ARCHIVES of Exercise in Health and Disease

DOI: 10.5628/aehd.v3.i3.126

Original Research Manuscript

The Pilates Method to Improve Body Balance in the Elderly

Isabela P. Coriolano Appell[1], Vicente Romo Pérez[1], Marcelo de Maio Nascimento[2], Hans J. Appell Coriolano[3]

[1]Faculty of Education and Sport, Campus Pontevedra, University of Vigo, Spain
[2]School of Physical Education, Federal University Vale do São Francisco, Petrolina, PE-Brasil
[3]Department of Physiology and Anatomy, German Sport University Cologne, Germany

Objective: Considering a world-wide increase of the elderly population and the age-related ceasing of functional capacities, maintenance of body balance is crucial to avoid falls and the risk of fractures. The Pilates Method offers exercises aimed at stabilizing the postural muscles and therefore appears to have a good potential in this context. The aim of the study was to assess the possible effects of a Pilates program on body balance in elderly people. The hypothesis was that this type of intervention would improve body balance as compared to another group of elderly people, who participated in a program with unspecific physical activities. ***Design***: The Pilates group (PG, n=19) and the control group (CG, n=20) exercised twice a week for 10 weeks. All participants were submitted to a balance test before and after the intervention. ***Results:*** The groups showed similar balance abilities in the pre-test, classified as regular balance abilities. The participants in the CG did not show any improvement in body balance during the post-test, while the participants in the PG showed significant improvements, with a tendency toward a good classification. Older subjects showed a tendency toward a lower capacity in body balance within the groups. ***Conclusion:*** The Pilates Method offers a beneficial tool to improve the abilities to maintain body balance. The effects of this method probably represent an entity of improved postural muscle functionality and an improved integration of the information provided by various receptor systems in the control of the activity of these muscles.

Arch Exerc Health Dis 3 (3): 188-193, 2012

Key Words: equilibrium, postural control, GGT, trunk muscles, proprioception

INTRODUCTION

The age-related structure of the human population has changed world-wide during the last decades as the consequence of alterations in both reproducibility and mortality. A lower birth rate and an increased life expectancy result in an increase of the older population, in absolute and relative numbers (10, 15). A person is considered old at an age of more than 65 years, although more modern concepts divide this group into the young elderly (65-74 yrs), the old elderly (75-84 yrs), and the older elderly (above 85 years) (34). Recent demographic data identified 17% of the European population to be 65 or older, as the result of a 10% increase of the group aged 65-79 years and also of a 35% increase of the group older than 80 years between 1998 and 2008. For the year 2060, it is foreseen that the elderly will represent 30% of the total European population (8).

Although aging should not be considered a pathological process, it results in a progressive reduction of the functional capacities of every person. Although this process may occur differently among individuals (7), it cannot be avoided, and the challenge is to maintain an active and healthy lifestyle as long as possible. The benefits of physical activity and conversely the disadvantages of an inactive lifestyle for the older population, with its physical, psychological, and social factors, have recently been highlighted in a review paper (28).

The functional alterations that come with aging are multifarious. In the context of this study, the components of the locomotor system are of special interest; elderly people experience an eventual

Corresponding author:
Hans J. Appell Coriolano: German Sport University, D-50927 Cologne, Germany • Tel: +49(0) 221 498 25430 • Email: appell@dshs-koeln.de

decrease in muscle mass and strength, in bone mineral density, and in their coordinative capacities due to modifications within the nervous system (9, 27, 29).

Coordination, in particular with regard to its contribution to the maintenance of corporal stability and equilibrium, is based on the functionality of the optical, kinaesthetic, tactile, and static-dynamic sensors, but also on a sufficient functional capacity of the muscular system. Ceasing of corporal stability with advancing age depends on the inability of the muscles to respond to external or internal stimuli (33), on a reduced muscle strength (12), and on impaired proprioceptive information (37). As a functional result, the capacity to maintain corporal stability and postural control eventually starts to deteriorate from the sixth decade of life (13).

