*ORIGINAL ARTICLE*

# Effects of a 12-Week Tai Chi Chuan Program Versus a Balance Training Program on Postural Control and Walking Ability in Older People

***Thierry Lelard, PhD, Pierre-Louis Doutrellot, PhD, MD, Pascal David, PhD, Said Ahmaidi, PhD***

ABSTRACT. Lelard T, Doutrellot P-L, David P, Ahmaidi S. Effects of a 12-week Tai Chi Chuan program versus a balance training program on postural control and walking ability in older people. Arch Phys Med Rehabil 2010;91:9-14.

**Objective:** To compare the respective effects of 2 balance training programs: a Tai Chi (TC) program and a balance training program on static postural control and walking ability.

**Design:** Randomized controlled trial.

**Setting:** General community.

**Participants:** Older subjects (N=28) participated in the study.

**Interventions:** The TC group (n=14; mean age ± SD, 76.8±5.1y) and the balance training group (n=14; 77.0±4.5y) were both trained for 12 weeks.

**Main Outcome Measures:** Static postural control was assessed via measurement of center of pressure sway under eyes open (EO) and eyes closed (EC) conditions. Walking speed over a 10-meter course was also assessed.

**Results:** After the 12-week training period, there were no significant differences in walking speed or postural parameters in either the EO or EC conditions for the TC and balance training groups. Performance in the EC condition was lower than in the EO condition in pretest and posttest for the balance training and TC groups. The Romberg quotient (EO/EC ratio) was significantly higher after the balance training program than the TC program ($P<.05$).

**Conclusions:** We cannot conclude that the balance training program has better effects than the TC program on postural control or walking ability. None of the outcome measures showed significant change posttraining in either the TC or the balance training groups. However, the differences described in the Romberg quotient after the training period between the TC and the balance training groups suggest that TC should be helpful to limit the deleterious effects of eye closure on postural balance.

**Key Words:** Aged; Postural balance; Proprioception; Rehabilitation.



AGE-RELATED CHANGES in postural imbalance and the incidence of falls have generally been associated with deterioration of the proprioceptive and motor systems.[1,2] The decrease in walking speed reflects postural control degradation and is related to the risk of falling. Even though falls rarely occur under static conditions, postural body oscillations during a normal, quiet stance as characterized by the displacement of the COP reflect postural ability.

The perception of sway in a normal, upright stance requires information from the proprioceptive, visual, and vestibular systems. Cross-sectional studies have shown that postural body oscillations are greater in older people than in younger adults.[3] Follow-up studies have confirmed the postural deterioration with aging by showing a progressive increase in sway velocity over a 3-year or 5-year period.[4,5] In healthy adults, information from the soles of the feet and from the leg muscles makes a major contribution to stance maintenance.[6] With aging, the role of vision in postural regulation becomes predominant[7,8] and may reflect a decrease in the accuracy of the other sensory receptors.[1,9,10] Eye closure in older subjects leads to an increase in instability, as expressed by an increase in postural parameters of between 20% and 70% relative to the EO stance.[11] Likewise, walking speed falls with aging (notably after the age of 70y).[1,12]

Although postural maintenance and walking deteriorate with age, these parameters can be positively influenced by physical activity.[2,11] Of the various activities that have been suggested in healthy subjects over 60 years, those that improve proprioceptive inputs prompt a greater enhancement in postural ability.[13,14] These studies have shown more beneficial effects on static postural control after long-term, regular practice (90min/wk). The authors have explained the reduced disturbance recorded under EC conditions as the result of the somesthesic and vestibular sensitivity development prompted by proprioceptive physical activity. In the last decade, a number of publications have reported significant improvement in older people after TC practice; this involves weight shifting during the performance of a sequence of movement modules (a form)[15] and enhances proprioceptive inputs.[16-18] Several authors suggest that TC practice serves as an efficient fall prevention program for older subjects in a short-term program.[19] Some results indicate better balance performance in dynamic or static postural tests after short-term and long-term TC training.[19] A short-term TC program (8 or 12wk) showed enhancement of lateral stability, of[16] Romberg stance maintenance,[20] of Berg Balance Scale, and Timed Up & Go tests.[21]

