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Effects of *Tai Chi Chuan* on knee extensor muscle strength and balance in elderly women

Efeitos do *Tai Chi Chuan* na força dos músculos extensores dos joelhos e no equilíbrio em idosas

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Abstract

Background: Some studies have indicated that *Tai Chi Chuan* (TCC) is capable of improving physical fitness, muscle strength and balance in elderly people. This improvement could prevent falls, fractures and physical dependence. **Objective:** To investigate the effects of TCC on balance and knee extensor muscle strength among elderly women. **Methods:** Seventy-seven healthy women who were not engaged in any guided physical activity participated in this study. There were 38 volunteers (68 ± 5 years) in the Experimental Group and 39 volunteers (69 ± 7 years) in the Control Group. The Experimental Group practiced 24-movement Yang-style TCC for 12 weeks, consisting of 50-minute sessions three times per week. The Control Group did not perform any guided physical activities. Strength was measured using the one maximum repetition test in an extensor chair and balance was evaluated using the unipodal support test with the eyes closed. The statistical analysis consisted of the normality test, split-plot analysis of variance (ANOVA) and Pearson's correlation coefficient. **Results:** The Experimental Group presented increases of 17.83% in knee extensor muscle strength and 26.10% in balance. The Control Group did not show any significant changes in these variables. No significant correlation was observed between these two variables in the Experimental (r= 0.09; p= 0.554) or in the Control Groups (r= 0.07; p= 0.660). **Conclusions:** These results suggest that TCC improves knee extensor muscle strength and balance among elderly women. However, knee extensor muscle strength was not necessarily linked to balance in this activity.

Key words: aging; *Tai Chi Chuan*; strength; balance.

Resumo

Contextualização: Alguns estudos têm indicado que o *Tai Chi Chuan* (TCC) é capaz de melhorar o condicionamento físico, a força muscular e o equilíbrio entre os praticantes idosos, prevenindo quedas, fraturas e dependência física. **Objetivo:** Verificar os efeitos do TCC no equilíbrio (EQ) e na força dos músculos extensores dos joelhos (F) em mulheres idosas. **Materiais e métodos:** Participaram do estudo 77 mulheres saudáveis, não praticantes de atividade física orientada. No Grupo Experimental (G1) foram incluídas 38 voluntárias (68 ± 5 anos) e no Grupo Controle (G2), 39 voluntárias (69 ± 7 anos). O G1 praticou o TCC estilo Yang de 24 movimentos durante 12 semanas, três vezes por semana, com duração de 50 minutos. O G2 não realizou atividades físicas orientadas. A força foi mensurada pelo teste de 1-RM na cadeira extensora e o equilíbrio foi avaliado utilizando o teste de apoio unipodal com os olhos fechados. Na análise estatística, utilizou-se teste de normalidade, *split-plot* análise de variância (ANOVA) e correlação de *Pearson*. **Resultados:** O Grupo Experimental apresentou incrementos de 17,83% na F e 26,10% no EQ. O Grupo Controle não apresentou alteração significativa em nenhuma variável. Não foi observada correlação significativa entre estas duas variáveis no G1 (r= 0,09; p= 0,554) e no G2 (r= 0,07; p= 0,660). **Conclusões:** Estes resultados sugerem que o TCC melhora F e EQ em mulheres idosas. Entretanto, a força dos músculos extensores dos joelhos não está necessariamente ligada ao equilíbrio nesta modalidade.

Palavras-chave: envelhecimento; *Tai Chi Chuan*; força; equilíbrio.

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Introduction

The aging process in human beings is characterized by a slowing of the neuromotor system, associated with a decrease in the number and the size of muscle fibers, resulting in a gradual loss of muscle strength. Muscular weakness reduces elderly individuals' capacity to carry out daily life activities (DLA), forcing them to be more dependent. Baumgartner[2] related muscle strength with postural stability and suggested that significant decreases in strength could be correlated to the increase of falls in elderly individuals.