Accordingly, modifications can be observed in the pattern of locomotion in elderly people, characterized by difficulties in coordinating the movement of the leg during the initial phase of a step with the anticipating transfer of the body weight (25). This results in altered gait patterns, with prolonged phases of bipedal support, higher step frequency, and shorter step width (30, 38). A reduced strength and flexibility of the peripelvic muscles should at least in part be held responsible for these alterations in gait pattern (19).

Coordinative impairments and the altered gait pattern in the elderly result in an elevated incidence of falls; about 30% of subjects aged >65 have the risk for a fall at least once a year (36), because when stumbling, their functional capacities are no longer sufficient to recover, and they might fall (31). Falls include a great risk for fractures in elderly people, because osteoporosis is a common pathology, especially among women, whose bone mass may be reduced by 30% at the age of 70 years (29). Hip fractures are the most frequent ones and often require prolonged phases of hospitalization. Survivors of a hip fracture have a life expectancy reduction of 10-15% (20). Falling and experiencing a fracture is a traumatizing event for the elderly, leading to post-fall anxiety syndrome (36) with the overall result of a reduced quality of life (24).

The development of measures to avoid falls should therefore be desirable. There appears to exist a dose-effect relationship; i.e., the more frequently a subject exercises, the less the risk of falling (40). Since a sufficient function of the muscular system is considered a prerequisite for corporal stability, Skelton (41) analyzed the effects of various exercise programs on postural stability; he considered aerobic and flexibility exercise less effective than strengthening and coordinative exercise. In a recent review article, Mann et al. (26) described a stunning increase of studies dealing with preventive programs against falls in elderly subjects over the last 15 years. His meta-analysis revealed that most exercise programs offer little specificity, using very common exercises or training in daily life activities. Within the analyzed period, he did not find any systematic study that used the Pilates Method to improve body balance in the elderly (26).

The Pilates Method is composed of a collection of functional exercises and movements, initially using only the person's own body weight and later extended with the aid of some equipment (39). This method is aimed at better integrating the individual into his or her functional challenges in daily life, involves the whole body as a functional unit, tries to correct postural deficits, and develops corporal stability (23, 32). Special emphasis is given to the "powerhouse," denoting the abdominal and peripelvic muscles, which are especially responsible for postural control and corporal stability. Pilates exercises appear to have a great potential to improve various motor abilities, and there is a common consensus that the Pilates Method is effective in improving body stability and balance (17, 18). Since the Pilates Method does not offer any risk of lesions due to the mild character of the exercises (22), it should be the ideal method to be applied to elderly people within preventive programs against falls.

The objective of the present study was to analyze the effects of a 10-week Pilates exercise program on body balance in a group of young elderly people, in comparison to the effects of an unspecific exercise program.

MATERIAL AND METHODS

Subjects

Initially, the study comprised 40 subjects with a mean age of 69.6±3.0 years (range 65-74), among which were 21 women and 19 men; all of them were functionally autonomous. They were part of a larger group that gathered once a week to participate in a program with unspecific physical activity of low intensity without specific objectives for at least three months. The participants of the study were selected according to inclusion and exclusion criteria: willingness to do physical exercise twice a week with regular attendance (at least 80%), age between 65 and 74 years, not practicing any other type of sports or physical therapy, absence of fall history with fractures, age-related good health status with absence of pathologies in the locomotor, cardiovascular, and nervous system, and no surgical treatment during the last year; all participants had to present a medical attestation about their physical activity readiness for inactive older adults (5). After explanation of the aims and the methods of the study, they signed an informed consent. The study was planned and conducted in accordance with the Helsinki Declaration of Human Rights and with the ethical standards in sport and

Table 1. Characteristics of the groups.

	Men/Women	Age	BMI	Attendance %
Control Group	10/10	69.7±2.9	25.6±1.2	89.3±5.7
Pilates Group	9/10	69.6±3.1	25.5±1.3	90.0±4.7

exercise science research (11).