**List of Abbreviations**

| | |
|---|---|
| COP | center of pressure |
| EC | eyes closed |
| EO | eyes open |
| TC | Tai Chi |
| $V_{COP}$ | center of pressure velocity |

From the Adaptations Physiologiques à l'Exercice et Réadaptation à l'Effort, Faculté des Sciences du Sport, Université de Picardie Jules Verne (Lelard, Doutrellot, David, Ahmaidi); and the Service d'Explorations Fonctionnelles de l'Appareil Locomoteur, Centre Hospitalier Universitaire (Doutrellot), Amiens Cedex, France.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Reprint requests to Said Ahmaidi, PhD, Faculté des Sciences du Sport, Université de Picardie Jules Verne, Avenue P. Claudel, F-80025 Amiens Cedex, France, e-mail: *said.ahmaidi@u-picardie.fr*.

0003-9993/10/9101-00449$36.00/0
doi:10.1016/j.apmr.2009.09.014

Indeed, there is evidence that TC practice improves postural control system and functional ability in comparison with sedentary groups. However, it is not yet known whether TC has a specific effect on balance control (as suggested by previous studies) compared with other balance training programs. Indeed, physical activity programs have been developed and proposed to older populations with the objective to prevent falls and to maintain autonomy. This type of balance training program involved a postural control system by center of gravity displacement but did not focus on body movement and posture.

We hypothesized that a focus on accurate movement reproduction helps TC practitioners to perform better in postural tasks than balance training subjects. Thus, the aim of the present study was to assess and compare modifications in postural control and walking ability after TC training and a balance training program. We hypothesized that the TC program shows better improvement in these abilities than an alternative balance training program.

## METHODS

### Subjects

Twenty-eight healthy subjects age 70 to 85 years (mean ± SD, 77.0±5.9y) took part in the study and volunteered to participate in a training program. All subjects signed informed consent accepted by the local ethical committee prior to participation in the study in accordance with the Helsinki declaration of 1975. All subjects were free from any disease that could influence postural maintenance. The subjects were physically active; they walked from 1 to 3 hours a week before and during the study. The subjects were randomly assigned to a training program. Fourteen subjects (mean age ± SD, 76.8±5.1y; 3 men) were trained in TC for 3 months, and 14 (77.0±4.5y; 4 men) were engaged in a balance training program. A questionnaire was used to verify that none of them changed their daily living activities during the training period.[22] The subjects took part in 2 experimental sessions of postural testing. The first session, called pretraining, was used to evaluate the initial capacities of postural stance. The last session, called posttraining, was done after 3 months of TC training or the balance training program. A clinical examination was performed for each of the 2 experimental sessions to exclude subjects showing any possible cause of balance alteration (medication or disease). All subjects obtained more than 24 points in Mini-Mental State Examination, showing no cognitive impairments.[23] At the beginning of the study, the Independent Activity of Daily Living test showed that every subject could be considered independent in activities of daily living.[24]

### Procedure

Self-selected walking speed was assessed during a 10-m walk test.[25] Subjects were instructed to walk at their comfortable and preferred speed. Subjects began on the signal "ready, start." The investigator walked beside the patient and began timing with a digital stopwatch when the subject's first foot crossed the start line. Timing was stopped when the first foot crossed the stop line, although the patient continued to walk. The displacements of the COP were recorded during a 25.6-second unperturbed stance by a posturographic platform[a] at a sample rate of 40Hz.[26] The Satel software[a] calculated the temporal evolution of the COP displacements.

The subjects with arms hanging along the body as relaxed as possible placed their bare feet on the footprints (30° apart) of the posturographic platform. During the test under the EO condition or just before the test under the EC condition, the subjects had to stare at a spot placed 1.5m ahead. They were asked to keep as immobile as possible during the recordings. We insured the stability of the environmental conditions (no visual or auditive perturbations). The subjects were asked to perform 3 trials of bipedal stance maintained on the posturographic platform for each of the EO and EC conditions randomly for each visual condition.

