its central shaft at the Sphirion point with one of the staffs fixed at the internal side of the leg (on an imaginary line drawn from the Sphirion point up to the tibial point) and the other staff on a line drawn from the prolongation of the fourth metatarsus (forming an angle of 90°). The dorsal flexion movement was performed followed by plantar flexion and both angles were summed up for the attainment of the ankle articulation complete movement arc.

The maximum strength for knee extension was quantified by the 1-RM test in the leg-press, according to standardization proposed by Matsudo[28]. As preparation, the subjects were allowed to perform a series from five to ten exercise repetitions with load equivalent to 40-60% of the 1-RM (estimated or observed). Shortly after, the test that should involve a maximum of six attempts was performed. The subjects were discouraged to perform the Valsalva movement, once they should breathe in before performing the movement, breathe out during the positive phase (concentric) and breathe in again when the weight was returning to the initial position (eccentric). A measure of relative strength, obtained through the ratio between load associated to 1-RM and the subject's body weight, was adopted as final result.

The analysis of the results involved: a) descriptive statistics for all variables; b) determination of the interclass association degree between variables of strength, flexibility, and step length and pacing taken separately through the Pearson correlation coefficient; c) calculation of the multiple correlation coefficient between step length and pacing and the strength and flexibility variables combination. To do so, the step length and pacing were successively adopted as dependent variables. In each case, the independent variables initially were: ankle and hip flexibility and then, lower limbs relative strength and relative resistance; d) determination of the canonical correlation coefficient between the step set of variables (pacing and length) and the strength and flexibility set of variables; e) calculation of the canonical scores for the step set of variables from the canonical analysis. These scores were considered as indicative of the gait efficiency set. Later on, the crescent sequential multiple regression (forward stepwise) was calculated with the canonical scores representing the dependent variable and the others (strength and flexibility) representing the independent variables. In all cases, the level of significance was adopted as 5% for error type I.

RESULTS

Table 1 illustrates the descriptive results found considering the parameters evaluated of the corrected step average length (SL), corrected step pacing (SP), right ankle articulation flexibility (FLEXA) and hip articulation flexibility (FLEXH) and finally, muscular strength (FORCAR) and resistance (RESISR). Simple correction calculations, multiple correlation, canonical analysis and multiple regression were used for the treatment of results. The results from the statistical analysis are presented in tables 2, 3 and 4.

The Pearson correlation coefficients between variables step length and pacing and strength, flexibility and resistance revealed significant correlation only between step length and resistance, with 66% of association. When a multiple correlation analysis was performed between step length and flexibility (FLEXH + FLEXA) as well as between the step pacing and flexibility (FLEXH + FLEXA), no significant coefficients were observed.

On the other hand, for variables muscular strength (FORCAR + RESISR), the correlation was significant for the step length ($p < 0.05$).

The results for the canonical analysis between step length and pacing and flexibility (FLEXH + FLEXA) and between the step length and pacing and variables muscular strength (FORCAR + RESISR), are presented in table 3. The coefficients obtained reveal interesting aspects: for variables flexibility (FLEXH + FLEXA), the r-canonical (r_{can}) was not significant ($p = 0.48$), although the association has not been neglectable ($r_{can} = 0.51$). For variables strength (FORCAR + RESISR), the association had been sufficiently strong to detect statistical significance ($r_{can} = 0.70$, $p = 0.04$). When all MFC measures were correlated (FORCAR + RESISR and FLEXH + FLEXA) with step variables, however, the association revealed to be more important than with the strength and flexibility measures taken separately ($r_{can} = 0.79$; $p = 0.04$).