Study design

Using an inter-group semi-experimental design with one-factorial measurements before and after the intervention, two groups were formed, a Pilates group (PG) and a control group (CG), to assess the effects of Pilates exercises or unspecific physical activity on body balance. Body balance was tested in both groups before and after the intervention with the balance test ("Gleichgewichtstest" – GGT) developed by Bös and Wydra (4). The participants of the study were pooled according to sex and were randomly assigned to the CG or PG, respectively, to have men and women equally distributed in both groups.

Exercise programs

The control group continued participating in the program as before, but twice a week for one hour over 10 weeks. The unspecific program included flexibility, strengthening, and aerobic exercises of low intensity and short sport games; all sessions were supervised by a physical education teacher. The Pilates group received a specific program of various Pilates exercises without further equipment twice a week for one hour over a total of 10 weeks. The exercises were done in supine or standing position, were easy to perform in the correct manner, and were aimed at the muscles stabilizing the trunk and the pelvic girdle; some of the exercises in standing position also challenged body balance in correct execution. More specifically, the exercises were, according to their inherent nomenclature, Back lift, Bridge, Double leg stretch, Half roll up, Hundred, Knee twist, Leg stretch stance, One leg tip, Side flex, Single leg stretch, Spine stretch, Squat, Stretching dog, Tandem stance, and Side leg stretch. All exercises or movements were done with the required rhythm of inspiration and expiration, with about 10 repetitions before the next exercise commenced. The Pilates exercises were supervised by a physical education teacher who was also a certified Pilates instructor.

Balance test

The balance test ("Gleichgewichtstest" – GGT) by Bös and Wydra (4) is composed of 14 items, half of which are directed toward static balance, the other half toward dynamic balance. Interoceptive and/or exteroceptive regulation is required in each single item, apart from general proprioceptive information required by the muscles to maintain body balance. Every item has a distinct level of difficulty, and the items are arranged in the order of increasing difficulty (45). The evaluation of the test items is dichotomous (0=not succeeded, 1=succeeded), resulting in a maximum score of 14 points. According to Bös (3), this test is appropriate for all ages from 18 to 80 years and has a good objectivity, validity, and reliability. Norm tables to judge body balance classified from very weak to very good exist for populations of both sexes for the fourth, fifth, and sixth decades of life (3, 45). All tests were supervised and evaluated by an experienced physical education expert who had not been actively involved in the exercise program. The testing was done the week before the exercise programs began and during the week after the programs ended.

Statistical Analysis

All obtained data were treated using SPSS (v.18) and expressed as means with standard deviations. Normality of distribution was verified using the Kolmogorov-Smirnov test with an alpha of 10% after Lillefors correction. For normally distributed data (which was always present), intra- and intergroup differences for the results obtained before and after the intervention were calculated using two-factorial ANOVA with a Bonferroni post-hoc test; the level of significance was set at $p<0.05$.

RESULTS

All participants, except for one who dropped out due to a car accident, completed their exercise programs without any unwanted side effects like injuries. The two groups (CG n=20, PG n=19) were similar and did not differ with respect to sex distribution, age, and

Table 2. GGT scores for the Control and Pilates groups before and after the intervention.

Group	Pre	Post	Pre vs. Post
Control (n=20)	4.20±1.24	4.25±1.25	p = 0.78
Pilates (n=19)	4.32±1.29	5.47±0.96	*p = 0.00*
Control vs. Pilates	p = 0.78	*p = 0.002*	

body mass index; the compliance of the participants to the exercise program was the same in both groups with an average of 90% (range 80-100%) of attendance (Table 1).

The scores for the balance tests are shown in Table 2. At the beginning of the intervention phase, both groups had a similar level of body balance. In comparison to the pre-test, the subjects of the CG did not show any improvement in body balance after the program, while the participants of the PG improved significantly in the post-test compared to the pre-test. An intergroup comparison revealed no differences in the pre-test, but a significantly better body balance for the PG in the post-test.

