A Lower-Limb Training Program to Improve Balance in Healthy Elderly Women Using the T-Bow® Device

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Abstract: Ageing impairs balance, which increases the risk of falls. Fall-related injuries are a serious health problem associated with dependency and disability in the elderly and results in high costs to public health systems. This study aims to determine the effects of a training program to develop balance using a new device called the T-Bow®. A total of 28 women > 65 years were randomly assigned to an experimental group (EG) (n = 18; 69.50 [0.99] years), or a control group (CG) (n = 10; 70.70 [2.18] years). A program for lower limbs was applied for 8 weeks using 5 exercises on the T-Bow®: squat, lateral and frontal swings, lunges, and plantarflexions. The intensity of the exercises was controlled by time of exposure, support base, and ratings of perceived exertion. Clinical tests were used to evaluate variables of balance. Static balance was measured by a 1-leg balance test (unipedal stance test), dynamic balance was measured by the 8-foot-up-and-go test, and overall balance was measured using the Tinetti test. Results for the EG showed an increase of 35.2% in static balance ($P < 0.005$), 12.7% in dynamic balance ($P < 0.005$), and 5.9% in overall balance ($P > 0.05$). Results for the CG showed a decline of 5.79% in static balance ($P > 0.05$) but no change in the other balance variables. Thus the data suggest that implementing a training program using the T-Bow® could improve balance in healthy older women.

Keywords: falls; geriatrics; physical exercise; swinging; instability

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Introduction

Ageing is associated with the deterioration of many biological systems and functional capabilities.[1–3] This impairment significantly reduces mobility and functional fitness, and increases dependency in the elderly. Balance can be seen as a skill that will gradually deteriorate with age,[4,5] causing a greater risk of falls and fall-related injuries, which in turn affects healthy life expectancy.[6] Falls are the result of any event that suddenly and unintentionally precipitates a person to the ground.[7] Researchers have estimated that one-third of those ≥ 65 years will suffer a fall.[8–12] This risk increases by 8 times in those ≥ 80 years.[13] Within this risk group, one-half may suffer another fall,[8,9] which could result in weakness and dependence.[14]

Balance is the ability to maintain the body's position over its base of support involving static and dynamic components.[15] It requires postural stability, which is the ability to maintain the body in spatial equilibrium under both static and dynamic conditions.[16] Reactive balance is conceived as postural control that involves effective responses to situations of disturbed or changed stability.[17] In general, these abilities can facilitate the process by which the center of body mass is controlled, using the support base, in a static or dynamic way during voluntary stances or movements and as a response to external shocks.[18] The deterioriation of these abilities has been identified as one of the most common risk factors for falling among the elderly.[15,19] About 10% to 25% of falls are associated with poor balance and gait abnormalities.[16] Because the ability to maintain balance is influenced by such a variety of factors, the mechanisms that explain the age-related deterioration of balance are difficult to identify. Nevertheless, intrinsic factors are significant.[20] For example, Choy et al[21] showed that changes in sensation and vision in women ≥ 40 years could be the principal reasons for deterioration in balance.

Physical activity programs have been successfully used to strengthen the physical parameters associated with fall risk, including improving balance. Both specific programs (balance activities) and comprehensive programs (to integrate the strengthening of lower limbs, specific balance, overall strengthening, flexibility, and agility) have been shown to have a positive influence on a subject's

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balancing ability, thus reducing the risk of falls.[22–26] Success in such programs has led to the development or design of specific devices to help improve balance. One device recently developed by T-Bow® Switzerland (Instyle, West Sussex, UK) (Figure 1) consists of a multifunctional arch that allows for a wide range of exercises to strengthen lower limbs, enhance specific balance, and improve general strength, flexibility, and agility. We speculate that this device could increase general physical fitness and all the specific abilities related to balance. Scientific knowledge about the benefits of improving balance in older people using physical conditioning exercises and specific balance exercises performed with a T-Bow® is sparse. This study aims to quantify the effects of a training program using the T-Bow®, on the ability to maintain balance in a group of healthy elderly women.

