A review of Tai Chi Chuan and parameters related to balance

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Abstract

Introduction: Previous systematic reviews of the literature on the effects of Tai Chi Chuan (TCC) on balance have focussed either on determining the quality of the research design or have provided just a general description of the studies. To the best of our knowledge none have approached this topic by conducting an analysis from the point of view of the factors which affect balance. It is important to present this perspective as it will help to guide future research in this field.
Methodology: Seven electronic data bases were searched for publications dated between 1996 and 2012. The inclusion criteria were; randomized controlled trials (RCT) written in English.
Results: From a total of 397 articles identified, 27 randomized controlled trials were eligible for the analysis.
Conclusions: Studies reviewed appear to confirm that TCC improves static and dynamic balance and in the functional factors which affect balance in persons of over 55 years of age. Only one study was identified on people affected with problems with the vestibular system. No studies on the influence of TCC on improvement in balance in individuals suffering from deteriorated brain function were identified.

Keywords: Elderly people; Vestibular system; Visual system; Proprioceptive system; Tai Chi Chuan; Balance

Introduction

For people over 65 years of age, falls represent a serious problem leading to both the loss in quality of life and to the expense to public health care systems resulting from treatment [1]. One of the main factors associated with falls in elderly people is the deterioration in balance control which occurs, due to the degeneration of the brain function, proprioceptive and motor systems – which is clearly manifested in their reduced walking speed and stride length [2].

Among the physical activity and sports programmes which are used to improve balance in the elderly, Tai Chi Chuan (TCC) has become the focus research internationally. TCC is a physical activity for health originating as we know it today, in the 17th Century in China. With time different schools or styles have been created, the most important being Chen, Yang, Wu, Hao and Sun. This activity consists in a kind of choreography performed with slow but continuous, circular and fluid movements, postural alignment and relaxed body, with trunk rotations around the hips and body weight changes from one leg to the other in different directions (forward–backwards, laterally or a combination), patterns that some authors naturally associate with an improvement in the balance of the participants [3]. TCC has been recommended in health programmes for its calm non-competitive nature, the fact that it does not need special equipment, because practice time and place can be very flexible and because people of all ages can participate [4].

Although review articles can be found in the literature on the effects of Tai Chi Chuan on balance [5–10], these have focused on providing systematic reviews to determine the quality of the research design used in the studies analyzed or have been limited to simple general descriptions of the studies. To our knowledge no study has approached this topic by analyzing these papers from the point of view of the factors which affect balance (static and dynamic balance, and physiological systems which influence it: vestibular, proprioceptive, visual and cerebral). This aspect is important in order to inform guidance for future research in this area.

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Methods

Search strategy and exclusion process

Seven electronic data bases were used: Medline-Pubmed, Scirus, Cochrane, Pascal, ScienceDirect, SportDiscuss, Science Citation Index and BIOSIS using as key words Tai Chi, Tai Chi Chuan, T′ai Chi, Taiji, Tai Ji Quan, balance and biomechanics. The search focussed on publications dated between 1996 and 2012 and excluded studies which were not published in English, were not randomized controlled trials, or were abstracts, posters, or summaries from congresses. From a total of 397 articles found, 27 randomized controlled trials were selected following the above mentioned criteria.

Data extraction and analysis

The articles found were classified in two domains: (a) studies which include balance as an additional factor in their research, and (b) original studies which analyzed balance from a functional point of view. In this second division the studies were differentiated according to whether they focussed on analyzing balance from a vestibular, proprioceptive or visual viewpoint.

Results

Twenty seven RCT were identified and analyzed with regard to balance (see Table 1).

These studies were carried out between 1996 and 2012 in different countries: USA (14), China (10), Australia (2) and France (1). The TCC styles used were: (a) Yang in simplified versions of 5, 8, 9, 10, 12 and 24 movements (18 studies) and only 1 used the traditional system of 108 movements, (b) Chen (1 study), (c) Sun (1 study) and (d) NG (1 study). The duration of the interventions oscillated between 3 weeks and 4 years. The mean for the frequency of the classes was 2–3 times per week and the duration of the session 1 h.