As the norm tables of the GGT (3, 45) show differences in the obtained score between women and men, indicating that men have a better body balance within the respective age classes, we analyzed the scores separately for each gender. As shown in Table 3, this analysis did not reveal considerable differences; although the women seemingly presented slightly higher scores, the significance levels are not enough to even discuss tendencies.

Moreover, the norm tables published for three decades of life (3, 45) show that the older the subjects, the lower the score. We therefore divided our groups with respect to age (under and over 70 years). The results of this analysis are not completely unanimous (Table 4).

Table 3. GGT scores differentiated for men and women.

Group and Sex		Pre	Post
Control	**Women** (n=10)	4.30±0.95	4.30±1.16
	Men (n=10)	4.10±1.52	4.20±1.40
		p=0.56	p=0.87
Pilates	**Women** (n=10)	4.50±1.35	5.50±1.08
	Men (n=9)	4.11±1.27	5.44±0.88
		p=0.70	p=0.93

Even when a tendency toward a better body balance can be observed in the younger subjects (CG pre-test and PG post-test), the only significant difference was found in the post-test of the CG, and the sexagenarians of the PG did not differ significantly from their septuagenarian peers in the pre-test.

DISCUSSION

To assess body balance in the present study, the GGT (4) was selected as it is a balance test easy to conduct, it asses both static and dynamic balance, it has been proven to be applicable for the age group of this study, and it allows simple scoring due to its dichotomous character. There exists, however, a variety of other tests, among which the Berg balance scale (1) and the Tinetti-test (42) are the most frequently used (44). The Berg balance scale uses 14 items directed toward simple skills (such as standing up from a chair or picking something up from the floor) and is often used in geriatric institutions with subjects having corporal deficits to judge whether they are able to perform daily life activities at home. The Berg balance scale did not appear the best candidate to be used in the present study, because our subjects were physically completely independent. The Tinetti-test is composed of two parts, one dealing with static equilibrium and the other assessing various gait characteristics. The problem of that test is inherent to its scoring units of 0, 1, or 2 points, which might leave some interpretation to the examiner; therefore, the Tinetti-test was considered second choice. The advantage of the GGT appears to be the order of the items with increasing difficulties. The fifth item seems to be crucial, because this is the first one to exclusively test dynamic balance. Dynamic balance is considered necessary during locomotion (40) to avoid the risk of stumbling or falls.

At the beginning of the study, the subjects of the CG and PG showed similar scores in the balance test (Table 2). In spite of the lack of norm tables for older ages, one might interpolate the scores described for the fourth, fifth, and sixth decades of life (3, 45) for the present subjects of the seventh and eighth decades, because a decline of body balance with increasing age is clearly apparent. Such an interpolation allows judging the body balance of the studied population as being, on average, regular or fair at the beginning of the study. When differentiating among the subjects' age groups and comparing sexagenarians with septuagenarians, we observed a decline of body balance with increasing age (Table 4), which is in accordance not only with the existing norm tables for the GGT (3, 45) but also with common concepts about postural stability (43). In contrast to the contentions about a lower body balance in women as compared to

Table 4. GGT scores differentiated for age groups.

Group and Age		Pre	Post
Control	65-69 (n=10)	4.70±1.16	4.80±1.40
	70-74 (n=10)	3.70±1.16	3.70±0.82
		p=0.08	*p=0.02*
Pilates	65-69 (n=10)	4.40±1.27	5.90±0.74
	70-74 (n=9)	4.22±1.39	5.00±1.00
		p=0.76	*p=0.06*

men of the same age deduced from the norm tables for the GGT (3, 45), we were not able to confirm that, because we did not find any intersex differences (Table 3).

The subjects of the CG did not benefit from their unspecific physical exercise program with respect to body balance (Table 2). This contrasts with the findings of other studies (2, 35), which can be explained by the longer periods of intervention and completely sedentary subjects in these studies. It appears evident that motor skills, among them body balance, improve when such a sedentary population is submitted to physical exercise. Since the subjects of the CG were experienced in regular physical exercise, not even doubling the weekly exercise time resulted in further improvements. This is in accordance with the concept that exercises directed only toward strength and flexibility have little impact on body balance (6).