TABLE 1
Values related to muscular fitness and mobility in subjects older than 60 years old (n = 25)

Variable	Average	Standard-Deviation	Maximum	Minimum
SL (m)	0.70	0.09	0.86	0.52
SP (step/sec)	2.44	0.24	2.83	2.06
FLEXH (degrees)	73.2	13.3	90	38
FLEXA (degrees)	48.6	7.1	63	34
FORCAR (load/weight)	1.18	0.21	1.71	0.78
RESISR (rep)	90.3	14.2	126	64

TABLE 2
Multiple and simple correlation between step variables (SL + SP) and Muscular Fitness Components (n = 25)

Variable	FLEXH (r)	FLEXA (r)	FORCAR (r)	RESISR (r)
SL (simple)	0.28 NS	0.12 NS	0.36 NS	0.66*
SP (simple)	0.43 NS	0.35 NS	0.15 NS	0.22 NS
	FLEXH + FLEXA		FORCAR + RESISR	
SL (multiple)	0.31 NS		0.72*	
SP (multiple)	0.41 NS		0.21 NS	

TABLE 3
Canonical analysis between step variables (SL + SP) and flexibility (FLEXH + FLEXA) and strength (FORCAR + RESISR) measures: r-canonical, variance and eigen values (n = 25)

FLEXH + FLEXA	***r – canonical = 0.51 p = 0.48***	
	Left set	**Right set**
Number of variables	2	2
Variance extracted	100%	100%
General redundance	17.1%	19.8%
FORCAR + RESISR	***r – canonical = 0.70 p = 0.04***	
	Left set	**Right set**
Number of variables	2	2
Variance extracted	100%	100%
General redundance	27.2%	29.4%
FLEXH + FLEXA + FORCAR + RESISR	***r – canonical = 0.79 p = 0.04***	
	Left set	**Right set**
Number of variables	2	2
Variance extracted	100%	46.9%
General redundance	40.2%	25.6%

TABLE 4
Summary of the multiple regression results (canonical scores x flexibility and strength variables) (n = 25)

Multiple regression		Dependent variable: canonical scores (right set) $p < 0.0001$ $r = 0.95$ $r^2 = 0.90$ estimation standard error (SEE) = 0.35			
n = 25	**Beta**	**SEE Beta**	**B**	**SEE B**	**P-level**
Intercept			7.5355	0.637538	0.00000
RESISR	–0.741416	0.74118	–0.05323	0.05322	0.00000
FORCAR	–0.381775	0.71832	–1.87035	0.351909	0.00033
FLEXH	–0.340317	0.75803	–0.02645	0.005891	0.00022
FLEXA	0.204407	0.81256	0.02933	0.011660	0.02054

DISCUSSION

This study had as objective to correlate the decrease on the step length and pacing in elder subjects with the behavior of the muscular fitness components, more specifically strength, resistance and flexibility of the lower limbs. To do so, multivariate and simple correlation strategies as well as multiple regression were used. Some limitations as result of the adoption of statistical techniques must be mentioned. Indeed, the canonical analysis is a multifactor statistical strategy that should ideally be applied only in samples with over than 50 subjects[30], once its power needs to be elevated in order for the statistical significance to be obtained. Stevens[31] suggests that this amount of cases is required for associations reasonably important to be identified (order of 0.70).

As observed from table 3, the canonical coefficients (r_{can}) obtained were not reduced, remaining between 0.51 (in the case of the variables flexibility) and 0.79 (when all variables were analyzed as a whole). In the first case, the possibility of the non-statistical significance is a result of the error type II must be considered. The fact that the correlation coefficient obtained in the multiple regression, between the canonical scores calculated for each individual and the muscular fitness variables has been elevated (r = 0.95) trends to reinforce this opinion. Anyway, one may affirm that the isolate association with variables strength was higher than with variables flexibility, corroborating the results obtained in the multiple and simple correlation. However, when the step standard is analyzed as a whole, correlating the set SL and SP with muscular fitness, the canonical analysis reveals something that could not be demonstrated through the SL and SP analysis separately. The outstanding r_{can} obtained for the relation between the step variables and the four muscular fitness indicatives was higher than the r_{can} obtained for flexibility and strength taken separately. This suggests that, when the gait general performance is considered, the analysis of the movements' length interaction in the lower limbs (flexibility) with resistance and relative strengths would be more important than the observation of each component alone.

Someway, this corroborates what is presented in literature in the sense that the improvement of the muscular fitness components may lead to an increment of the gait potential. The evidences indicate that elder subjects walk more slowly than young individuals[6,13,25,32]. This would mainly occur due to a reduction on the step length associated to a decline on hip and ankle flexibility and on strength of the ankle flexor muscles and knee flexors and extensors[3,6,33,34]. This would be, someway, compensated by the increase on the step support phase time and pacing[6,35-37], even though with a shorter contact of the ankle with the ground[19].