From these studies, 13 out of 19 which analyzed this item found that TCC caused significant improvements in static balance [3,11,12,18–20,22,24,25,30,31,33,35], 14 out of 16 in dynamic balance [3,4,13,14,19–21,23–26,29–31] 5 out of 7 in the proprioceptive system [3,21,29,31,34], 4 out of 5 in the vestibular system [21,27,28,31], 2 out of 3 in the visual system [27,31], none of them analyzed the influence of deteriorated brain function and only 4 studies [15–17,32] did not find significant improvements in any parameter.

Table 2 shows the diversity of instruments used to evaluate data on static and dynamic balance; and the proprioceptive, vestibular and visual systems:

The framework which includes studies related to balance can be classified in two sections:

(A) Studies which include balance as secondary outcome factor in their research

This section includes the studies in which general balance tests are administered together with the analysis of other parameters which affect health, without going into the sensory motor aspects of balance in depth. Among these studies Audette et al. [11], Barnett et al. [12], Li et al. [18], Qin et al. [22], Taylor-Piliae et al. [24]; Taylor-Piliae and Coull [25] and Yan [4] confirmed significant improvements, and only Hartman et al. [16] found none.

In the studies which consider balance in the elderly from a general point of view, some authors like Wong et al. [31] and Yan [4], feel that priority should be given to dynamic balance over static balance, because it implies greater difficulty to integrate the sensory motor information and requires better coordination of the body segments coinciding with the demands of the activities of daily living which the elderly have to perform (walking, going up and down stairs, etc.), and has a closer relation with falls. However, many authors [11,12,22] have concentrated their research on improvements in static balance ignoring these recommendations.

(A) Original studies which analyze balance from a functional point of view

This section includes the interventions which study this problem by analyzing in depth the sensory motor aspects of balance. Wong et al. [31] distinguish two types of basic strategies for recovering balance control: (a) proactive ones which are the body adjustments which happen before the destabilizing forces which are directly associated with walking; and (b) reactive strategies which are applied afterwards. Proprioceptive, visual and vestibular information is fundamental in both aspects and has become the focus of study in the different research projects which analyze the benefits of TCC for balance.

- *Proprioception* concerns the bodily awareness of the person in space, the position of their joints, their movement and their acceleration [36].

Five of the studies analyzed in this paper confirm that TCC produces an improvement in the proprioceptive system of its practitioners [3,21,29,31,34] while two did not find significant improvements [27,32]. The length of time that the subject has practised seems to be of great importance to achieve these improvements. In particular a long experience of 2–20 years [31] and 4 or more years [34] revealed a better reflex action in the lower limbs to compensate balance and a higher level of proprioception in the knee and ankle. However, Tsang et al. [27] found that although the practitioners with more than 1 year of practice improved their visual and vestibular systems they did not show improvement in their proprioceptive system, and Woo et al. [32] found that an intervention of 12 weeks (3 times per week) was still not sufficient to improve this aspect.

Among the studies on proprioception and fall prevention, special mention should be given to the results obtained with regard to improvements in proprioception and strength in the ankle joint in people who practised TCC. It has been found that the negative changes which appear with ageing and foment falls in the elderly, include the lack of muscle strength in the ankle joint and the lesser use of the somatosensorial information

Table 1
Studies which analyze the benefits of TCC for balance.