**Table 1: Description of the Balance Training Program**

| | |
|---|---|
| Warm-up period (sitting in a chair) | 5 min |
| Send and receive a ball while sitting on a chair, standing, and walking | 10 min |
| Avoiding obstacle while walking | 10 min |
| Relaxation | 5 min |

### Training Program

The subjects trained in TC took part weekly in 2 sessions of 30-minute TC training for 3 months. The TC program performed in this investigation was that previously described by Wolf et al[15] and also used in other studies.[21,27] Briefly, it consists of learning a sequence of 10 TC forms specially adapted for the older people. This sequence of postures involves weight shifting movements that stress the postural balance. The physical therapist focuses the attention of the practitioner on the accuracy of posture reproduction. The 10-forms sequence was carried out under EO and EC conditions.

The subjects trained in balance training took part weekly in 2 sessions of 30 minutes of balance training for 3 months. This balance training program consists of practicing exercise that involves shifting of the body mass center (see description in table 1). The balance exercise included standing with a decreased base of support and also stressed postural balance (ie, during playful activities with a ball, during 1 leg standing exercises). Exercise included forward and sideways stepping, ascending and descending stairs, walking obstacle courses or on a foam floor, and reaching activities in standing (ie, small perturbations of balance were performed by a partner with backward and forward pushes). The exercises were realized, as much as possible, in the EO and EC conditions.

### Data Analysis

For walking and postural data, subjects performed 2 familiarization tests, and the analysis was performed on the third trial. Walking ability was quantified as the time necessary to perform a 10-m walk test and expressed as walking speed (m/s). Performance in postural maintenance was quantified by several parameters calculated by the Satela[a] and Matlab software[b] from the COP displacements—that is, the area covered by COP displacements ($mm^2$), path (mm), $V_{COP}$ (mm/s), and $V_{COP}$ variance (100 × SD [$V_{COP}$]/mean [$V_{COP}$] expressed in %). In order to explore the contribution of visual information during normal standing, we calculated for each parameter the ratio of EC to EO values expressed as the Romberg quotient. We calculated mean and SD of these parameters for each group and each session of the test.

### Statistics

Statistical analysis were performed with Statview software.[c] Data are expressed as mean ± SD. Changes in variables between pretraining and posttraining and between groups were analyzed. Repeated-measures analysis of variance was conducted for EO and EC conditions. When F analysis of variance values were significant, we performed a Tukey test to locate the

