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Original Article

Effects of Pilates on muscle strength, postural balance and quality of life of older adults: a randomized, controlled, clinical trial

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Abstract. [Purpose] The aim of the present study was to determine the effects of Pilates on lower leg strength, postural balance and the health-related quality of life (HRQoL) of older adults. [Subjects and Methods] Thirty-two older adults were randomly allocated either to the experimental group (EG, n = 16; mean age, 63.62 ± 1.02 years), which performed two sessions of Pilates per week for 12 weeks, or to the control group (CG, n = 16; mean age, 64.21 ± 0.80), which performed two sessions of static stretching per week for 12 weeks. The following evaluations were performed before and after the interventions: isokinetic torque of knee extensors and flexors at 300°/s, the Timed Up and Go (TUG) test, the Berg Balance Scale, and the Health Survey assessment (SF-36). [Results] In the intra-group analysis, the EG demonstrated significant improvement in all variables. In the inter-group analysis, the EG demonstrated significant improvement in most variables. [Conclusion] Pilates exercises led to significant improvement in isokinetic torque of the knee extensors and flexors, postural balance and aspects of the health-related quality of life of older adults.

Key words: Exercise, Age, Muscle strength dynamometer

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INTRODUCTION

The proportion of older adults has been growing throughout the world. In Brazil, where the classification of older adult begins at the age of sixty years, 12.6% of the population is currently in this phase of life that elderly and this figure is expected to rise to 26.7% by the year 2060[1)]. This increase in the older population and the frailty individuals can experience have led to growing concerns among healthcare professionals, who are seeking strategies that can diminish the occurrence of events that place the health of older adults at risk[2)].

Sarcopenia and the consequent loss of muscle strength and endurance that can occur in older adults potentiates the risk of falls, as postural balance and functional mobility are also affected[3, 4)]. To attenuate these aspects, physical exercise is used to build muscle mass, strength and endurance[5)], thereby improving postural balance, which reduces the risk of falls[6)] and improves quality of life[7)]. However, some forms of physical exercise that provide progressive resistance training have been under-investigated, such as Pilates. This method was developed during World War I by the German, Joseph Hubertus Pilates, and involves resistance provided by the subject's own body weight in exercises conducted on the floor or the resistance of springs attached to equipment employed while practicing the method[8)].

Pilates has recently gained in popularity[9)] and seems to be an efficient manner of strengthening the muscles of the trunk (core training)[10)], postural balance[11)], and aspects of quality of life[12)]. However, little is known regarding the effects of Pilates when the focus is on the lower limb muscles. We hypothesized that a Pilates exercise protocol with equipment that prioritizes strengthening the lower legs could have a positive effect on the muscle strength, postural balance and quality of life of older adults. Thus, the aim of the present study was to determine the isokinetic torque of the knee extensors and flexors, static and dynamic balance, functional mobility and quality of life of community-dwelling older adults who performed a Pilates exercise protocol.

SUBJECTS AND METHODS

This study was conducted in accordance with the ethical norms established in the Declaration of Helsinki (1975, revised in 1983) and received approval from the Human Research Ethics Committee of the Universidade Norte do Paraná (Brazil) under process number 513.001. All volunteers signed a statement of informed consent. A randomized, controlled, clinical trial was conducted involving community-dwelling older adults in the city of Jacarezinho,

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State of Paraná, Brazil. The sample size was calculated using the peak isokinetic torque reported in a previous study[13]. Considering a 20% error rate and α value of 0.05, it was determined that 16 participants would be required for each group to give the results sufficient statistical power.