Some authors verified that the strength and flexibility training could contribute with the improvement of the gait speed and hence with the improvement of the step length and pacing, among other gait-limiter factors[23,24,38-40]. Fiatarone *et al.*[41], in a study frequently mentioned in literature, verified that the muscular strength and gait speed in advanced-aged elder subjects (between 87 and 90 years old) improved about 113% and 12%, respectively after 10-weeks endurance training with intensity of 80% of the maximal strength. Ades *et al.*[42] demonstrated that three months of weight training resulted in increments of the gait submaximal capacity (80% of the $\dot{V}O_{2peak}$) in individuals from 65 to 79 years old. Those who trained improved their times in 9 minutes (from 25 ± 4 min to 34 ± 9 min), representing a gain of about 38%. Lord *et al.*[43] also identified significant improvements in the gait usual speed in elder subjects after 22 weeks of training involving strength, balance and flexibility.

Hausdorff *et al.*[5] published extensive analysis of the gait instability genesis, performed with a group of 67 men and women older than 70 years old. Besides investigating the limitations that could lie on the origin of the involvements verified, a 6-months domestic training program was applied with controlled randomized design aimed at the muscular strength and balance development. The authors came to the conclusion that the reasons for the change on the gait standards are many, but general increments (even if moderate) in the lower limbs muscular function may contribute to reduce the strolling instability. The modifications on the gait standards in elder subjects may someway be an attempt of compensating physiological-functional limitations.

In this context, Menz *et al.*[6] reported that, if compared to younger subjects, the elder subjects adopted an old-line gait standard, characterized by reduced speed, shorter step length and higher frequency variability, what trends to worsen in irregular surfaces. Among the factors that contribute for the adoption of this standard, the authors emphasized the reduction on the lower limbs muscular strength. Ringsberg *et al.*[3], in turn, verified in 230 women older than 75 years old that strength deficits in knee and ankle flexion and extension movements would be more associated to the gait performance than to static or dynamic balance. Finally, Judge *et al.*[34] came to conclusions similar to those previously described with regard to the gait standard in elder subjects, but reported that the impact of the ankle movements (flexion and extension) both for strength deficits and flexibility would have more influence on the step length than those associated to hip and ankle movements.

Generally, it is well accepted that the MFC decline trends to affect negatively the gait, causing a decrease on the step length and/or pacing. Thus, it is not surprising that the multiple regression analysis has revealed good correlation between the muscular fitness components (FORCAR + FLEXH + FLEXA + RESISR) and the factorial scores calculated from the canonical weights attributed to SL and SP in the left set of the canonical analysis equation. The factorial scores may be seen as indicative of gait quality, once they are originated from the step length and pacing measures (table 4). Indeed, an equation which adjustment coefficient was of 0.90 was obtained; the estimation standard error was found within acceptable limits (SEE = 0.35) and high significance level ($p < 0.0001$). Thus, if we wanted to foresee the gait efficiency from the muscular fitness variables here observed, we could work with the following equation: EMB = 7.53 – 0.26 (FLEXH) + 0.29 (FLEXA) – 1.87 (FORCAR) – 0.05 (RESISR) and FGE = 7 (EMB) + 76, where, *EMB = Raw Gait Score* and *FGE = Final Gait Score*.

As seen above, the equation final result was transformed into scores proportional to the age average and standard deviation found in the sample. The *Raw Gait Score* (EMB) is of difficult interpretation, once the factorial scores exhibit 0 as average and standard deviation equal to 1, similar to what is seen in scores Z. The strategy adopted for the scores transformation follows the same principle as the Scale T that corrects the predicted values into an average of 50 and standard deviation of 10 (for details, see Thomas, Nelson[44]). However, one rather chose using the age of the individuals as comparison parameter that, besides removing negative values from the equation final result, facilitates the interpretation. An individual, whose EMB is at the average of the sample analyzed will present *Final Gait Score* (FGE) approximately equal to the age average obtained and so on. Similar strategy was adopted by Kim and Tanaka[45] in the development of the functional autonomy index.