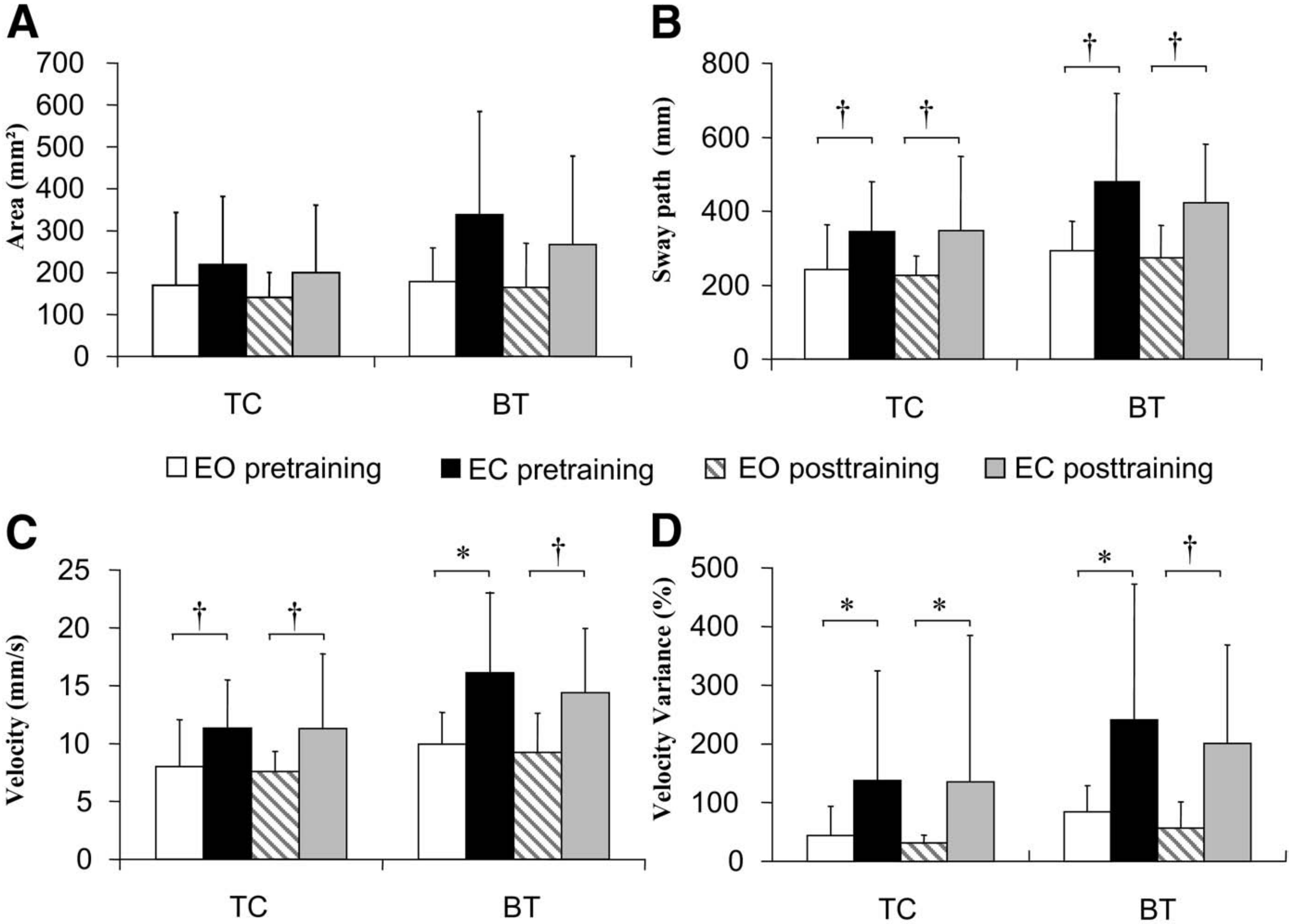


**Fig 1. Means and SDs of the sway parameters in eyes open and eyes closed conditions before (pretraining) and after (posttraining) a training period in TC or balance training (BT) exercises. (A) Area ($mm^2$); (B) sway path (mm); (C) $V_{COP}$ (mm/s); (D) $V_{COP}$ variance (%). Statistical significance was tested between the exercise and TC groups, between pretraining and posttraining sessions, and between EO and EC conditions for each group. Significant differences are indicated as follows: *$P$<.05; †$P$<.01.**

differences. We used a Mann-Whitney *U* test for across-group comparison. The differences were considered significant for *P* less than .05.

## RESULTS

First, we made sure that no significant differences were observed in pretraining between the TC and the balance training group for walking speed (1.07±0.26m/s for TC vs 1.09±0.23m/s for balance training) and postural parameters (fig 1). In posttraining sessions, we did not find significant differences between the TC and balance training groups for walking speed (1.06±0.23m/s for TC vs 1.07±0.24m/s for balance training) and postural parameters in the EC condition and in the EO condition. Nevertheless, trends of decrease in area (see fig 1A), path (see fig 1B), $V_{COP}$ (see fig 1C), and $V_{COP}$ variance (see fig 1D) of COP displacements were observed in both groups after the training period.

Results in the EO and EC conditions for postural sway did not change significantly between the two sessions of test for TC and balance training groups. However, differences between EC and EO performance, and the EC/EO ratio revealed the importance of visual inputs in control of the postural task. In pretraining, we found significant differences between the EC and EO conditions for each postural parameter in the TC and balance training groups except for area (see fig 1). In pretraining, postural sway was significantly higher in EC than in EO for sway path ($P$<.01 in the TC and balance training groups), $V_{COP}$ ($P$<.01 in the TC group and $P$<.05 in the balance training group), and $V_{COP}$ variance ($P$<.05 in the TC and balance training groups).

In posttraining, values of sway parameters obtained in the EC condition were still higher than in the EO condition; that is, for sway path, $V_{COP}$ ($P$<.01 in the TC and balance training groups) and $V_{COP}$ variance ($P$<.05 in the TC group and $P$<.01 in the balance training group).