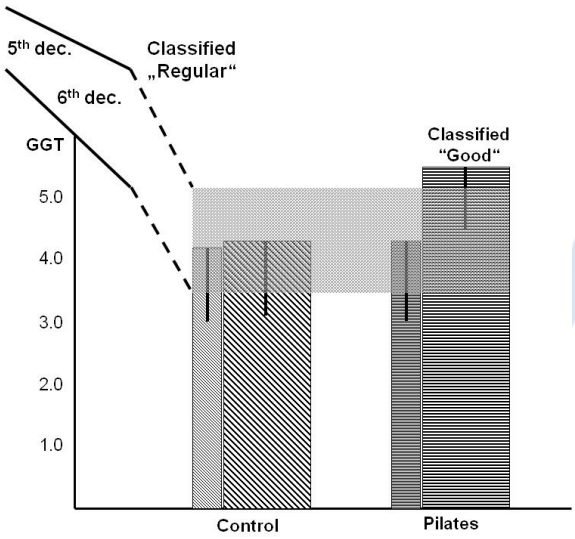

Figure 1. Graphic draft of the GGT scores for the Control and Pilates groups before (slim columns) and after (wide columns) the intervention (cf. Table 2); the existing norm values for the fifth and sixth decades of life for a regular body balance (3, 45) have been interpolated for the seventh and eighth decades; scores above the gray box (PG after) should be classified good.

The subjects of the PG doubtless improved their body balance, receiving average scores about 30% higher after the 10-week Pilates program (Table 2). In an attempt to qualitatively classify the body balance of this group after the intervention (as done before, see above), with the use of the existing norm tables (3, 45) they may be classified “Good,” which clearly is the effect of the Pilates exercises. Since, as outlined in the introduction, there are scarce studies on Pilates with old people to improve equilibrium, the results of the present study are difficult to compare with others. A similar series of exercises called “calisthenics body balance training” was used with elderly subjects for five months (14), resulting in considerable improvements in static balance and gait pattern. Other authors (18) studied the effects of an eight-week exercise program that was inspired by the Pilates Method in subjects of the same age group and obtained good results for static but not for dynamic balance. When submitting healthy mid-aged adults to a Pilates program for 12 weeks, no improvements were detected with regard to body balance (21), which may be explained by the fact that these subjects do not yet have balance deficits (16) and therefore did not further benefit from the Pilates program. On the other hand, that finding (21), together with those of the present study, clearly demonstrates that Pilates exercises are very useful to improve body balance at advanced ages.

When considering the mechanisms resulting in the improvement of body balance after Pilates exercise, strengthening of the trunk and peripelvic muscles in the sense of the “powerhouse” (32) is certainly an important measure to stabilize posture and gait pattern, with the concomitant effect on maintaining equilibrium (33). Only looking at muscle strengthening, however, appears an oversimplified mechanistic approach, as the functioning of other systems might also be positively influenced by the Pilates exercises. Since the correct execution of the movements requires skills like, e.g., movement fluidity, control, and precision (23), the proprioceptive analyzers are potential candidates to contribute to the correct execution of the Pilates exercises. The improved integration of their information about joint positions or muscle length and tension should enable an elevated kinaesthetic quality, thereby allowing the subjects to better control posture and movements. Since impairments of proprioception have been described for the elderly (37) and are held at least in part responsible for the increased risk of falls, exercises aimed at stimulating the kinaesthetic sense should be recommended for the older population.

It can be concluded that a 10-week Pilates program improved body balance in elderly subjects, probably by strengthening the muscles involved in postural control and by improving the quality of proprioceptive

regulation of muscle actions. Future studies on the effects of the Pilates Method should deal with the neural modulations of motor drives. Moreover, longitudinal studies with larger populations analyzing the incidence of falls in older subjects practicing Pilates exercise appear meaningful.