Thus, one may have an idea of the gait deficit through the comparison with the chronological age. An individual with 65 years old and with FGE of 35 probably presents step variables better preserved if compared other individual with the same age but with FGE of 80. Figure 1 illustrates the comparison procedure, exhibiting the chronological age of 25 subjects and the difference obtained between FGE and these values (Delta = FGE – age). As observed, the delta is systematically lower than zero, suggesting a trend to lower gait efficiency in elder subjects – this could even be taken as validity evidence of the equation proposed. However, the differences seem to remain more or less constant, regardless the age values. This indicates that elder subjects would trend to exhibit modifications progressively unfavorable in the step variables, what would result in the delta maintenance between the chronological age and the FGE. This possibility was corroborated by the graphic drawing of the age and delta relations with the calculation of the correlation coefficient between these variables. The Pearson coefficient did not reveal to be significant ($p = 0.61$). Furthermore, the figure 2 demonstrates that the delta evolution with age assembles a line parallel to the abscissas axis with a slight trend to increase with more advanced ages.

The step length and pacing test may represent, therefore, a simple and fast way to verify the elder subject's frailty in an important daily task such as gait. Once verified that the elder subject presents limitations in one of the variable, the performance of other tests to analyze the muscular fitness components separately is required, as those proposed in this study. Therefore, one may observe in which aspect the limitation is higher, either in flexibility, strength, muscular resistance or in more than one physical quality.

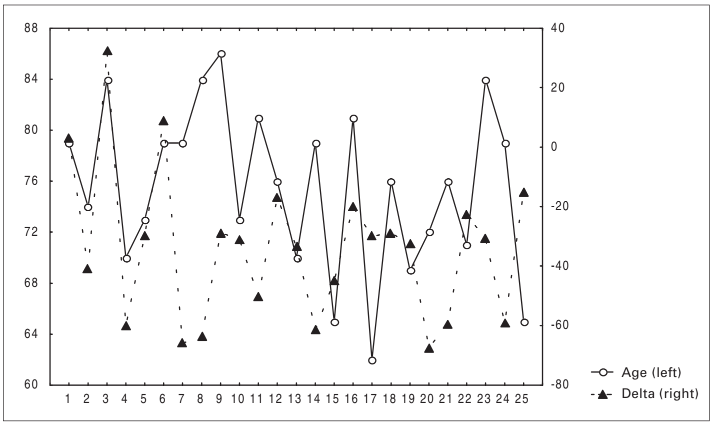

Fig. 1 *– Chronological age of the 25 subjects observed and difference obtained between the final gait score (FGE) and these values (Delta = FGE – chronological age).*

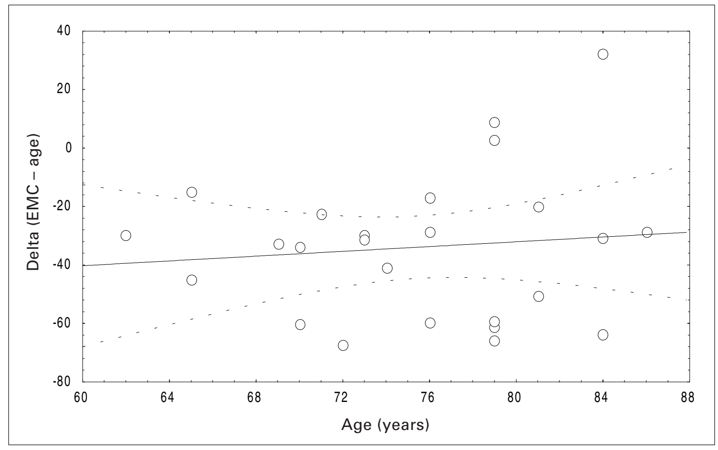

Fig. 2 *– Delta evolution (Final gait Score – chronological age) with age (r = 0.11; p = 0.61). Dotted lines represent the confidence interval established in 95%.*

CONCLUSIONS

Despite the number of evidences suggesting that the MFC preservation trends to contribute with the maintenance of gait standards suitable to daily living in elder subjects, researches that have analyzed the muscular fitness as a unique set of interrelated variables and their association with gait components are rarely found. The present study had as objective to perform a correlative analysis of the step length and pacing, vital characteristics of the human gait with the muscular fitness components (MFC), more specifically flexibility, strength and muscular resistance in individuals older than 60 years old. The results obtained allowed to come to the following conclusions: a) the variables step length and pacing are associated with MFC, as evidenced by the r-canonical (r_{can} = 0.79); b) the step length seems to be more influenced by strength than by flexibility, more specifically by muscular resistance; c) the conjoint interrelation of several MFC (flexibility, resistance and lower limbs strength) with the gait general efficiency seems to be more important than the association between this variable and each one of those components, taken separately.