Studies	Design	Country	*n*	Sex	Age	TCC style and no. of movements	Duration-frequency
Audette et al. [11]	RCT	USA	11	m–w?	71.5 years (±4.6)	Yang 10	12 weeks (3t/w – 1 h/s)
Barnett et al. [12]	RCT	Australia	83	25 m 58 w	74.4 years (±4.9)	?	1 year (t/s? – 1 h/s)
Gatts and Woollacott [13]	RCT	USA	11	1 m 10 w	77.5 years	Yang 12	3 weeks (5t/w – 1.5 h/s)
Gyllensten et al. [3]	RCT	China	24	m–w?	68.5 years (±6.6)	Yang 24	3 years (3t/w – 1 h/s)
Hackney and Earhart [14]	RCT	USA	13	11 m 2 w	64.9 years (±8.3)	Yang 12	13 weeks (2t/w – 1 h/s)
Hall et al. [15]	RCT	USA	8	m–w?	72.2 years (±7.7)	Yang 24	12 weeks (2t/w – 1.5 h/s)
Hartman et al. [16]	RCT	USA	18	3 m 15 w	68.6 years (±7.9)	Yang 9	12 weeks (2t/w–1 h/s)
Lelard et al. [17]	RCT	France	14	m–w?	76.8 years (±5.1)	? 12	12 weeks (t/w?– 30 min/s)
Li et al. [18]	RCT	USA	62	10 m 52 w	75.3 years (±7.8)	Yang 8	24 weeks (3 t/w – 1 h/s)
Li et al. [19]	RCT	USA	65	45 m 20 w	68 years (±9)	? 6	24 weeks (2t/w– 1 h/s)
Mark and Ling [20]	RCT	China	19	m–w?	61.8 years (±4.7)	Yang 24	1 year (3t/w – 30/45 min/s)
McGibbon et al. [21]	RCT	USA	19	m–w?	61.7 years (±11.3)	Yang 5	10 weeks (1t/w – 70 min/s)
Qin et al. [22]	RCT	China	48	0 m 48 w	55.8 years (±3.5)	?	+3 years (t/w? – 3 h/s)
Ramachandran et al. [23]	RCT	USA	15	8 m 7 w	45.7 years (±10.6)	Chen (?)	?
Taylor and Coull [24]	RCT	USA	16	10 m 6 w	72.8 years (±10.1)	Yang 24	12 weeks (3t/w – 1 h/s)
Taylor et al. [25]	RCT	USA	37	13 m 24 w	70.6 years (±5.9)	Yang 24	24 weeks (t/w? – 45 min/s)
Thorton et al. [26]	RCT	China	17	0 m 17 w	47.2 years (±4.07)	Yang 108	12 weeks (3t/w – 1 h/s)
Tsang et al. [27]	RCT	China	20	10 m 10 w	70.7 years (±5.1)	NG?	1 year (2t/w – 1 h/s)
Tsang and Hui-Chan [28]	RCT	China	24	12 m 12 w	69.3 years (±5.0)	?	4 weeks (t/w? – h/s?)
Voukelatos et al. [29]	RCT	Australia	347	52 m 295 w	69 years (±6.5)	Sun y Yang	16 weeks (1t/w – 1 h/s)
Wolfson et al. [30]	RCT	USA	100	64 m 36 w	+75 years	Yang?	24 weeks (1t/w – 1 h/s)
Wong et al. [31]	RCT	China	25	1 m 6 w	66.4 years (±9)	?	–
			17	6 m 11 w	69.9 years (±4.5)		
Woo et al. [32]	RCT	China	30	m–w?	68.2 years (±2.4)	Yang 24	1 year (3t/w – h/s?)
Wu et al. [33]	RCT	USA	64	m–w?	+65 years	Yang 24	15 weeks (3t/w – 1 h/s)
Xu et al. [34]	RCT	China	21	12 m 9 w	66.1 years (±5.2)	?	4 years (7t/w – 1.5 h/s)
Yan [4]	RCT	USA	28	m–w?	78.8 years	Yang 24	8 weeks (3t/w – 45 min/s)
Zhang et al. [35]	RCT	China	24	12 m 12 w	70.2 years (±3.6)	Yang 24	8 weeks (7t/w – 1 h/s)

Note: RCT, randomized controlled trials; t/w, times per week; h/s, hours per session; min/s, minutes per session; m, men; w, women; ?, unknown.

Table 2
Instruments used to evaluate balance in the studies.