Materials and Methods

Study Design

A randomized controlled trial was used to assess the effects on balance of different exercises using the T-Bow® for a period of 8 weeks. Subjects were randomly assigned to an experimental group (EG) or a control group (CG). The EG performed a program based on resistance training using the T-Bow®. The CG continued normally, without performing other kinds of exercise. Pretest and post-test measures were recorded for both groups.

Subjects

An advertisement was placed in a geriatric center. The study's principal researcher used a questionnaire and a complementary interview to assess the physical and sporting activities of a total of 55 elderly women. The inclusion criteria for the exercise groups were: a) age ≥ 65 years; b) predominantly healthy and with no history of significant cardiovascular, pulmonary, metabolic, musculoskeletal, or neurological disease; c) no prior history of falls; d) no use of specific medication known to impair balance or strength; and e) living independently in the community with a normally active lifestyle. Eleven subjects did not meet the inclusion criteria and 16 refused to participate. Eventually, 28 women were randomly divided into the EG or the CG (Figure 1).

Based on the results provided in previous research,[27] a power analysis for a comparison within the EG estimated that a sample of 15 subjects was needed to detect a size effect of 0.79, with a power of 0.80 and a 2-tailed alpha of < 0.05. Power analyses were performed with the software GPower (GPower, v.3.0.10, Universitat Kiel, Alemania) using the outcome variable 10-minute walking test similar to 8-foot-up-and-go test. We decided to employ a nonequilibrated design because only 28 women met the inclusion criteria. To achieve sufficient statistical power to enable detection of significant differences within an experimental group, at least 15 subjects were needed. In view of the possibility of drop-out, we decided to expand the sample size of the exercise group by 20%. Thus, the EG and CG were formed with 18 and 10 subjects, respectively. Table 1 shows descriptive data on the characteristics of participants in each group.

All subjects were informed of the training and testing involved by means of a consent form. The women were told not to modify their behavior and were strictly forbidden to perform any other type of physical exercise. The study was approved by a research commission from the Department of Physical Education and Sports of the University of Valencia, Spain.

Procedures

Several balance measures were used to assess whether subjects in the EG improved their balance. A Tinetti test, 1-leg stance test, and 8-foot-up-and-go test were applied in both pretest and posttest. Participants performed each test twice, separated by 3 minutes between attempts. The best result of each participant was stored for further statistical analysis.