Regular physical exercise has been indicated as an important factor in the reduction of falls[3-6]. However, the most appropriate modality of exercise that should be practiced by the elderly is still a subject of discussion. Feder et al.[7] and Oliveira et al.[8] indicated that tai chi chuan (TCC), a Chinese modality of gymnastics, as efficient in increasing physical condition, strength and balance among elderly practitioners, thus helping to prevent falls.

Feder et al.[7] in their study provided important orientations on how to prevent falls for people over 65 years old. The research aimed to transform recommendations to reduce the number of falls in elderly people with the clinical use of experimental evidence. In the studies of Oliveira et al.[8], the objective was to verify the effects of TCC in relation to anthropometric and neuromotor variables. They verified that the practice of TCC shows positive results in physical fitness and it is suggested for the maintenance of functioning capability and for the improvement of the quality of life in women. Lan et al.[9] applied TCC training to elderly women during a six month period, 54 minutes per session, five times a week, with an intensity of 70% of maximum heart rate (HRMax). After this intervention, the researchers noticed an improvement in the strength of knee extensor muscle.

Researchers have questioned specific correlations between the strength of the inferior members and balance improvement in elderly women[10]. This represents a controversy in the literature when researchers explained the balance improvements found after TCC interventions in elderly groups, resulted from improvements in the strength of the inferior members. On the one hand, the aging process favors sarcopenia and the reduction of strength, and on the other, physical activity contributes directly to the maintenance and the improvement of the locomotor system, thus easing the effects of sedentary lifestyle, disuse, immobility, maladaptation and chronic diseases[11]. Blair and Garcia[12] affirmed that TCC is a modality of exercise capable of maintaining muscular strength in elderly individuals. Lan et al.[13] demonstrated that TCC applied to elderly people with intensity of 52% and 63% of maximum heart rate, significantly improved the muscular strength of the knee flexors and extensors in relation to the control group. Balance improvements and the reduction of falls in elderly people have been related as a result of the practice of physical exercise in general, and the practice of TCC in particular[5, 6, 14, 15].

Therefore, there is a lack of studies which aim to clarify a possible correlation between balance improvements in TCC practitioners and the development of the strength of the inferior members, either generally or specifically, relating to the muscular groups, such as the knee extensor musculature. The purpose of this study was to verify the hypothesis that the improvements in the strength of the knee extensor musculature of elderly women who were TCC practitioners was correlated to balance improvements. Therefore, this would explain, in part, the mechanism of the reduction of falls which is related as one of the effects of TCC exercise training.

Methods

Sample

This project was approved by the Ethics in Research Committee of the Universidade Católica de Brasília protocol number 006/2004. After this was approved, procedures for the selection of volunteers were taken and interventions began.

From 100 elderly women registered in the university's physical activity program for elderly people, 77 were recruited and all participants signed an Informed Consent Form. The participants were randomly distributed into groups. The participants of the experimental group (G1; n= 38; age= 68 ± 5 years, height= 152.46 ± 3.54cm), practiced TCC for 12 months. The participants of the Control Group (G2; n= 39; age= 69 ± 7 years, height = 152.13 ± 3.93 cm), maintained doing their daily activities, but were advised not to exercise during the period of the study.

The inclusion criteria were as follows: the volunteers should be aged between 60 and 82 years old, they should not have practiced any Chinese type of exercise and should provide a medical declaration specifying that the volunteers were able to practice physical exercise. The exclusion criteria was as follows: presence of symptoms of disease which disabled participants' mobility, strength, balance or ability to practice exercise, such as lesions of the locomotor system (tendonitis, tenosynovitis, arthrosis, etc.) or painful syndromes (labirynthitis, tension-type or headaches). During the experiment, no participant dropouts have occurred.