All the authors declared there is not any potential conflict of interests regarding this article.

REFERENCES

1. Pendergast DR, Fisher NM, Calkins E. Cardiovascular, neuromuscular and metabolic alterations with age leading to frailty. J Gerontol 1993;48:61-7.
2. Phillips WT, Haskell WL. 'Muscular fitness' – Easing the burden of disability for elderly adults. J Aging Phys Activity 1995;3:261-89.
3. Ringsberg K, Gerdhem P, Johansson J, Obrant KJ. Is there a relationship between balance, gait performance and muscular strength in 75-year-old women? Age Ageing 1999;28:289-93.
4. Kell RT, Bell G, Quinney A. Musculoskeletal fitness, health outcomes and quality of life. Sports Med 2001;31:863-73.
5. Hausdorff JM, Nelson ME, Kaliton D, Layne JE, Bernstein MJ, Nuernberger A, Fiatarone Singh MA. Etiology and modification of gait instability in older adults: a randomized controlled trial of exercise. J Appl Physiol 2001;90:2117-29.
6. Menz HB, Lord SR, Fitzpatrick RC. Age-related differences in walking stability. Age Ageing 2003;32:137-42.
7. Shkuratova N, Morris ME, Huxham F. Effects of age on balance control during walking. Arch Phys Med Rehabil 2004;85:582-8.
8. Guyatt GH, Thompson PJ, Berman LB, Sullivan MJ, Townsend M, Jones NL, Pugsley JO. How should we measure function in patients with chronic heart and lung disease? J Chron Dis 1985;38:517-24.
9. Cunningham DA, Paterson DH, Himann JE, Rechnitzer PA. Determinants of independence in the elderly. Can J Appl Physiol 1993;18:243-54.
10. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995;332:556-61.
11. Sonn U, Frändin K, Grimby G. Instrumental activities of daily living related to impairments and functional limitations in 70 year-old and changes between 70 and 76 years of age. Scand J Rehabil Med 1995;27:119-28.
12. Woo J, Ho SC, Yu AL. Walking speed and stride length predicts 36 months dependency, mortality, and institutionalization in Chinese aged 70 and older. J Am Geriatr Soc 1999;47:1257-60.
13. Bosscher RJ, Van Der Aa H, Van Dasler M, Deeg DJH, Smit JH. Physical performance and physical self-efficacy in the elderly. J Aging & Health 1995;7:459-75.
14. Cress ME, Schechtman KB, Mulrow CD, Fiatarone MA, Gerety MB, Buchner DM. Relationship between physical performance and self-perceived physical function. J Am Geriatr Soc 1995;43:93-101.
15. Gama EV, Damian JE, Perez de Molino J, Lopez MR, Lopez Perez M, Gavira Iglesias FJ. Association of individual activities of daily living with self-rated health in older people. Age Ageing 2000;29:267-70.
16. Jylha M, Guralnik JM, Balfour J, Fried LP. Walking difficulty, walking speed, and age as predictors of self-rated health: the women's health and aging study. J Gerontol A Biol Sci Med Sci 2001;56:M609-17.
17. Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. J Am Geriatr Soc 1997;45:313-20.
18. Nagasaki H, Itoh H, Hashizume K, Furuna T, Maruyama H, Kinugasa T. Walking patterns and finger rhythm of older adults. Percept Mot Skills 1996;82:435-47.
19. Lockhart TE, Woldstad JC, Smith JL. Effects of age-related gait changes on the biomechanics of slips and falls. Ergonomics 2003;46:1136-60.
20. Daley MJ, Spinks WL. Exercise, mobility and aging. Sports Med 2000;29:1-12.
21. Muhlberg W, Sieber C. Sarcopenia and frailty in geriatric patients: implications for training and prevention. Z Gerontol Geriatr 2004;37:2-8.
22. Stel VS, Smit JH, Pluijm SM, Lips P. Consequences of falling in older men and women and risk factors for health service use and functional decline. Age Ageing 2004;33:58-65.
23. Daniels MAL, Worthingham C. Provas de função muscular: técnicas de exame manual. Rio de Janeiro: Guanabara, 1987.
24. Bassey EJ, Fiatarone MA, O'Neill EF, Jelly M, Evans WJ, Lipsitz LA. Leg extensor power and functional performance in very old men and women. Clin Sci 1992;82:321-7.
25. Williams K, Bird M. The aging mover: a preliminary report on constraint to action. Int J Aging Hum Develop 1992;34:241-55.
26. Vandervoort AA, Chesworth BM, Cunningham DA, Paterson DH, Rechnitzer PA, Kovall JJ. Age and sex effects on mobility of the human ankle. J Gerontol Med Sci 1992;47:M17-21.
27. Rikli RE, Jones CJ. Development and validation of a functional fitness test for community-residing older adults. J Aging Phys Activity 1999;7:129-61.
28. Matsudo SMM. Avaliação do idoso – física e funcional. Londrina: Midiograf, 2000.
29. Kendall FP, McCreary EK, Provance PG. Músculos: provas e funções. 4ª ed. São Paulo: Manole, 1995.
30. Morrow JR, Jackson AW, Disch JG, Mood DP. Measurement and evaluation in human performance. Champaign: Human Kinetics, 1995.