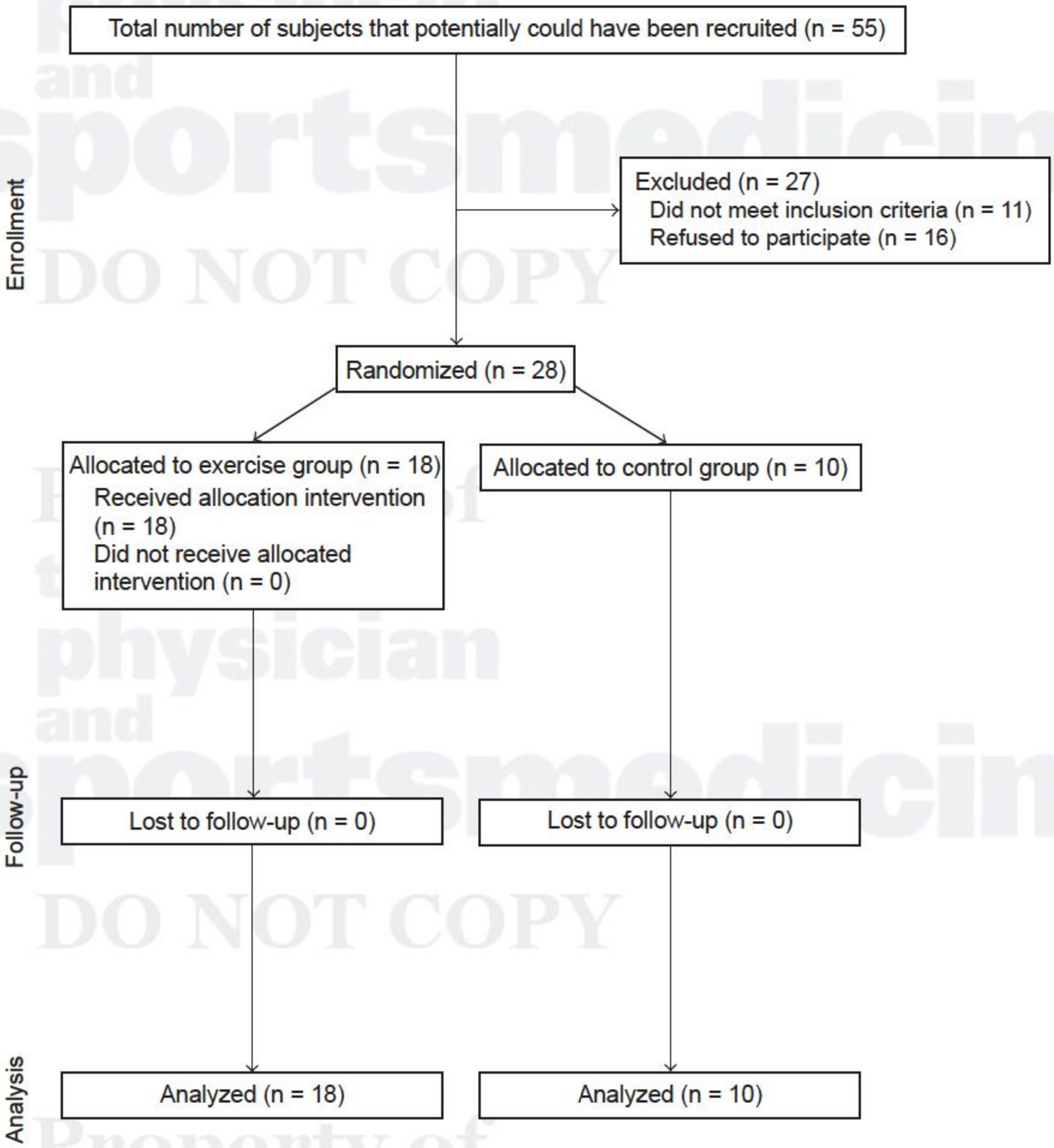
Tinetti Test

This test is usually applied to evaluate the risk of falls among the elderly[28,29] and is a good tool to assess progress in overall balancing skills after performing a physical training program.[30] Thus, it is a useful, effective, and reliable clinical assessment tool, which applies a questionnaire that includes items addressing transition skills such as sitting to standing or standing to sitting, as well as gait variables. The value of the sum of the scores of all items can vary from 0 to 28; values < 26 are related to an impaired condition of balance and values < 19 may involve a high risk of falls.[30]

One-leg Stance Test

Static balance was assessed using the 1-leg stance test,[31] which is a reliable marker of frailty during the aging.[31,32] The test can be applied to elderly patients with impaired balance or to healthy elderly patietns.[30] In this test, the participant stands on the preferred foot, while resting the hands at waist level, then

Figure 1. Flow diagram for randomized subjects assignment.



raises the other foot approximately 10 cm off the floor. Balance is scored by the number of seconds for which the foot is kept raised or until balance is lost. Timing is terminated when the subject touches the free foot to the floor, removes the hands from the waist, or moves the supporting foot from the original starting position. The maximum stance is 30 sec, because after this time those tested demonstrate a high level of balancing skills.[14,32] This test has been used on subjects with motor impairment to assess balance disorders in otherwise healthy people,[33] and applied in a wide variety of ages.[4,31,32]

Eight-foot-up-and-go Test

Dynamic balance was assessed using the 8-foot-up-and-go test, which is included in the Senior Fitness Test, a series of functional assessments aimed at the elderly, conducted by Rikli and Jones.[34,35] The intraclass correlation coefficient

Table 1. Subject Characteristics

	Age	Height (cm)	Weight (kg)	BMI (kg/m²)
EG	69.5 (0.99)	157.5 (1.8)	65.54 (2.32)	26.42 (0.82)
CG	70.7 (2.18)	156.8 (1.91)	65.15 (3.25)	26.43 (0.93)

Data are expressed as mean (SEM).
Abbreviations: BMI, body mass index; CG, control group; EG, experimental group.