Evaluation procedures

The TCC training took place at the university campus, in an open, flat and shaded environment. The evaluation of the protocols as well as the training methodology was selected

following previous studies, which showed low risks for the target population[16-18]. Two weeks before the test, some TCC familiarization training sessions took place with the participants and demonstrations of the instruments and the tests. The evaluation of the muscular strength of the knee extensors and balance were carried out both G1 and G2 at two specific moments: before the TCC training (pre-test) and after 12 weeks of TCC practice (post-test).

Evaluation of the muscular strength of the knee extensors

A *Weider* bank (model Pro 330, Brazil) was used to measure the muscular strength of the knee extensor muscle by means of a 1-RM test (Repetition Maximum Isotonic Test), the maximum weight with which the individual could completely extend the knees, following the recommendations of the American Physiological Society (APS)[19]. The test consisted of three phases: general warm-up, specific warm-up and the 1-RM test of the knee extensor muscles.

The general warm-up consisted of stretching and large movements of the largest muscular groups and this lasted for five minutes. Afterwards, the specific warm-up was performed with the participant's body positioned on the instrument, with the knees forming an angle of 90°. Eight series of movements of complete extension of the knees were performed, using approximately 50% of maximum weight estimated for the individual which was obtained using Baechle and Groves's[20] protocol. During the 1-RM test, the movement of complete extension of the knees was performed using 100% maximum weight estimated for the individual. The weight was increased or decreased a maximum of five times and the amount of weight was registered for the 1-RM. The period of rest between the series was 60 seconds and the period for the trials was 3 minutes.

Balance evaluation

The unipodal position test with eyes closed was used to measure balance, following the protocol suggested by Gustafson et al.[17]. The time of maintaining balance in the unipodal position was measured using a *Sanny* digital chronometer (progressive model, Brazil) with a resolution of 0.01s. The test consisted of three phases: a general and specific warm-up and the unipodal test. In the specific warm-up, a maximum maintenance trial with eyes opened was performed in the unipodal position for each foot. The unipodal test consisted of maintaining, for as long as possible, an orthostatic position, with the hands on hips, in a unipodal position, with the eyes closed. The time of maximum balance maintenance stipulated for each attempt was 30 seconds. Each volunteer took the initial position with the eyes opened, focusing on a point 1 meter in front at eye level. Then, the eyes were closed and the chronometer was started.

The conclusion of each trial was considered to be when the volunteer's eyes opened or returned to the bipedal position. The time of balance maintenance on the requested position was then registered. Three trials were performed for each unipodal position (using the left and right feet), the best of the three was registered. The balance score was the result of the mean score obtained using the two valid measures (for the right and the left feet) for each individual. The period of rest between trials was 60 seconds. An assistant remained close to each participant to minimize the risk of falls.

Intervention procedures

The TCC program was performed for 12 weeks, at a frequency of three weekly practices, with each class lasting for 50 minutes. The exercises performed in class were planned considering the practitioner's physical safety, following the TCC methodology for elderly people developed by Pereira and Safons[18]. The classes were administrated with simple exercises, short choreographies and small changes in direction.

A warm up of 15 minutes was performed and consisted of educational exercises selected from the 24 movements in the series of the Yang TCC training repertory and performed with an emphasis on muscular stretching and respiratory exercises. For each class, 10 exercises were chosen and each exercise was performed in a series of five repetitions, which were slowly and continuously performed, with mental concentration intensity values of either 1 or 2 on Borg's Effort Subjective Perception (ESP) scale[21].