The following were the inclusion criteria: age 60 to 65 years; female gender; the ability to perform basic and instrumental activities of daily living without assistance; a body mass index (BMI) within the ideal range for the age group (22 to 27 kg/m^2)[14]; a statement from a physician indicating sufficient fitness for the practice of physical exercises; not having practiced any type of physical exercise in the previous six months; and agreement not to participate in any other type of physical exercise during the study. The following were the exclusion criteria: cognitive deficit (score < 19 on Mini Mental Health Examination)[15]; functional walking limitations or use of a gait-assistance device (cane, walker or crutches); an affirmative answer to any item on a questionnaire for the identification of severe visual impairment, osteoarthosis of the knee or hip; and a history of orthopedic surgery of the hips, knees or ankles. Among the volunteers who met the eligibility criteria, 32 were included in the study and all were duly informed about its objectives and procedures.

The volunteers were submitted to an initial evaluation of the isokinetic strength of the knee extensors and flexors at 300 degrees per second (300°/s), as well as balance and functional mobility tests. The volunteers also answered a quality of life questionnaire. Randomization was then performed using a random numbers table generated by a computer, which allocated the individuals to the experimental group (EG) or the control group (CG), each comprising 16 participants. The EG performed Pilates exercises and the CG performed static stretching exercises. For both groups, 20 exercises were selected to encompass the main body segments (lower limbs, upper limbs, trunk flexors and extensors) in 60-minute sessions held twice a week for 12 weeks, with a minimum of two days between sessions. After the interventions, the volunteers were evaluated again by the same rater and submitted to the same evaluations performed prior to the interventions. Figure 1 illustrates the sequence of events.

An isokinetic dynamometer (Biodex System 4.0, Biodex Medical Systems, Shirley, NY, USA) was calibrated following the manufacturer's instructions and used to determine the muscle strength of the knee extensors and flexors before and after the exercise protocols. Prior to exercise, the participants warmed up on a stationary bike with a light load (25 watts) at a comfortable speed (40 rotations per minute) for five minutes. The rater then explained the procedures in detail and positioned the volunteer on the seat of the equipment with the chair angled at 120 degrees.

The rotation axis of the arm of the dynamometer was aligned with the lateral epicondyle of the right femur. The site of the application of force was positioned approximately two centimeters above the medial malleolus. Straps were attached to the trunk, pelvis and thigh to avoid compensatory movements[16]. Following brief familiarization with the equipment and range of motion, the subjects performed extension and flexion of the knee (concentric/concentric) at an angular velocity of 300°/s beginning with the knee flexed at 90 degrees. The subjects were instructed to perform maximum voluntary contraction of the knee extensors, followed immediately by maximum voluntary contraction of the knee flexors in a continuous fashion. The rater gave verbal encouragement ("more force"). Three sets of five repetitions were performed with a 30-second rest interval between sets[17]. The same procedure was then performed with the left leg. Peak torque (expressed as Newtons per meter) and total work (expressed as Joules) was recorded.