obtained for this test has revealed good test-retest reliability (r = 0.95).[34] The test has also been found to be significantly correlated to the Berg Balance Scale (r = −0.81), to gait speed (r = 0.61), and to the Barthel Activities of Daily Lives Index (r = 0.78). The test procedures were taken from Rikli and Jones.[34] The purpose of the 8-foot-up-and-go test is to assess physical mobility in terms of speed, agility, and dynamic balance. The score is based on the number of seconds required to get up from a seated position (knee flexion around 90°), walk 8 feet (2.44 m), turn around, and return to a seated position as fast as possible without running. Enhancing the skills needed to reduce the time to complete the distance in an easy and secure manner is important because these same skills are needed in the activities of daily life.[35]

Training Program

The T-Bow® can be positioned on the floor concave or convex side down depending on the type of exercise required. The dimensions of the T-Bow® were 700 mm (length) × 500 mm (width) × 170 mm (depth), and the weight was 3.2 kg. The T-Bow® will be unstable if the convex side is facing downward, and the instability may be lateral or anteroposterior depending on how the subject's weight is distributed. The training program consisted of 5 exercises using the T-Bow®. **1) Squat**. Figure 2 shows the start position. A flexo-extension movement of the hips and knees was performed until the thighs were positioned in a parallel position to the floor. **2–3) Side and frontal swinging**. With the convex side of the T-Bow on the floor, the subjects performed swinging movements with the flexo-extension of each leg alternately. They performed lateral swinging first and then frontal swinging. **4) Frontal lunges**. With the concave side of the T-Bow® in contact with the floor, the subjects placed 1 leg above the T-Bow®. They performed classical frontal lunges until the frontal thigh was parallel with the floor (Figure 3). 5) **Plantar flexo-extensions.** With the concave side of the T-Bow® in contact with the floor, the subjects placed 1 leg on each side of the T-Bow®, firmly in the inferior. Taking advantage of the convex shape of the T-Bow®, subjects performed ankle flexo-extensions.

The intensity of these exercises was controlled by exposure time, by modifying the support base, and according to the Adult OMNI Perceived Exertion Scale for Resistance Exercise (OMNI–Res). Balance exercise intensity was implemented by the time of the stance while balancing. The maximum length of stay was 30 sec. If subjects could maintain their position correctly for 30 sec the base of support was increased to allow a higher level of swing in the next set. Subjects were asked to maintain a rating of perceived exertion of between 4 and 5 on the OMNI–Res.[36] The intensity of strengthening exercises and balance training was monitored according to the OMNI–Res.[36] The exercise had to be moderate or somewhat easy (scored by 4 or 5), with the researcher asking to be shown the score of each set (12 repetitions of 1–3 sets). For squats and frontal and lateral swinging the intensity was changed, widening the gap between the support of the feet, while for the lunges and plantar flexo-extensions a slight elastic band was employed to adjust the number of repetitions at the target level of effort. The effectiveness of this monitoring has been reported in previous research[24] and allowed for sustained moderate effort throughout the intervention program.

Two weekly 30-minute sessions were held over a period of 8 weeks. We chose this duration because it has been shown to be effective in improving the balance of elderly,[37] especially when applying specific exercises to improve balance.[38] Training sessions for the entire group were always led by someone with a professional degree in physical activity and sport. At least 1 trained monitor was always present to corroborate the correct application of the methodology, ensuring a closely supervised training study.

Statistical Analyses

The data were processed using SPSS 15.0. The Kolmogorov-Smirnov test (K-S test) for normality and Levene's test for homoscedasticity were used to verify all variables before analysis. Standard statistical methods were used to obtain the descriptive statistics. The data are expressed as mean (standard error of mean). A mixed-model analysis of variance (ANOVA) 2 (tests of the program) × 2 (group) was applied to determine the effects of the training program on balance. Multivariate analysis was used to avoid increasing family-wise error (ie, increase the possibilities of one type I error) because 3 dependent variables were included in the analysis. Pair-wise

Figure 2. An example of balance training with the T-Bow® device.

Figure 3. Subject performing frontal lunge with the T-Bow® device.