Parameters	Measuring instruments	Authors
Balance in general	Balance platforms	Mark and Ling [20]; Voukelatos et al. [29]; Wu et al. [33]; Yan [4]
	Posturographic platforms	Gyllensten et al. [3]; Lelard et al. [17]; Li et al. [19]; Xu, Hong and Chan [34]
	Video cameras	Gatts and Woollacott [13]; Ramachandran et al. [23]

Parameters	Clinical test	Authors
Static balance	Single-leg stance test (OLS)	Audette et al. [11]; Barnett et al. [12]; Hackney and Earhart [14]; Hartman et al. [16]; Li et al. [18]; Qin et al. [22]; Taylor-Piliae and Coull [24]; Taylor-Piliae et al. [25]; Wolfson et al. [30]; Woo et al. [32]; Wu et al. [33]; Zhang et al. [35]
Dynamic balance	6, 8, 10 or 50 m walking speed test	Hackney and Earhart [14]; Hartman et al. [16]; Lelard et al. [17]; Li et al. [18]; Li et al. [19]; Mark and Ling [20]; McGibbon et al. [21]; Taylor-Piliae and Coull [24]; Woo et al. [32]; Zhang et al. [35]
	Berg Balance Scale (BBS)	Gatts and Woollacott [13]; Hackney and Earhart [14]
	Functional Reach Test (FRT)	Gatts and Woollacott [13]; Li et al. [19]; Mark and Ling [20]; Taylor-Piliae et al. [25]; Thorton et al. [26]
	Single-leg jumping test	Gyllensten et al. [3]; Hall et al. [15]
Proprioceptive, vestibular and visual systems	Sensory Organization Test (SOT)	Hall et al. [15]; Tsang et al. [27]; Tsang and Hui-Chan [28]; Wolfson et al. [30]; Wong et al. [31]; Woo et al. [32]
	Body Awareness Scale-Health (BAS-H)	Gyllensten et al. [3]
	Activities-Specific Balance Confidence Score	Wu et al. [33]

received from the feet [34]. In fact, to control postural stability, the elderly rely more on compensatory movements from the hips (in contrast to young people who use the ankle more), which negatively affects the biomechanics of the trunk during walking thus compromising balance [21].

Xu, Hong and Chan [34] found that elderly people who regularly practise TCC have better proprioception in the ankle than sedentary elderly, or elderly swimmers or runners and McGibbon et al. [21] found that 10 weeks of practice were sufficient to increase the biomechanical contribution of the ankle to walking and to reduce the dependency on compensatory movements of the hip, improving speed and stride length during walking. These results confirm that TCC as well as favouring balance and preventing falls, in a certain sense "rejuvenates" the elderly helping them to again take somatosensory information from the ankle as they did when they were young.

- The *vestibular system* represents another of the fundamental components for maintaining balance and is closely related to head movements, especially when these are done quickly. Tsang and Hui-Chan [28] defend the importance of working on the vestibular system in the elderly, because in difficult situations like lack of vision, this system becomes a fundamental reference for avoiding falls, although the natural deterioration of this system with age can become a handicap.

Four of the studies analyzed confirm that the practice of TCC produces an improvement in the use of the vestibular system for controlling balance [21,27,28,31] while one found no significant improvement [32].

As with the previously mentioned system, the length of time devoted to practising seems to be of great importance for obtaining these improvements. In particular, long experience of more than 1 year [27], more than 2 years [28] and more than 3 years [31] produced significant improvements at the vestibular level. Tsang et al. [27] also confirmed that these improvements placed these elderly subjects in an equivalent situation with regard to their ability to control their balance to the young population when faced with difficult situations of a visual, vestibular and somatosensorial nature.

With regard to the results obtained, it should be underlined that most of the studies mentioned did not contain patients with specific vestibular problems in their samples. The only study which included patients with this pathology (bilateral and unilateral) was the one by McGibbon et al. [21], and these authors confirmed a very interesting improvement, as it compared the practice of TCC with a control group who performed a programme of specific exercises for vestibular rehabilitation.