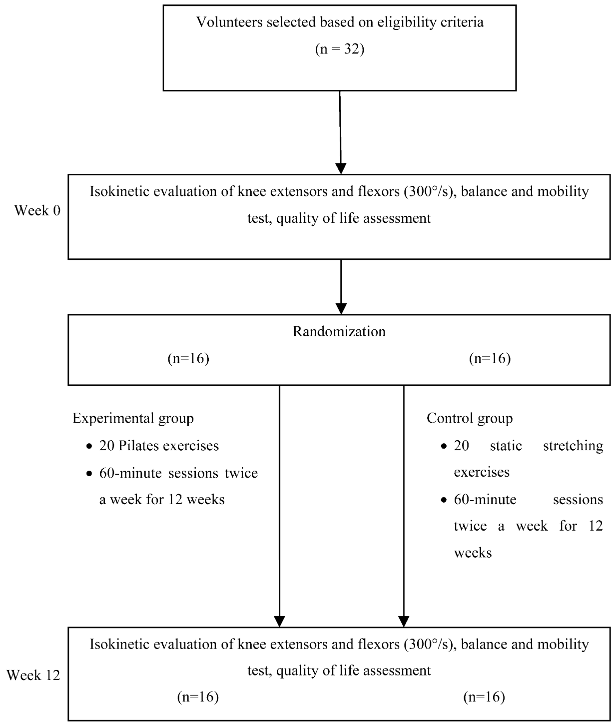

Fig. 1. Flowchart showing the progression of the study

The Berg Balance Scale[18] was employed to evaluate static and dynamic balance. This ordinal scale is based on 14 tasks of daily living, such as reaching for an object, turning around, transfers, standing up, standing with feet together, etc., and is an efficient tool for detecting the likelihood of falls. Each task has five response options scored from 0 to 4 points. The maximum score is 56 points and indicates a low likelihood of falls, whereas scores ≤ 45 points indicate a high likelihood of falls. The test takes 15 to 20 minutes to complete. The following equipment is necessary for the test: a stopwatch or clock, bed, footstool, two chairs (one with arm rests and one without) and a ruler.

The Timed Up and Go (TUG)[19] test was used to evaluate functional mobility and the risk of falls. Upon the command "go", the subjects stood up from a chair with arm rests, walked three meters to a mark placed on the floor, turned around, walked back to the chair, and sat down again. The stopwatch was started with the command "go" and stopped when the volunteer had sat down again, and the time was recorded. Less than 10 seconds to complete the task is considered indicative of a low risk of falls; 10 to 20 seconds is considered indicative of a moderate risk of falls and more

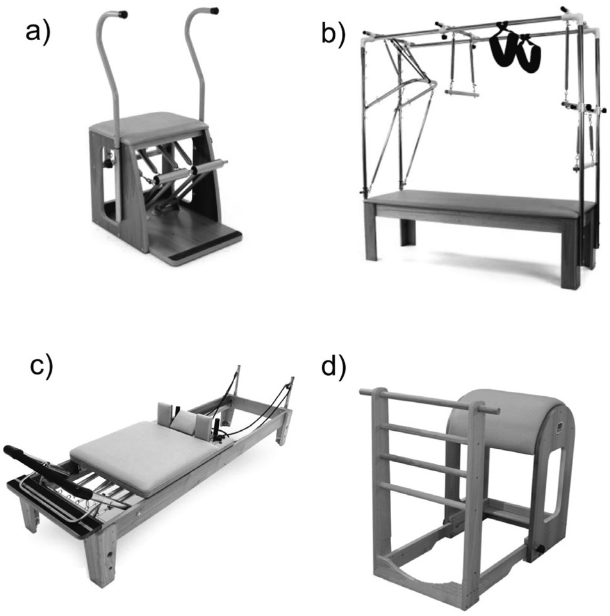

Fig. 2. Equipment Used: a) Combo chair; b) Cadillac trapeze table; c) Universal reformer; d) Ladder barrel

than 20 seconds is considered indicative of a high risk of falls. The test was performed three times and the best time was used in the analysis.

The Brazilian version of the 36-item short-form health survey (SF-36)[20] was used for the assessment of health-related quality of life. This questionnaire has 36 items distributed among eight subscales: physical functioning (10 items), physical role functioning (four items), bodily pain (two items), general health state (five items), vitality (four items), social role functioning (two items), emotional role functioning (three items) and mental health (five items). The score ranges from 0 to 100, with higher scores denoting a better quality of life.

The EG performed 60-minute sessions of Pilates held twice a week for 12 weeks (total of 24 sessions). The first session was used to familiarize the subjects with Pilates, explain the correct execution of each movement, and to provide a greater understanding of the principles of the method. The following equipment was used (Fig. 2): combo chair, Cadillac trapeze table, universal reformer and ladder barrel (Institute of Orthopedics and Physical Therapy, São Paulo, Brazil). Twenty strengthening and stretching exercises were used for the main body segments (lower limbs, upper limbs, trunk flexors and extensors). The exercise sequence, equipment and traditional names of each exercise were as follows:

a) Initial stretching on the Cadillac trapeze table (*Spine Stretch, Mermaid, Stretching Knee)*;