Table 2. Changes in 1-Foot Stance Time, 8-foot-up-and-go Time and Tinetti's Test Score after Intervention Period in Both Groups

		One-foot stance (sec)	8-foot up-and-go (sec)	Tinetti's test (score)
EG	Pretest	16.56 (1.68)	6.84 (0.33)	22.5 (0.834)
	Posttest	22.39 (1.62)*	5.97 (0.22)*	23.83 (0.57)†
CG	Pretest	19.00 (1.77)	7.53 (0.66)	21.90 (0.65)
	Posttest	17.90 (1.33)	7.04 (0.62)	20.90 (0.64)

Data are expressed as mean (SEM).
*Significant difference between pretest and post-test values ($P < 0.005$).
†Significant difference between groups in post-test values ($P < 0.005$).
Abbreviatons: CG, control group; EG, experimental group..

comparisons were requested when the ANOVA showed a significant effect. The level of significance was set at 5%.

Results

The program had a significant main effect on the outcome variables ($F[3,24] = 8.36$; $P = 0.001$). Pair-wise comparisons showed that the time on 1-leg stance test was greater and the time to perform the 8-foot-up-and-go test was less ($P < 0.005$). Nonetheless, the group had no significant main effect on the outcome variables ($F[3,24] = 1.73$; $P = 0.187$).

There was also a significant interaction effect between the training program and the subjects ($F[3,24] = 7.96$; $P = 0.001$). This result indicates that changes in test performance between pretest and post-test were different in the EG and CG. Post-hoc analysis revealed that the EG spent less time performing the 8-foot-up-and-go test, and the group's 1-leg stance time was greater in the post-test compared with pretest ($P < 0.001$). The CG showed no significant differences between pretest and post-test. No significant difference between the groups in the pretest was found. However, the EG showed a higher Tinetti test score that the CG in the post-test ($P = 0.003$).

Discussion

The results of our study show a discrete increase in the values of static and dynamic balance after a period of 8 weeks of comprehensive training using the T-Bow® by healthy and active elderly women. The results demonstrate a slight effectiveness of the training program that we implemented with the T-Bow®. However, we found no differences between the groups in the 1-leg stance test or in the 8-foot-up-and-go test in the post-test, possibly because the sample size was large enough to find intragroup differences, but not to establish any intergroup differences, or because the intervention was not sufficiently intense for women who were healthy and active.

To our knowledge, Hugener and Reidt[39] are the only authors to have previously conducted a study on the implementing the T-Bow® as a device for training. The design of this comprehensive study was very similar to ours (45-minute sessions, 2 days per week for 8 weeks). Although Hugener and Reidt did not use the same exercises or assessment tools, their results were similar to those obtained in our study. Their research led to greater improvements in balance and strength than those obtained in our study, perhaps because our study used active participants, whereas theirs used women with a sedentary lifestyle. Our study of physically active participants showed that a resistance training program using the T-Bow® could be a more effective way to improve balance than other types of exercise, because participants were able to improve their balance. To confirm our findings, detailed comparisons between training programs using the T-Bow® and other trainings programs, such as traditional resistance training or tai chi, are needed. Furthermore, the balance tests used in our study were more functional tests than the tests employed by Hugener and Reidt.[39]

A tendency to increase balance capacity in the short term is not a surprising discovery because early improvement of balance performance is known to follow physical exercise.[37] Improvement in balance is more significant after specific exercises.[38] For instance, it is possible to measure improvements in balance after 4 weeks of specific exercise training.[40] Other studies have employed more balance-specific training programs using tai chi,[41–43] unstable surfaces,[44,45] specific exercises and changes in the support base,[25] and multimodal exercises.[46,47] These programs are effective because they target specific physiological systems involved in balance control (visual, vestibular, somatosensory, and musculoskeletal systems), and appear to improve balance in older adults. However, the difference between these proposals and our research using the T-Bow® must be stressed. T-Bow® exercises can be understood as balancing exercises that work by counteracting body weight resistance whereas other forms of exercise such as tai chi involve changes in the distribution of body weight and unipedal stances. Furthermore, our study introduces the possibility of applying some resistance exercises for the lower extremities using the same device. Although this variable is not directly measured it is possible that the increase in strength could provoke additional positive effects on balance.[26]

We found that both static and dynamic balance improved after the intervention proposed, as previously shown in other 10-week trials applying specific balancing exercise.[25,48] Our data showed that the greatest increase was recorded in the length of unipedal stance (35.20%), while dynamic balance improved by 12.7%; finally, the Tinetti test showed a tendency toward improvement, although not to a statistically significant degree ($P > 0.05$). We can reasonably conclude that the exercises we used showed greater effectiveness in the development of static balance because they did not involve displacements. Other exercise programs based on exercises such as ballates', step aerobics, and walking—which all include dynamic maneuvers—have been shown to produce a very significant increase in the capacity of dynamic balance in women aged 50 to 75 years.[49]