- The *visual system* is another of the key factors in postural control in the elderly, because it helps to compensate for the degeneration of the vestibular system [17]. Of the studies analyzed, only 3 make specific mention of the measurement of this parameter and of these 2, Tsang et al. [27] and Wong et al. [31] confirmed a significant improvement and 1, Woo et al. [32], did not.
- No study was identified which analyzed the effects of TCC on people with balance problems due to deterioration in *brain function*.

Discussion

Although the reviews on TCC and balance have either concentrated on analyzing the research design using systematic review instruments [8–10], or have simply offered a general description of the characteristics of the studies [5–7], none has been found that has classified and described the studies according to the influence of TCC on the static and dynamic component of balance; on the physiological systems which support balance, or that has described the measurement instruments used. Furthermore the number of randomized controlled trials included in the present paper (27) is higher than previous review studies found on this topic.

It has to be underlined that most of the studies analyzed confirmed a positive effect of TCC practice on the static and dynamic balance of the practitioners aged over 55, whereas the review studies showed divergence with regards to the possible benefits. However, this contradiction is easier to understand when observing that the original studies used different styles and forms, application rates, sample sizes, and measuring instruments, which make it difficult to perform a meta-analysis. That is why the majority of reviews choose to focus on evaluating the quality of the methodological design of the research undertaken. The same fact could also be observed in other systematic reviews and meta-analyses which looked at the benefits of this activity for other health aspects [37–41].

Most of the analyzed studies do not comment on the causes which are behind this effect, leading us to understand that it is simply the result of the improvement in the proprioceptive, vestibular and visual system. Nevertheless, with regards to teaching this activity, it is important to have practical clues for arranging the exercises and the execution of the form in order to get the highest benefits relative to balance. The research field of biomechanics can provide some answers for this purpose [42].

Wu and Hitt [43] state that the biomechanical characteristics of the contact of the foot with the ground can offer very important information on how to understand the improvement in movement control, and thus in balance and stability thanks to the practice of TCC. From the viewpoint of this discipline it is considered that the improvement in balance has a close relation with the constant change of weight which occurs during the movement and which alternates between weight bearing on both legs to weight bearing on a single leg; an action which constantly challenges the system of balance control to maintain the centre of mass within the base of support.

In particular, studies have focussed on analyzing walking performance, movement patterns to overcome obstacles, weight distribution on the soles of the feet and the transfer of the centre of gravity [24,28,43–47], although there are other papers which have been directed at analyzing how different pathologies like arthritis, muscle strength in the lower limbs or flexibility affect balance [43,47–50]. In these studies significant improvements have been found due to the practice of TCC in stride length, in

directional control; increase in backward movements (3.1 cm) of the centre of pressure of the foot (COP) in the initial contact of the heel with the ground and improving the smoothness in the movement of the centre of mass during performance, an equal distribution of weight between the fore and rear regions of the foot, a longer step in the direction of the medial lateral in the COP of the foot, and how the COP of the foot is located in the mid-foot region, especially during the single stance phase.

Another aspect which is not included in most of the original studies on TCC and balance is to offer information on the specific parameters which are taken into account in the intervention protocols. This information would help to gain more insights into the effects of TCC practice on balance and would facilitate the making comparative studies.

Taking as a reference the work by Wayne and Kaptchuk [51], when analyzing the effects of TCC on balance in the studies, there are a series of parameters which could be borne in mind:

Tai Chi Chuan styles and forms

There are five main schools or styles of TCC: Chen, Yang, Wu, Hao and Sun, with considerable difference between the Chen style and the rest as regards performance. The Yang, Wu, Hao and Sun styles consist of slow continuous circular movements, while the Chen style, more close to the martial art concept, has lower positions, changing rhythms with explosive movements and even jumps, and considerable emphasis on joint rotation [41,52]. Although each style originally has one or two traditional forms, with time variation and simplifications have evolved into what are known as modern or simplified styles. For example, in comparison with the 108 movements in the Yang style, there are currently official variants which are popularly practised worldwide with 13, 24, 42, 88 or 108 movements. Furthermore, this evolution continues to increase its complexity when, from the health research viewpoint, different authors have created new forms based on the traditional styles to adapt practice to the needs of the patients in terms of their pathologies (the "Moving for better balance" form of 8 movements [53], STEP [52] or el Tai Chi Qigong (TCQ) [54]).