Walking speed was not significantly different between pretraining and posttraining in the balance training and TC groups.

When analyzing the Romberg quotient for each subject group (table 2), we did not find significant changes between the pretraining and posttraining periods for the balance training and TC groups. We also did not find significant differences in pretraining between the balance training and TC groups for any postural sway parameters. However, in posttraining, the Romberg quotients were significantly different between the balance training group and the TC group for $V_{COP}$ ($P$<.05) and for velocity variance ($P$<.01). After training, the Romberg quo-

**Table 2: Romberg Quotient Expressed as EC/EO Ratios for Each Parameter and Each Subject**

| | Area ($mm^2$) | | | | $V_{COP}$ (mm/s) | | | | Path (mm) | | | | $V_{COP}$ Variance (%) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BT | | TC | | BT | | TC | | BT | | TC | | BT | | TC | |
| | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining | Pretraining | Posttraining |
| Mean | 1.91 | 1.59 | 1.70 | 1.25 | 1.56 | 1.65 | 1.57 | 1.30* | 1.54 | 1.55 | 1.54 | 1.34 | 2.87 | 3.15 | 2.32 | 1.80* |
| SD | 1.00 | 0.47 | 0.91 | 0.52 | 0.25 | 0.28 | 0.26 | 0.25 | 0.37 | 0.31 | 0.31 | 0.26 | 1.44 | 1.27 | 0.73 | 0.63 |

NOTE. Subjects engaged in a BT program or a TC program for 3 months were tested before (pretraining) and after (posttraining) their respective physical practice program. Means and SDs are reported for each group of subjects in pretraining and posttraining. No significant difference between pretraining and posttraining for TC and BT groups. Significant differences between the TC and BT groups were reported.
Abbreviation: BT, balance training.
*$P<.01$.

tient was 16.5% higher for velocity and 17.8% higher for velocity variance in the balance training group than the TC group. This can be explained by a nonsignificant decrease in the TC group and a nonsignificant increase in the balance training group for these parameters between pretest and posttest.

## DISCUSSION

The goal of our study was to identify specific improvements in postural abilities prompted by the TC program in comparison with a balance training program. The 12-week training period appeared not sufficient to produce differences between TC and balance training in upright standing control or in walking ability. Indeed, no significant differences have been shown after the TC and balance training groups in any postural parameters or in walking speed. In the present study and as expected, eye closure resulted in a significant increase in $V_{COP}$, sway path, and $V_{COP}$ variance compared with the EO condition. However, the posttraining Romberg quotient for $V_{COP}$ and $V_{COP}$ variance obtained in the 2 groups (which did not significantly differ from the pretraining value) appeared to be significantly different between the TC group and the balance training group.

We did not find any significant modifications of postural parameters and walking speed in either group. However, the trend toward a decrease in postural parameters and maintenance of walking speed could reflect the beneficial influence of the training periods in older people. Indeed, in the absence of training, aging leads to greater postural sway and lower walking speeds.[1,5,12] However, given the lack of a sedentary control group, we cannot draw conclusions about such improvement. Posturographic parameters and gait velocity are not sensitive enough to report changes after 12 weeks of balance training and TC programs. Our study is inconsistent with previous studies, which have shown significant effects of short-term TC training (for about 3 months) on postural control.[16,20,21] Improvements in static postural control after 8 or 12 weeks of a TC program were very often found compared with a control group. In other studies, the short-term effects of TC in older subjects were recorded with clinical tests,[21] under more challenging conditions,[28] or after a more intensive program (6 times a week for 4 or 8 weeks).[29] No significant enhancement of posturographic parameters was reported previously after TC training. Our subjects were also physically active; the 2 balance training programs did not enhance their baseline ability in static postural control and walking speed. There can be several reasons for this–for example, insufficient length or frequency of exercise. Indeed, beneficial effects on posturographic parameters were described in subjects who regularly practiced proprioceptive physical activity.[13]