Rogers and Mille[50] explain another possible contributing factor to an improvement in balancing skills. These authors cite the importance of lateral postural control on the risk of falls in older people. Deterioration in the ability to respond effectively to loss of lateral stability increases the risk of side falls.[51] Other research has demonstrated that medial-lateral balance in the elderly is superior to that of falls in young and elderly patients, but worse when compared with young patients who do not fall.[52–54] In this situation, these authors recommended activities in which lateral and medial lower-limb muscle groups are activated, using the subject's own body weight. The peculiar and specific shape of the T-Bow® enabled our program to include lateral balancing/swinging exercises, as outlined by Rogers and Mille,[50] which can be a major factor in justifying improved balance performance.

A final factor that may improve balance is the instability of the T-Bow® for lower-limb strengthening exercises.[55] In our study, 3 calisthenics exercises aimed at strengthening lower limbs were performed on labile surfaces, which offer a degree of instability due to rolling, thus leading to improved balance. For healthy older women at low risk for falls, engaging in a broad range of specific balancing physical activity with the T-Bow® is likely to be sufficient to substantially reduce the risk of falling as a result of an improvement in balancing skills.

The sample size in our study was limited. Perhaps a larger sample may reveal intergroup differences in the post-test. The lack of comparison between this intervention and other kinds of programs could be an additional limitation.

Future research is required to obtain a quantitative assessment of balance level after T-Bow® training in older women. Finally, we suggest further studies to verify the effects that we found in our study in other groups, and more comparative research on various specific balance training exercises, and other populations groups.

The T-Bow® can be an effective device to improve performance balance in a short time in elderly subjects. Because ageing leads to a deterioration of many capacities such as balance, extensive studies have established training programs to avoid this deterioration. The present study has important clinical implications. It showed a significant clinical improvement of the balance function in elderly people who completed a training program using the T-Bow®. Thus, this type of intervention is effective to prevent and treat impaired balance as a result of ageing. Safety issues need to be considered when subjects use the T-Bow®, however, and some modifications of the device may be needed for balance-impaired individuals.

In conclusion, the main clinical highlight of this study is our demonstration that the T-Bow® could be an effective tool to gain moderate improvement of balance in healthy older women. Thus, it could be applied in conjunction with other traditional devices.

Conflict of Interest Statement

Iván Chulvi-Medrano, Juan C. Colado, PhD, Carlos Pablos, PhD, Fernando Naclerio, PhD, and Xavier García-Massó have no conflicts of interest to disclose.