REFERENCES

1. Berg K, Wood-Dauphinee S, Williams JI, Gayton D. Measuring balance in the elderly: Preliminary development of an instrument. *Physiother Canada* 1989; 41: 304-311.
2. Bird ML, Hill K, Ball M, Williams AD. Effects of resistance- and flexibility-exercise interventions on balance and related measures in older adults. *J Aging Phys Act* 2009; 17: 444-454.
3. Bös K. *Handbuch motorischer tests*, 2nd ed. Göttingen: Hogrefe, 2001, 283-286.
4. Bös K, Wydra G, Karisch G. *Gesundheitsförderung durch Bewegung, Spiel und Sport*. Erlangen: Perimed, 1992, 161-169.
5. Cardinal BJ. Assessing the physical activity readiness of inactive older adults. *Adapt Phys Act Quart* 1997; 14: 65-73.
6. Chang JT, Morton SG, Rubenstein LZ, Mojica WA, Maglione M, Suttorp MJ, Shekelle PG. Interventions for the prevention of falls in older adults: Systematic review and meta-analysis of randomized clinical trials. *Br Med J* 2004; 328: 680-687.
7. Duarte JA, Appell, HJ. Physical activity for longevity – does the dosage make the poison? *Eur Rev Aging Phys Act* 2005; 2: 6-12.
8. Eurostat. *Europe in Figures. Eurostat Yearbook 2010*. Luxembourg: Publication Office of the European Union, 2010.
9. Figueiredo PA, Mota MP, Appell HJ, Duarte JA. Ceasing of muscle function with aging: Is it the consequence of intrinsic muscle degeneration or a secondary effect of neuronal impairments? *Eur Rev Aging Phys Act* 2006; 3: 75-83.
10. Goulding M, Rogers M, Smith S. Public health and aging: Trends in aging – United States and worldwide. *MMWR* 2003; 52: 101-106.
11. Harriss DJ, Atkinson G. Update – Ethical standards in sport and exercise science research. *Int J Sports Med* 2011; 32: 819-821
12. Heathcote G. Autonomy, health and ageing: Transnational perspectives. *Health Educat Res* 2000; 15: 13-24.
13. Illing S, Choy NL, Nitz J, Nolan M. Sensory system function and postural stability in men aged 30-80 years. *Aging Male* 2010: 13: 202-210.
14. Iwamoto J, Suzuki H, Tanaka K, Kumakubo T, Hirabayashi H, Miyazaki K, Matsumoto H. Preventive effects of exercise against falls in the elderly: A randomized controlled trial. *Osteoporos Int* 2009; 20: 1233-1240.
15. Jiménez Sanz M, Fernández Viadero C, Verduga Vélez R, Crespo Santiago D. Anthropometric values in an elderly institutionalized population [in Spanish]. *Nutr Hosp* 2002; 17: 244-250.
16. Johnson CB, Mihalko SL, Newell KM. Aging and the time needed to reacquire postural stability. *J Aging Phys Act* 2003; 11: 419-429.
17. Johnson EG, Larsen A, Ozawa H, Wilson CA, Kennedy KL. The effects of Pilates-based exercise on dynamic balance in healthy adults. *J Bodyw Mov Ther* 2007; 11: 238-242.
18. Kaesler DS, Mellinfont RB, Swete K, Taaffe DR. A novel balance exercise program for postural stability in older adults. *J Bodyw Mov Ther* 2007; 11: 37-43.
19. Kerrigan DC, Lee LW, Collins JJ, Riley PO, Lipsitz LA. Reduced hip extension during walking: Healthy elderly and fallers versus young adults. *Arch Phys Med Rehabil* 2001; 82: 26-30.
20. King MB, Tinetti ME. A multifactorial approach to reducing injurious falls. *Clin Geriatr Med* 1996; 12: 745-759.
21. Kloubec JA. Pilates for improvement of muscle endurance, flexibility, balance, and posture. *J Strength Cond Res* 2010; 24: 661-667.
22. Lange C, Unnithan V, Larkam E, Latta PM. Pilates inspired exercise for learning functional motor skills. *J Bodyw Mov Ther* 2000; 4: 99-108.