b) Strengthening of lower limbs on the combo chair (*Footwork Double Leg Pumps Toes, Pumping One Leg, Pump One Leg Front, Achilles Stretch*) and the Cadillac trapeze table (*Leg Series Supine Lowers, Leg Series Supine Circles*);

c) Strengthening of trunk flexors and extensors on the Cadillac trapeze table (*Sit Up, Sit Up One Leg, The Hundred, Trunk Up, Body Extension*);

d) Strengthening of the lower limbs on the universal reformer (*Arms Pulling, Arms Biceps, Arms Triceps*);

e) Final stretches on the universal reformer (*Front Splits, Stretching the Posterior Chain*) and ladder barrel (*Stretch Back and Forward*).

All exercises were performed with one set of ten repetitions. The spring intensity was changed based on the progress of each volunteer while maintaining the same number of repetitions. The Borg CR10 scale[21] was used to determine the level of effort and load progression: Borg ≤ 2 = light load; Borg > 2 to < 5 = moderate load; Borg ≥ 5 to < 7 = heavy load; Borg ≥ 7 = close to maximum load. The level of effort maintained during the sessions was moderate (Borg 3 and 4). Whenever the exercise intensity was changed, the new load was recorded on individual charts.

The exercises were selected to improve overall muscle strength, as traditionally employed with Pilates[9], but greater emphasis was given to strengthening the lower limbs to meet the objectives of the present study. The volunteers received clarifications regarding the principles of the method (centering, control, concentration, flow, precision and respiration) that need to be respected during the execution of each exercise[8]. The sessions were supervised by a professional with a Pilates certificate and ample experience of supervising the method.

The CG performed static stretching exercises (no strengthening exercises) in 60-minute sessions for 12 weeks (total of 24 sessions). Twenty exercises were used for the following regions of the body: neck and upper limbs (superior trapezius, scalene muscles, sternocleidomastoid muscles, flexors and extensors of the wrists and fingers, deltoid, triceps and pectoral muscles), lateral chain stretches and lower limbs (oblique muscles, quadratus lumborum, hamstrings, adductors, gluteal muscles, abductors and triceps surae). The exercises were performed actively, with three sets of one repetition maintained for 30 seconds and a one-minute rest interval between sets. Mats made of ethylene vinyl acetate were used. The subjects remained seated, lying in the supine position or standing, depending on the stretching exercise being performed. All sessions were supervised by a trained professional.

Descriptive analysis was performed and the data were expressed as the mean and standard deviation. The Mann-Whitney U test was used to determine differences between groups in baseline characteristics (age, weight, height and BMI). The Shapiro-Wilk test was used to determine the normality of the data. For data with a normal distribution, two-way repeated-measures analysis of variance (ANOVA) followed by Tukey's post hoc test was used to determine the significance of differences in both the intra-group and inter-group analyses. The Kruskal-Wallis test followed by the Student-Newman-Keuls test was used for non parametric variables. The level of confidence was chosen as 95% ($p < 0.05$). The SPSS 20.0 program (SPSS Corp., Chicago, IL, USA) was used for all statistical analyses.

Table 1. Physical characteristics of the experimental and control groups at baseline (mean ± SD)

Baseline	EG (n=16)	CG (n=16)
Age (years)	63.6 ± 1.0	64.2 ± 0.8
Weight (kg)	64.5 ± 2.0	64.7 ± 2.5
Height (cm)	161.9 ± 4.5	160.7 ± 4.9
BMI (kg/m^2)	24.7 ± 1.3	25.0 ± 1.2

EG: experimental group; CG: control group; BMI: body mass index

RESULTS

No statistically significant differences between the groups were found in the physical characteristics at baseline. Age ranged from 60 to 65 years, body weight ranged from 54.2 to 69.0 kg, height ranged from 155 to 174 cm, and BMI ranged from 22.6 to 26.8 kg/m^2 (Table 1).