Posture height and speed of execution

In TCC there are three posture heights for performing the movements: high, medium and low, and once chosen, all the forms should maintain it. In fact, many authors have related height to the intensity of the activity. With a low posture and slow pace of foot movement and when the posture cannot be raised, there is a greater demand for balance on the part of the practitioner. In addition, it is considered that the slower the execution, the greater the difficulties for maintaining balance and the greater the activation of the leg muscles [44,49].

Movement pattern

It is important to quantify the movements in TCC to be able to better understand the effects of this activity on balance [45,55]. Chau and Mao [56] propose two criteria for this parameter: postures adopted and direction of movement.

Adherence

Normally longer experience practising the activity and a higher level of performance have been related to greater benefits for health with regard to TCC practice. However, the level of performance or mastery of the activity is not always associated with the length of time it has been practised. According to Tsai et al. [57] the duration of practise (minutes of training) is a better indicator of TCC benefits than the level of mastery.

Design of the session

In some studies with TCC different parts of the session are listed (warm up, forms and cool down), the time devoted to each one and the number of repetitions which are made of the TCC form taught [58–62]. However, the type of exercises included in each part are not usually specified, an important fact because perhaps some of the benefits associated with the practice of TCC may be due to the type of exercises developed in these complementary activities.

Experience of the instructors and teaching methodology

The number of years of experience, the number of instructors and the ratio per student, and the specific training of the teachers with regard to the form they are going to teach, are aspects which have been considered important by some authors because of their possible influence on the research results [54,60,63,64]. The time necessary for the students to learn the form can also be important [54,58,60], together with the progressive increase in practice time during the intervention [5,65]; the number of postures taught in each session [57]; the type of attention which the participants receive from the instructors during the intervention [54,58,60,63,64]; or the modifications made to the form with regard to the needs of the participants [62].

Further research is needed to examine how TCC practice influences the improvement of the functions of the proprioceptive, vestibular and visual systems during balance control and to study the relative impact of each one of them. Furthermore, more investigation is necessary to determine the length of time and minimal application rate required to provide the mentioned benefits. And also the level of benefits with regard to balance should be tested among different age groups and study populations should also include elderly people suffering from different pathologies in terms of balance.

Conclusion

The framework of the studies related to TCC and balance can be classified in two categories: (A) studies which include balance as an additional factor in the research and (B) specific studies which analyze balance from a functional point of view, including the analysis of its effects on the proprioceptive, vestibular and visual systems.

Although the results of the studies seem to confirm the improvement in static and dynamic balance and in the functional factors which affect balance in persons of over 55 years, the number of studies carried out regarding the latter criterion is still very scarce. In fact, in the case of the effects of TCC on the vestibular system only one study has been found with persons affected with problems in this area, and studies on the influence of TCC on the improvement of balance in individuals suffering from deteriorated brain function have not been found.

In order to be able to better evaluate the effects of TCC practice on balance, establishing comparative analyses of different styles and forms and acquiring strategies in the teaching of the activity, it would be of great importance to include information on the specific parameters taken into account when designing the intervention protocols.

From the biomechanical viewpoint important research is being done on the characteristics of movement, weight distribution on the soles of the feet, the transfer of the centre of mass and even the movement patterns for overcoming obstacles which help to better understand the causes which contribute to the positive effects of TCC with regard to balance.

Lastly, it should be emphasized within the limitations of this study that the number of articles found, and the criteria used for the search and selection of articles may have caused some more appropriate analysis parameter or measuring instrument to be ignored.

Conflict of interest

All authors state that there are not any conflicts of interest.

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