23. Latey P. The Pilates method: History and philosophy. *J Bodyw Mov Ther* 2001; 5: 275-282.
24. Lenze EJ, Munin MC, Skidmore ER, Amanda Dew M, Rogers JC, Whyte EM, Reynolds CF. Onset of depression in elderly persons after hip fracture: Implications for prevention and early intervention of late-life depression. *J Am Geriatr Soc* 2007; 55: 81-86.
25. Maki BE, McIlroy WE. Control of rapid limb movements for balance recovery: Age-related changes and implications for fall prevention. *Age Ageing* 2006; 35 (Suppl.2): ii12-ii18.
26. Mann L, Kleinpaul JF, Mota CB, dos Santos SG. Equilíbrio corporal e exercícios físicos: Uma revisão sistemática. *Motriz Rio Claro* 2009; 15: 713-722.
27. Marzetti E, Leeuwenburgh C. Skeletal muscle apoptosis, sarcopenia and frailty at old age. *Exp Gerontol* 2006; 41: 1234-1238.
28. Mechling H, Netz Y. Aging and inactivity – Capitalizing on the protective effect of planned physical activity in old age. *Eur Rev Aging Phys Act* 2009; 6: 89-97.
29. Meléndez-Ortega A. Osteoporosis, falls and exercise. *Eur Rev Aging Phys Act* 2007; 4: 61-70.
30. Meyer G, Ayalon M. Biomechanical aspects of dynamic stability. *Eur Rev Aging Phys Act* 2006; 3: 29-33.
31. Mills PM, Barrett RS. Swing phase mechanics of healthy young and elderly men. *Hum Mov Sci* 2001; 20: 427-446.
32. Muscolino JE, Cipriani S. Pilates and the "powerhouse." *J Bodyw Mov Ther* 2004; 8: 15-24.
33. Orr R. Contribution of muscle weakness to postural instability in the elderly: A systematic review. *Eur J Phys Rehabil Med* 2010; 46: 183-220.
34. Papalia DE, Olds SW, Feldman RD. *Desenvolvimento Humano*. 8ª Edição. Porto Alegre: Artmed 2006.
35. Park H, Kim KJ, Komatsu T, Park SK, Mutoh Y. Effect of combined exercise training on bone, body balance, and gait ability: A randomized controlled study in community-dwelling elderly women. *J Bone Miner Metab* 2008; 26: 254-259.
36. Pereira CLN, Vogelaere P, Baptista F. Role of physical activity in the prevention of falls and their consequences for the elderly. *Eur Rev Aging Phys Act* 2008; 5: 51-58.
37. Ribeiro F, Oliveira J. Aging effects on joint proprioception: The role of physical activity in proprioception preservation. *Eur Rev Aging Phys Act* 2007; 4: 71-76.
38. Rosengren KS, McAuley E, Mihalko SL. Gait adjustments in older adults: Activity and efficacy influences. *Psychol Aging* 1998: 13: 375-386.
39. Shedden M, Kravitz L. Pilates exercise. A research-based review. *J Dance Med Sci* 2006; 10: 111-116.
40. Sherrington C, Whitney JC, Lord SR, Herbert RD, Cumming RG, Close JC . Effective exercise for the prevention of falls: A systematic review and meta-analysis. *J Am Geriatr Soc* 2008; 56: 2234-2243.
41. Skelton DA. Effects of physical activity on postural stability. *Age Aging* 2001; 30 Suppl 4: 33-39.
42. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc* 1986; 34: 119-126.
43. Tuna HD, Edeer AO, Malkoc M, Aksakoglu G. Effects of age and physical activity level on functional fitness in older adults. *Eur Rev Aging Phys Act* 2009; 6: 99-106.
44. Varela S, Ayán C, Cancela M. Batteries assessing health related fitness in the elderly: A brief review. *Eur Rev Aging Phys Act* 2008; 5: 97-105.
45. Wydra G. Bedeutung, Diagnose und Therapie von Gleichgewichtsstörungen. *Motorik* 1993; 16: 100-107.