No statistically significant differences between the groups were found in the pre-intervention values of peak torque, total work, the Berg Balance Scale or the TUG test. In the intra-group comparisons of the evaluations before and after the exercise protocols, significant differences were only found in the EG ($p < 0.05$) for all measures except the Berg Balance Scale ($p = 0.0509$) (Table 2).

No significant differences between groups were found at baseline with regard to quality of life measured using the subscales of the SF-36. In the intra-group analysis, the EG exhibited significant improvements on all subscales at the post-intervention evaluation, whereas the CG only demonstrated improvement in social role functioning ($p = 0.0228$). In the inter-group analysis of the post-intervention evaluation, significant differences favoring the EG were found on all subscales except social role functioning ($p = 0.6963$) and emotional role functioning ($p = 0.1511$) (Table 3).

DISCUSSION

Considering the growing search for novel intervention methods, it is necessary to determine the effects of such methods on variables of interest. The literature states that Pilates can contribute to the improvement of postural balance, consequently reducing the risk of falls[11]), through muscle strengthening of the muscles responsible for lumbopelvic stabilization, such as the flexors and extensors of the trunk[10]). A previous study demonstrated that the practice of Pilates also resulting in improvements in quality of life among community-dwelling older adults[12]).

As few studies have addressed Pilates as a form of progressive resistance exercise, the aim of the present investigation was to determine the isokinetic torque of the knee extensors and flexors achieved by this form of exercise as well as its effects on static/dynamic balance and functional mobility. Quality of life was also measured to determine whether older adults performing this method would show changes in the different domains addressed by the SF-36 questionnaire.

In the EG, peak isokinetic torque improved significantly after the intervention in both legs with regard to both extension and flexion of the knee at 300°/s. Although isokinetic

Table 2. Inter-group and intra-group comparisons of isokinetic torque, postural balance and functional mobility of the experimental and control groups before and after the exercise protocols (mean, SD; two-way ANOVA followed by Tukey's post hoc test)

		Mean ± SD	
		EG (n=16)	CG (n=16)
PT 300°/s Ex. RL	Before	43.2 ± 5.9	42.2 ± 8.0
	After	58.6 ± 7.7^{ab}	42.4 ± 9.1
PT 300°/s Ex. LL	Before	42.9 ± 6.3	43.1 ± 8.6
	After	51.1 ± 8.2^{ab}	41.6 ± 9.4
PT 300°/s Fle. RL	Before	32.3 ± 6.2	31.1 ± 6.7
	After	50.5 ± 8.9^{ab}	31.0 ± 5.1
PT 300°/s Fle. LL	Before	36.0 ± 5.2	35.6 ± 5.9
	After	49.0 ± 6.4^{ab}	34.7 ± 8.3
Berg	Before	54.0 ± 2.5	54.1 ± 2.7
	After	55.8 ± 0.5^{a}	54.5 ± 2.1
TUG	Before	7.7 ± 0.8	7.8 ± 1.3
	After	5.7 ± 1.0^{ab}	7.4 ± 1.1

EG: experimental group; CG: control group; PT: peak torque (Newtons per meter); 300°/s: angular velocity 300 degrees per second; Ex.: extension of knee; Fle.: flexion of knee; RL: right leg; LL: left leg; BERG: Berg Balance Scale; TUG: Timed Up and Go test; ^{a} significant intra-group difference ($p < 0.05$) from pre-intervention; ^{b} significant inter-group difference ($p < 0.05$) at post-intervention

Table 3. Inter-group and intra-group comparisons of health-related quality of life of the experimental and control groups as assessed by the SF-36 before and after the exercise protocols (mean, SD; Kruskal-Wallis test followed by Student-Newman-Keuls test)