References

1. Shephard RJ. *Aging, Physical Activity, and Health*. Champaign, Il: Human Kinetics; 1997.
2. Lopez J, Izquierdo, M. Physiological aspects of exercise in relation to aging. In: Lopez J, Fernández A, eds. *Exercise Physiology*. 3rd ed. Madrid, Spain: Panamericana; 2006:613–639.
3. Buatois S, Gauchard GC, Aubry C, Benetos A, Perrin P. Current physical activity improves balance control during sensory conflicting conditions in older adults. *Int J Sports Med*. 2007;28(1):53–58.
4. Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J. Decrease in timed balance test scores with aging. *Phys Ther*. 1984;64(7):1067–1070.
5. Woollacott MH, Shumway-Cook A. Changes in posture control across the life span—a systems approach. *Phys Ther*. 1990;70(12):799–807.
6. Kannus P, Parkkari J, Koskinen S, et al. Fall-induced injuries and death among older adults. *JAMA*. 1999;281(20):1895–1899.
7. World Health Organization. International Classification of Diseases. Manual of the International Statistical Classification of Diseases, Injuries and Causes of death. 9th revision. Geneva: World Health Organization; 1977.
8. Prudham D, Evans JG. Factors associated with falls in the elderly: a community study. *Age Ageing*. 1981;10(3):141–146.
9. Gardner MM, Robertson MC, Campbell AJ. Exercise in preventing falls and fall related injuries in older people: a review of randomised controlled trials. *Br J Sports Med*. 2000;34(1):7–17.
10. Hausdorff JM, Nelson ME, Kaliton D, et al. Etiology and modification of gait instability in older adults: a randomized controlled trial of exercise. *J Appl Physiol*. 2001;90(6):2117–2129.
11. Tinetti ME, Williams CS. Falls, injuries due to falls, and the risk of admission to a nursing home. *N Engl J Med*. 1997;337(18):1279–1284.
12. Gates S, Fisher JD, Cooke MW, Carter YH, Lamb SE. Multifactorial assessment and targeted intervention for preventing falls and injuries among older people in community and emergency care settings: systematic review and meta-analysis. *BMJ*. 2008;336(7636):130–133.
13. World Health Organization (WHO). Healthy ageing. Ageing and daily physical activity. Ginebra: 1998. http://209.85.129.132/search?q=cache:pbuAUhR1AP0J:www.imsersomayores.csic.es/documentos/documentos/oms-envejecimiento-02.rtf+www.imsersomayores.csic.es/documentos/documentos/oms%E2%88%92envejecimiento%E2%88%9202.rtf.&cd=2&hl=es&ct=clnk&gl=es. Accessed June 10, 2009.
14. Del Nogal ML, González-Ramírez A, Palomo-Iloro A. Assessment of risk of falls. Protocols for clinical assessment. *Rev Esp Geriatr Gerontol*. 2005;40:54–63.
15. Rogers ME, Fernandez JE, Bohlken RM. Training to reduce postural sway and increase functional reach in the elderly. *J Occup Rehabil*. 2001;11(4):291–298.
16. Shumway-Cook A, Woollacott MH. *Motor Control: Theory and Practical Applications*. 2nd ed. Baltimore, MD: Lippincott Williams & Wilkins; 2000.
17. Houglum P. The ABCs of proprioception. In: Houglum P, ed. *Therapeutic Exercise for Musculoskeletal Injuries*. 2nd ed. Champaign, Il: Human Kinetics; 2005:259–274.
18. Daubney ME, Culham EG. Lower-extremity muscle force and balance performance in adults aged 65 years and older. *Phys Ther*. 1999;79(12):1177–1185.
19. Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. *Clin Geriatr Med*. 2002;18:(2)141–158.
20. Lord SR, Menz HB, Tiedemann A. A physiological profile approach to falls risk assessment and prevention. *Phys Ther*. 2003;83(3):237–252.
21. Choy NL, Brauer S, Nitz J. Changes in postural stability in women aged 20 to 80 years. *J Gerontol A Biol Sci Med Sci*. 2003;58(6):525–530.
22. Judge JO, Lindsey C, Underwood M, Winsemius D. Balance improvements in older women: effects of exercise training. *Phys Ther*. 1993;73(4):254–262.
23. Bellew JW, Fenter PC, Chelette B, Moore R, Loreno D. Effects of a short-term dynamic balance training program in healthy older women. *J Geriatr Phys Ther*. 2005;28(1):4–8, 27.
24. Colado JC, Triplett NT. Effects of a short-term resistance program using elastic bands versus weight machines for sedentary middle-aged women. *J Strength Cond Res*. 2008;22(5):1441–1448.
25. Nnodim JO, Strasburg D, Nabozny M, et al. Dynamic balance and stepping versus tai chi training to improve balance and stepping in at-risk older adults. *J Am Geriatr Soc*. 2006;54:1825–1831.
26. Moreland JD, Richardson JA, Goldsmith CH, Clase CM. Muscle weakness and falls in older adults: a systematic review and meta-analysis. *J Am Geriatr Soc*. 2004;52(7):1121–1129.
27. Holviala JHS, Sallinen JM, Kraemer WJ, Alen MJ, Häkkinen KK. Effects of strength training on muscle strength characteristics, functional capabilities, and balance in middle-aged and older women. *J Strength Cond Res*. 2006;20(2):336–344.
28. Neira M, Rodríguez-Mañas L. Repeated falls in the residential area. *Rev Esp Geriatr Gerontol*. 2006;41:201–206.
29. Ortuño MA, Barona R, Martin E. Functional balance assessment. In: Sanchez I, Ferrero A, Aguilar JJ, eds. *SERMEF Handbook of Physical Medicine and Rehabilitation*. Madrid, Spain: Panamericana; 2006:103–108.
30. Tinetti ME. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*. 1986;34(2):119–126.
31. Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. *J Geriatric Physical Therapy*. 2007;30(1):8–15.
32. Briggs RC, Gossman MR, Birch R, Drews JE, Shaddeau SA. Balance performance among noninstitutionalized elderly women. *Phys Ther*. 1989;69(9):748–756.
33. Suni JH, Oja P, Laukkanen RT, et al. Health-related fitness test battery for adults: aspects of reliability. *Arch Phys Med Rehabil*. 1996;77(4):399–405.
34. Rikli R, Jones CJ. Development and validation of a functional fitness test for community–residing older adults. *J Aging Phys Act*. 1999;7(2):129–161.
35. Jones CJ, Rikli RE. Measuring functional. *J Active Aging*. 2002;1(1):24–30.
36. Robertson RJ, Goss FL, Rutkowski J, et al. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. *Med Sci Sports Exerc*. 2003;35(2):333–341.
37. Howe TE, Rochester L, Jackson A, Banks PMH, Blair VA. Exercises for improving balance in older people. *Cochrane Database of Systematic Reviews* 2007;(4)CD004963.
38. de Bruin ED, Murer K. Effect of additional functional exercises on balance in elderly people. *Clin Rehabil*. 2007;21(2):112–121.
39. Hugener D, Reidt S. Fitness Benefits with T-Bow Training. 2005–2006. Institute of Movement and Sports Sciences, Zurich University. http://www.t-bow.net/res_invest_manual2006.htm. Accessed September 1, 2008.
40. Hinman MR. Comparison of two short-term balance training programs for community-dwelling older adults. *J Geriatric Physical Ther*. 2002;25:10–17.
41. Tsang WW, Hui-Chan CW. Effect of 4- and 8-wk intensive Tai Chi training on balance control in the elderly. *Med Sci Sports Exerc*. 2004;36(4):648–657.
42. Li F, Harmer P, Fisher KJ, McAuley E. Tai Chi: improving functional balance and predicting subsequent falls in older persons. *Med Sci Sports Exerc*. 2004;36(12):2046–2052.
43. Gatts S. A Tai Chi Chuan training model to improve balance control in older adults. *Curr Aging Sci*. 2008;1:68–70.