The main finding of our study in favor of TC practice versus balance training practice is that the Romberg quotient was higher after the balance training program than the TC program. The significant differences in EC/EO ratios observed between the balance training and TC groups can be explained by concomitant opposite trends in adaptation to visual information loss. Degradation of the Romberg quotient was reported with aging[7] and could explain a trend to increase in balance training. When visual information is removed, an increase in postural sway reveals the difficulty to be faced and the need to modify the relative weight of sensory inputs. This increase under the EC condition is accentuated with aging because of an increase in visual dependency. The significantly higher posttraining Romberg quotient for $V_{COP}$ and $V_{COP}$ variance in the balance training group (in comparison with the TC group) might argue in favor of TC training. It is interesting to note that Romberg quotient differences are not observed in terms of a postural system's performance (COP stabilization expressed by the area and sway) but appear in terms of a postural system's control (COP displacement expressed by the $V_{COP}$ and the $V_{COP}$'s variance).

Our description of TC prompts a hypothesis explaining the reason for such differences. Balance training and TC programs involve the postural system by COP displacement. Balance training and TC practitioners were encouraged to perform exercise with EC. With the deletion of visual feedback during movement, movement was controlled with proprioceptive inputs in order to reproduce articular angles and positions in space. However, in contrast with the balance training program, we assume that TC practice was more focused on accurate reproduction of movements and forms. Moreover, improvements in sensory information processing after short-term TC practice[16,17] have been observed. In the absence of visual information, TC practitioners were able to reproduce joint movements more accurately than sedentary or physically active subjects. Also, TC practitioners have shown smaller COP displacements in EC after vestibular stimulation compared with a control group.[30] The improvement of proprioception described in these previous studies could explain the stabilization or the slightly decreased trend in Romberg quotient after 3 months of practice in the TC group. To conclude, TC might be helpful to maintain or improve the proprioception threshold for perceiving body sway oscillation when this might deteriorate with aging in spite of a balance training program. Indeed, a TC program requiring the accurate reproduction of movements appeared more appropriate in decreasing the impact of visual dependency on postural control.

Hypothesis of a reweighting of proprioceptive inputs after TC practice will require further study in order to verify whether TC specifically helps practitioners perform better under EC conditions by limiting visual dependency after 12 weeks of practice. However, studies under more challenging postural conditions (ie, single leg stance) should be performed to verify this specific effect of TC training on postural control and its interest in older people daily living.

## CONCLUSIONS

Results of our study demonstrated similar effects of 12-week TC and balance training programs on postural control or walking ability in older people. None of the outcome measures showed significant change posttraining in the TC or balance training groups. However, compared with TC, the EO/EC ratio expressed as a Romberg quotient was significantly higher after the balance training program, suggesting that TC should be helpful to limit the eye closure effects on postural control. We thus hypothesize that a TC program might limit the deleterious effects of aging on sway perception in the absence of visual information compared with a balance training program.

**Acknowledgments:** We thank Mora Isabelle, PhD, and the staff of the involved department for their participation (Service d'Exploration Fonctionnelle de l'Appareil Locomoteur; Centre Hospitalier Universitaire Amiens-Nord; Faculté des Sciences du Sports; Université de Picardie Jules Verne and Centre Communal d'Action Sociale d'Amiens).