		Mean ± SD	
		EG (n=16)	CG (n=16)
PF	Before	81.2 ± 15.4	75.6 ± 21.8
	After	93.4 ± 10.9^{ab}	76.2 ± 22.6
PRF	Before	73.4 ± 21.3	70.3 ± 26.1
	After	92.1 ± 17.6^{ab}	68.7 ± 29.5
Pain	Before	68.8 ± 18.1	64.2 ± 21.6
	After	90.3 ± 12.4^{ab}	70.2 ± 25.9
GHS	Before	68.4 ± 13.7	74.1 ± 15.2
	After	87.2 ± 11.8^{ab}	76.6 ± 16.8
VT	Before	71.8 ± 13.7	74.0 ± 20.7
	After	90.9 ± 9.8^{ab}	80.0 ± 17.8
SRF	Before	81.4 ± 8.0	80.6 ± 16.9
	After	91.6 ± 8.7^{a}	90.0 ± 10.3^{a}
ERF	Before	82.4 ± 16.2	84.5 ± 16.2
	After	95.8 ± 16.7^{a}	88.6 ± 15.3
MH	Before	69.2 ± 21.3	73.5 ± 17.0
	After	90.2 ± 12.7^{ab}	77.7 ± 15.8

EG: experimental group; CG: control group; PF: physical functioning; PRF: physical role functioning; GHS: general health state; VT: vitality; SRF: social role functioning; ERF: emotional role functioning; MH: mental health; ^{a} significant intra-group difference ($p < 0.05$) from pre-intervention; ^{b} significant inter-group difference ($p < 0.05$) at post-intervention torque is a reliable variable for the evaluation of muscle strength, no previous studies addressing the effects of Pilates have analyzed this variable. However, investigations have found that progressive resistance exercises with the use of weights are effective for gains in isokinetic torque of the knee extensors and flexors in older adults[22–24].

Carvalho et al.[22] compared training involving strengthening, flexibility, balance and aerobic exercises with and without resistance exercises for older adults in two weekly sessions for 24 weeks. The group performing the combined protocol with resistance exercises demonstrated a significantly greater improvement in knee extensors and flexors (60°/s and 180°/s) for the majority of variables tested. Romero-Arenas et al.[23] compared high resistance training to traditional strength training performed in two weekly sessions for 12 weeks and found that both protocols led to significant improvement in isokinetic force of the knee extensors and flexors (90°/s and 270°/s) in older adults. Van Roie et al.[24] found that both low and high resistance training with weights led to significant improvements in isokinetic force of the knee extensors and flexors at 180°/s after three weekly sessions for 12 weeks, whereas no significant difference was found at 60°/s.

Among the studies cited above, Romero-Arenas et al.[23] used a protocol similar to that employed in the present investigation with regard to frequency and duration (two weekly sessions for 12 weeks), and one of the angular velocities (270°/s) was similar to that employed herein. The other two studies used either a different frequency (three times a week)[24] or duration (24 weeks)[22] as well as lower angular velocities (60°/s and 180°/s) for the evaluation of isokinetic torque. The use of different angular velocities (60°/s, 180°/s and 270°/s) hinders the comparison of the findings reported in the present study, in which 300°/s was used. However, it was demonstrated that Pilates contributes significantly to isokinetic torque and is an effective form of progressive resistance training for older adults eliciting gains in muscle strength when performed at a similar frequency and duration to the exercises employed in studies involving traditional training with the use of weights.

In the present study, Pilates led to significant improvements in postural balance and functional mobility, as demonstrated by the 1.81-point improvement on the Berg Balance Scale ($p = 0.0081$) and the 1.95-second improvement in the TUG test ($p < 0.001$) in the EG. However, few studies addressing the use of Pilates for older adults have employed these measures. Hyun, Hwangbo and Lee[11] found a 4.47-second improvement in the TUG test ($p < 0.05$) among older adults after 12 weeks of a Pilates protocol with three weekly sessions. Bird, Hill and Fell[25] found a 0.90-second improvement in the TUG test ($p < 0.05$) among older adults after five weeks of a Pilates protocol with two weekly sessions.