In the specific phase of the workout, the practitioners performed specific choreographies of TCC, maintaining slowness, fluidity and mental concentration. In each class, the choreographies consisted of eight movements chosen from the 24 movements of the Yang TCC style repertory. They also performed choreography in pairs (*Tai Chi Tuishou*) using exercises from the series of 24 movements. The exercises repertory consisted of the 24 movements list: 1. Preparation and opening movement; 2. Wild horse shakes its mane; 3. White crane spreads its wings; 4. Brush knee and twist step; 5. Playing the lute; 6. Step back and repulse the monkey; 7. Grasping the sparrow's tail on the left side; 8. Grasping the sparrow's tail on right side; 9. Single whip; 10. Wave hands like clouds; 11. Single whip, 12. High pat on horse; 13. Kick with right heel; 14. Box ears with both

fists; 15. Turn and kick with left heel; 16. Snake creeps down left leg and then Golden rooster stands on left leg; 17. Snake creeps down right leg and Golden rooster stands on right leg; 18. Fair lady works the shuttles; 19. Picking up the needle from the bottom of the ocean; 20. Unfolding arms like a fan; 21. Turn, shoulder strike, back fist, parry and punch; 22. Apparent close and push; 23. Turn, cross hands; 24. Closing form.

During the 15 minutes of stretching, *Tao Yin* exercises were performed aiming at both psychological and muscular comfort: stop, breathe and rest the mind. At the end of this phase, relaxation was sought with intensity lower than 1 in the ESP scale.

Statistical treatment

Kolmogorov-Smirnov's test was applied to verify parametric data and Levene's test was applied to verify homogeneity. The calculation of the means and the standard deviations were used in the descriptive statistics. The mean numbers of the dependent variables obtained in the pre- and pos-tests, the muscular strength of the knee extensors (S) and balance (B) were compared using Pearson's split plot ANOVA and linear correlations. In all tests, the level of significance was considered to be $p \leq 0.05$ and the calculations were obtained using the Statistical Package for the Social Sciences program (Version 10.0, for Windows).

Table 1. Means and standard deviations of pre- and post-tests of strength.

	Spre (kg)	Spost (kg)	Δ (Spost – Spre) (kg)	Δ%
G1	41.61 ± 13.65	49.03 ± 17.54*	7.42	17.83
G2	35.79 ± 12.60	36.10 ± 12.70	0.31	0.86**

S: strength; G1: Experimental group; G2: Control group.
* Significant difference between pre- and post-tests ($p < 0.05$)
** Significant differences between experimental and control groups ($p < 0.05$)

Table 2. Means and standard deviations in pre- and post tests of balance.

	Bal pre (s)	Bal post (s)	(Bal post – Bal pre) (s)	Δ%
G1	2.72 ± 1.12	3.43 ± 1.43*	0.71	26.10
G2	2.74 ± 1.10	2.66 ± 1.00	-0.08	- 2.91**

Bal: Balance; G1: Experimental group; G2: Control group
** Significant differences between experimental and control groups ($p < 0.05$).

Table 3. Correlations between muscular strength and balance.

	Δ (Spost – Spre) (kg)	Δ (Balpost – Balpre) (s)	Pearson (r)	p
G1	7.42	0.71	0.09	0.554
G2	0.31	-0.08	0.07	0.660

S: Strength; Bal: Balance; G1: Experimental group; G2: Control group.

Results

No missing cases in the data and no normality deviations were observed in the exploratory analysis of the two groups' descriptive data. No significant statistical differences ($p > 0.05$) were observed in any of the applications of Levene's test, that guarantees the acceptance of the Null Hypothesis (Ho) and demonstrates that the variance was homogeneous between the groups. Therefore, these findings meet the requirement of homoscedasticity for the performance of parametric tests. No significant statistical differences ($p > 0.05$) were observed in any applications of Kolmogorov-Smirnov test, which guarantees the acceptance of the null hypothesis (Ho) in which the variables showed normal distribution in between the groups. Regarding the mean numbers of age and height, no significant statistical differences ($p > 0.05$) were found between groups G1 and G2.

Table 1 shows that the knee extensor muscles' strength increased between pre- and pos-test evaluation ($p < 0.001$) only for the experimental group, which indicated significant differences ($p < 0.001$) between the groups.

Regarding balance, the period of maintaining balance in the unipodal position showed an increase of 26.10% for the experimental group and a decrease of 2.91% for the control group. Significant differences between the pre- and post-tests for the experimental group ($p < 0.01$) and a significant differences between the groups ($p < 0.001$) were observed.