44. Ruiz R, Richardson MT. Functional balance training using a domed device. *Strength Cond J*. 2005;27(1):50–55.
45. Yaggie JA, Campbell BM. Effects of balance training on selected skills. *J Strength Cond Res*. 2006;20(2):422–428.
46. Baker MK, Atlantis E, Fiatarone Singh MA. Multi–modal exercise programs for older adults. *Age Ageing*. 2007;36(4):375–381.
47. Shumway-Cook A, Gruber W, Baldwin M, Liao S. The effect of multidimensional exercises on balance, mobility, and fall risk in community-dwelling older adults. *Phys Ther*. 1997;77(1):46–57.
48. Carter ND, Kannus P, Khan KM. Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. *Sports Med*. 2001;31(6):427–438.
49. Clary S, Barnes C, Bemben D, Knehans A, Bemben M. Effects of ballates, step aerobics, and walking on balance in women aged 50–75 years. *J Sports Sci Med*. 2006;5(3):390–399.
50. Rogers MW, Mille ML. Lateral stability and falls in older people. *Exerc Sport Sci Rev*. 2003;31(4):182–187.
51. 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.
52. Maki BE, McIlroy WE. The role of limb movements in maintaining upright stance: the "change-in-support" strategy. *Phys Ther*. 1997; 77(5):488–507.
53. Melzer I, Benjuya N, Kaplanski J. Postural stability in the elderly: a comparison between fallers and non-fallers. *Age Ageing*. 2004;33(6):602–607.
54. Oddsson LI, Boissy P, Melzer I. How to improve gait and balance function in elderly individuals–compliance with principles of training. *Eur Rev Aging Phys Act*. 2007;4(1): 15–23.
55. Anderson K, Behm DG. The impact of instability resistance training on balance and stability. *Sports Med*. 2005;35(1):43–53.