31. Stevens J. Applied multivariate statistics for the social sciences. Hillsdale: Erlbaum, 1986.
32. Brach JS, Berthold R, Craik R, VanSwearingen JM, Newman AB. Gait variability in community-dwelling older adults. J Am Geriatr Soc 2001;49:1646-50.
33. Bendall MJ, Bassey EJ, Pearson MB. Factors affecting walking speed of elderly people. Age Ageing 1989;18:327-32.
34. Judge JO, Davis RB 3rd, Ounpuu S. Step length reductions in advanced age: the role of ankle and hip kinetics. J Gerontol A Biol Sci Med Sci 1996;51:M303-12.
35. Murray PM, Kory RC, Clarkson BH. Walking patterns in healthy old men. J Gerontol 1969;24:169-78.
36. Kaneko M, Morimoto Y, Kimura M, Fuchimoto K, Fuchimoto T. A kinematic analysis of walking and physical fitness testing in elderly women. Can J Sport Sci 1991;16:223-8.
37. Maruyama H, Kinugasa T. Walking patterns and finger rhythm of older adults. Percep Motor Skills 1996;82:435-47.
38. Sipila S, Multanen J, Kallinen M, Era P, Suominen H. Effects of strength and endurance training on isometric muscle strength and walking speed in elderly women. Acta Physiol Scand 1996;156:457-64.
39. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, et al. The effect of strength and endurance training on gait, balance, fall risk, and health services use in community-living older adults. J Gerontol A Biol Sci Med Sci 1997;52:M218-24.
40. Kozakai R, Tsuzuku S, Yabe K, Ando F, Niino N, Shimokata H. Age-related changes in gait velocity and leg extension power in middle-aged and elderly people. J Epidemiol 2000;10(1 Suppl):S77-81.
41. Fiatarone MA, Marks EC, Ryan ND, Meredith C, Lipsitz LA, Evans WJ. High intensity strength training in nonagenarians: effects on skeletal muscle. JAMA 1990;263:3029-34.
42. Ades PA, Ballor DL, Ashikaga T, Utton JL, Nair KS. Weight training improves walking endurance in healthy elderly persons. Ann Intern Med 1996;124:568-72.
43. Lord SR, Lloyd DG, Nirui M, Raymond J, Williams P, Stewart RA. The effect of exercise on gait patterns in older women: a randomized controlled trial. J Gerontol A Biol Sci Med 1996;51:M64-70.
44. Thomas JR, Nelson JK. Research methods in physical activity. 4th ed. Champaign: Human Kinetics, 2001.
45. Kim SH, Tanaka K. The assessment of functional age using 'activities of daily living' performance tests: a study of Korean women. J Aging Phys Activity 1995; 3:39-53.