No significant correlations were found between strength and balance variables, for G1 ($r = 0.09$) as well as for G2 ($r = 0.07$), were observed considering the pre- and post-test evaluations (Table 3).

Discussion

This study has shown that the muscular strength of the knee extensors significantly increased for the group who participate in TCC training. These increases of strength of the inferior members could be explained by the specific characteristics of TCC training. It demands that the legs are slightly bent during the whole performance of the exercise, with constant movement and weight transfer from one leg to the other[8]. The results of this study confirm the findings which demonstrate significant improvements in the strength of the knee extensor muscles in elderly people of both genders, who practice TCC, respectively, for 3, 6 and 12 months[8, 9, 13]. As the improvements of the strength levels over the 12 weeks of this study are intermediate to the values found in three anterior studies and are closer to the values observed over studies with six months of training. The specific effect of TCC training has

been verified, and excludes other explanations such as neural adaptation that occurs during the first weeks of any strength training program.

In relation to balance, significant increases were observed for the G1 group which participated in TCC training when compared to the control group. The gains in balance could be explained by an integration of the physical exercises with stretching and mental concentration, which perhaps resulted in an efficient training of the neuromotor reflexes[22]. The results of this study are in agreement with the studies of Tse and Bailey[23], Ross et al.[22] and Hong et al.[24] which also showed a significant improvement in balance of both legs for TCC practitioners tested in many difficult situations. However, these results oppose the findings of Wolf et al.[6,25], or classical studies which compared the effects of TCC practice with the effects of a computerized training of balance and with the actions taken for the control group. They have verified that, although TCC reduced the risk of falls, it was not sufficient to significantly improve balance of the participants. This lack of significance in this study was probably related to the kind of TCC intervention protocol they selected which used a low work load and only 10 standard movements of the TCC choreography, which was only equivalent to the warm-up workload performed in the TCC classes in the present study.

Finally, the results of this study have shown no significant correlations between the strength of the knee extensor muscles and the balance in elderly women, practitioners of TCC, which goes against the present initial hypothesis. These results contradict the studies of Gryfre et al.[26] and Rubenstein et al.[27], which showed positive correlations between the strength of the knee extensor muscles,, balance and the functional capability of elderly people. Gür and Çakin[28] proposed an explanation for this contradiction using multiple evaluations of the muscular groups which activate and move the knee. They affirmed that improvements in balance obtained through the strengthening of the inferior members are due to simultaneous improvements of the knee extensor and flexor musculature, in spite of a result of an absolute strength improvement of the extensor muscles. Therefore, an increase in stability could be caused by improvements in the antero-posterior muscular balance as the result of a mutual strengthening of the knee extensor and flexor musculature. Muscular balance would cause better control of movements and lower risks of falls, through other mechanisms, which would not necessarily come from equilibrium improvements.

Aniansson et al.[29], Lankhorst et al.[30] and Ringsberg *et al.*[10] have not found significant correlations between the strength of the knee extensor muscles and the improvements of static balance in elderly women applying various tests: unipodal test, computerized tests on fixed and flexible platforms and variations with the eyes opened and closed. It is possible that each test only obtains information regarding various aspects of balance. There is still a lack of specificity in the prediction of falls in the scientific literature. The need for further studies with elderly practitioners of TCC using computerized tests with both fixed and flexible platforms to verify the effects of TCC on coordination, strength, balance and falls is clear.

Conclusions

This study confirmed that, for elderly women, the practice of TCC increased the strength of the knee extensor muscles as well as of balance. However, no significant correlations were observed between the increases in the strength of the knee extensor muscles and the increases in balance. In conclusion, TCC incorporates the advantages of a low cost and versatile training activity which could be suggested for elderly people in addition to other physical activities that aim to improve the strength of the inferior member and general balance, thus helping in the prevention of falls.

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