Other studies employing forms of progressive resistance training other than Pilates for older adults have demonstrated the effects of exercise protocols using the Berg Balance Scale and TUG test[26–29]. Yu, An and Kang[26] analyzed the effects of an elastic exercise band protocol for older adults which was performed three times a week for five weeks, but found no significant changes in the Berg or TUG scores. Yoo, Chung and Byoung[27] analyzed a protocol involving muscle strengthening exercises combined with balance training developed specifically to improve the balance of older adults and compared the results with those achieved using virtual reality/enhanced reality training. Both protocols were performed three times a week for 12 weeks and both led to significant improvements on the Berg Balance Scale from 48.91 to 52.45 points and from 47.60 to 53.70 points, respectively. Beebe et al.[28] found that two weekly sessions of progressive isokinetic force training combined with balance training and dance for 12 weeks led to an improvement in the Berg Balance Scale score from 45 to 52 points and a 5.4-second improvement in the time needed to complete the TUG test among older adults with a history of falls. Avelar et al.[29] compared lower limb muscle strengthening exercises for older adults performed in and out of an aquatic medium twice a week for six weeks and found that both protocols led to a significant increase in the Berg score from 51 to 54.5 points and from 50.5 to 54 points, respectively.

Studies have used other measures (Tinetti test and force plate) for the determination of the postural balance of older adults practicing Pilates and they too have reported significant results ($p < 0.05$) when exercise sessions were held twice a week for eight weeks[12], or three times a week for 12 weeks[30]. In the present study, the decision was made to hold sessions twice a week for 12 weeks, and this was sufficient to achieve significant improvements in postural balance and functional mobility, as measured on the Berg Balance Scale and in the TUG test. In previous studies that employed the same measures[11, 25–29], a large portion of the investigations that reported significant results also used a 12-week protocol with two or three weekly sessions[11, 27, 28]. However, some studies have reported significant results with shorter protocols, i.e. two weekly sessions for five or six weeks[25, 29].

In the present study, the EG demonstrated significant improvements in quality of life ($p < 0.05$) on all subscales of the SF-36 questionnaire, whereas the CG only demonstrated an improvement in social role functioning. In a previous study on the effects of Pilates on the quality of life of healthy older adults, significant improvements were found on three of the six subscales of the WHOQOL-OLD questionnaire after two weekly sessions held for eight weeks[12]. Studies employing the SF-36 to assess healthy older adults performed progressive resistance training with weights have reported divergent results. After 12 weeks of training in two weekly sessions, Mariano et al.[31] found significant differences in physical functioning, general health state, vitality and mental health subscales of the SF-36. In contrast, Kimura et al.[32] found a significant difference only on the mental health subscale after 12 weeks of training with two weekly sessions. In the present study, significant differences were found on all SF-36 subscales using the same training frequency and duration. Quality of life is a subjective variable that has been under-investigated in studies involving older adults performing physical exercise protocols. However, the present findings suggest that a short period of Pilates can effectively improve all eight domains of quality of life assessed by the SF-36 questionnaire. It is possible that protocols lasting more than 12 weeks may achieve even better results. Indeed, Vieira et al.[33] found significantly higher scores on the SF-36 subscales of individuals practicing Pilates for more than a year in comparison to ex-practitioners and those who practiced the method for only three months.

The present study provides important information that can be used as a basis for future investigations. Further studies are needed to determine the effects of Pilates for older adults. Few data are available in the literature on the isokinetic torque of the knee extensors and flexors, static and dynamic balance, functional mobility and quality of life of older adults performing Pilates.

Based on the present findings, Pilates performed with equipment elicits improvements in lower limb muscle strength, static and dynamic postural balance, functional mobility and quality of life of older adults when performed in two weekly sessions for 12 weeks. Thus, Pilates is an efficient form of progressive resistance training for the variables analyzed herein.

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