### References

1. Maki BE, McIlroy WE. Postural control in the older adult. Clin Geriatr Med 1996;12:635-58.
2. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. N Engl J Med 1988;319:1701-7.
3. Pyykko I, Jäntti P, Aalto H. Postural control in elderly subjects. Age Ageing 1990;19:215-21.
4. Baloh RW, Jacobson KM, Enrietto JA, Corona S, Honrubia V. Balance disorders in older persons: quantification with posturography. Otolaryngol Head Neck Surg 1998;119:89-92.
5. Era P, Heikkinen E, Gause-Nilsson I, Schroll M. Postural balance in elderly people: changes over a five-year follow-up and its predictive value for survival. Aging Clin Exp Res 2002; 14:37-46.
6. Fitzpatrick R, McCloskey DI. Proprioceptive, visual and vestibular thresholds for the perception of sway during standing in humans. J Physiol 1994;478(Pt 1):173-86.
7. Lord SR, Menz HB. Visual contributions to postural stability in older adults. Gerontology 2000;46:306-10.
8. Perrin PP, Jeandel C, Perrin CA, Bene MC. Influence of visual control, conduction, and central integration on static and dynamic balance in healthy older adults. Gerontology 1997;43: 223-31.
9. Skinner HB, Barrack RL, Cook SD. Age-related decline in proprioception. Clin Orthop Relat Res 1984;(184):208-11.
10. Stelmach GE, Worringham CJ. Sensorimotor deficits related to postural stability. Implications for falling in the elderly. Clin Geriatr Med 1985;1:679-94.
11. Lord SR, Clark RD, Webster IW. Postural stability and associated physiological factors in a population of aged persons. J Gerontol 1991;46:M69-76.
12. Murray MP, Kory RC, Clarkson BH. Walking patterns in healthy old men. J Gerontol 1969;24:169-78.
13. Gauchard GC, Gangloff P, Jeandel C, Perrin PP. Influence of regular proprioceptive and bioenergetic physical activities on balance control in elderly women. J Gerontol A Biol Sci Med Sci 2003;58:M846-50.
14. Gauchard GC, Jeandel C, Tessier A, Perrin PP. Beneficial effect of proprioceptive physical activities on balance control in elderly human subjects. Neurosci Lett 1999;273:81-4.
15. Wolf SL, Coogler C, Xu T. Exploring the basis for Tai Chi Chuan as a therapeutic exercise approach. Arch Phys Med Rehabil 1997; 78:886-92.
16. Jacobson BH, Chen HC, Cashel C, Guerrero L. The effect of T'ai Chi Chuan training on balance, kinesthetic sense, and strength. Percept Mot Skills 1997;84:27-33.
17. Tsang WW, Hui-Chan CW. Effects of tai chi on joint proprioception and stability limits in elderly subjects. Med Sci Sports Exerc 2003;35:1962-71.
18. Tsang WW, Hui-Chan CW. Effects of exercise on joint sense and balance in elderly men: Tai Chi versus golf. Med Sci Sports Exerc 2004;36:658-67.
19. Wu G. Evaluation of the effectiveness of Tai Chi for improving balance and preventing falls in the older population—a review. J Am Geriatr Soc 2002;50:746-54.
20. Hain TC, Fuller L, Weil L, Kotsias J. Effects of T'ai Chi on balance. Arch Otolaryngol Head Neck Surg 1999;125:1191-5.
21. Taggart HM. Effects of Tai Chi exercise on balance, functional mobility, and fear of falling among older women. Appl Nurs Res 2002;15:235-42.
22. Voorrips LE, Ravelli AC, Dongelmans PC, Deurenberg P, Van Staveren WA. A physical activity questionnaire for the elderly. Med Sci Sports Exerc 1991;23:974-9.
23. Folstein MF, Folstein SE, McHugh PR. "Mini-Mental State": a practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189-98.
24. Katz S, Downs TD, Cash HR, Grotz RC. Progress in development of the index of ADL. Gerontologist 1970;10:20-30.

25. Duncan G, Wilson JA, MacLennan WJ, Lewis S. Clinical correlates of sway in elderly people living at home. Gerontology 1992;38:160-6.
26. Bizzo G, Guillet N, Patat A, Gagey PM. Specifications for building a vertical force platform designed for clinical stabilometry. Med Biol Eng Comput 1985;23:474-6.
27. Wong AM, Lin YC, Chou SW, Tang FT, Wong PY. Coordination exercise and postural stability in elderly people: effect of Tai Chi Chuan. Arch Phys Med Rehabil 2001;82:608-12.
28. Mak MK, Ng PL. Mediolateral sway in single-leg stance is the best discriminator of balance performance for Tai-Chi practitioners. Arch Phys Med Rehabil 2003;84:683-6.
29. 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;36:648-57.
30. Tsang WW, Hui-Chan CW. Standing balance after vestibular stimulation in Tai Chi-practicing and nonpracticing healthy older adults. Arch Phys Med Rehabil 2006;87:546-53.

## Suppliers

a. Satel, 6 rue du Limousin, 31700 Blagnac, France.
b. Matlab, 3 Apple Hill Dr, Natick, MA 01760.
c. SAS Institute Inc, SAS Campus Dr, Cary, NC 27513.