Using Tai Chi to Promote Balance and Prevent Falls – A Review from an Epidemiological Perspective

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Citation

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Abstract

Falls among older people constitute a serious public health problem. Exercise, specifically, Tai Chi was proposed as one of the preventive practices for falls and related injures. We reviewed existing observational and experimental studies and looked from an epidemiological perspective into the strength of the evidence for Tai Chi promoting balance and preventing falls. Many limitations were found in the research methodology of these studies and have been discussed in this review. Future studies should focus on how to address these limitations and improve their validity, hence contribute more convincing evidence on the effect of Tai Chi for balance and fall prevention.

INTRODUCTION

Falls among older people constitute a serious public health problem. It is estimated that one out of three adults over age 65 falls each year.[1] Moreover, among these older fallers, at least 20% suffer moderate to severe injuries that result in dependence and immobility, and even early death.[2,3] As the aging population continues to grow in many developed and developing countries,[4] the problem of falls among older people is expected to increase significantly worldwide.

The National Center for Injury Prevention and Control provides older adults a list of recommendations,[5] including a regular exercise program, to reduce their risk of falls. In addition, in the guideline of the Registered Nurses Association of Ontario, Tai Chi, an ancient Chinese therapeutic exercise, was proposed as one of the preventive practices for falls and related injures.[6] The recommendations and the guideline are based on positive results reported from many studies aiming to establish a causal association between Tai Chi, balance improvement and fall prevention. However, after reviewing the literature, Wu G[7] found that the study results with respect to the effectiveness of Tai Ch on balance and fall prevention were inconsistent. He attributed the conflicting findings in the studies to wide variations in the use of balance measures, subject population, and type and duration of Tai Chi exercise. Nonetheless, the potential methodological limitations of these studies have not been systematically discussed. Because of potential flaws in the research methods, the statistical association between Tai Chi and its effect on balance improvement and fall prevention established in these studies could arise through chance, through bias, or confounding, and, do not indicate a causal relation. As a result, the findings in these studies may be erroneous or distorted and the evidence for the benefits of Tai Chi may not be convincing.

In this paper, we reviewed existing literature and looked from an epidemiological perspective into the strength of the evidence for Tai Chi promoting balance and preventing falls. We examined the research methodology of these studies, and specifically, study designs, study samples and interventions of these studies. This is crucial because only well-designed studies yield valid and convincing evidence. The validity of a study mainly concerns internal validity and external validity. External validity is defined as the degree to which the results of an investigation on the benefit of Tai Chi on balance improvement and fall reduction can be generalized to other samples or situations. The internal validity refers to the extent to which observed improvement in balance or reduction of falls can be correctly inferred to be caused by Tai Chi practice, and not by other possible causes or alternative explanations. Thus, the internal validity is the primary concern for any study that is looking into the benefits of Tai Chi. For a poorly designed study, there are many threats to its internal validity. As a result, alternative explanations for observed improvement in balance become more credible, and the evidence for the benefits of Tai Chi become less convincing. We will explain these threats in

more detail throughout this article.

In this review, we focused on studies designed to assess the effectiveness of Tai Chi for balance improvement and fall reduction. However, the research methodology issue discussed is not limited to this specific context. Thus this review could be used as a general guide to examine the methodological quality of studies aiming to establish causality between Tai Chi and other health outcomes, such as cardiovascular, psychological, immunological and musculoskeletal health. In addition, this review can help readers to examine the claims made about the findings obtained from a study, and to understand the common pitfalls and errors of studies related to Tai Chi. Lastly, the review identifies priorities for strengthening the evidence base for future investigation of Tai Chi.

METHODS

Before the literature search, the authors decided the criteria for considering studies for this review include: 1) the publications are in English, 2) publication year is between 1966 and 2004, 3) one of the study variables is Tai Chi, 4) the study design is cross-sectional, case-control, cohort, quasi-experiment or randomized controlled trial (RCT), 5) outcome measures include but are not limited to self-report of changes in balance control, functional balance measures, laboratory-based balance measures and direct measures of falls.

Using key words "Taiji" or "Tai Chi" or "T'ai Chi", the authors performed a Medline search via OVID in April 2005, and found 187 articles. The abstracts and full article (when necessary) of these studies were screened independently by the authors. After reading the abstract, 29 studies [8910111213141516171819202122232425262728293031323334353 6] were included in this review because a majority of authors agreed they met the inclusion criteria.

Two authors (JL and SL) then classified the studies according to their study design. The research methodology of these studies was examined from three major aspects, study designs, study samples and interventions.

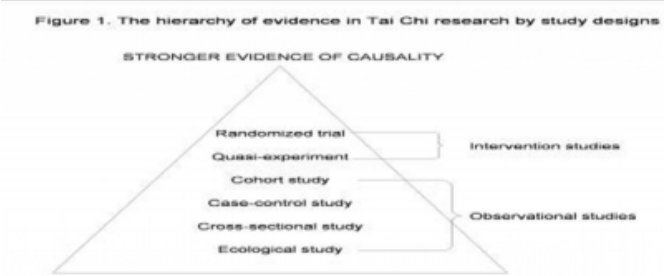
Any discrepancies between the authors were identified and reconciled.

RESULTS AND DISCUSSIONS

TYPES OF STUDY DESIGNS

The goal of different studies that assess the effects of Tai Chi is to establish a cause-effect relation between the exposure or intervention, Tai Chi, and the outcome, better balance or fewer falls. Different types of study designs have different ability to assess causal relation and hence, have different level of internal validity. Therefore, it is important to identify the type of study design used in a research report. The simplest classification in terms of study design is between intervention studies (experiments) and observational studies. Observational studies include ecological studies, cross-sectional studies, case-control studies and cohort studies. Based on whether randomization is present or not, intervention studies can be categorized as quasi-experiments and RCTs. In general, RCTs are considered to have the highest level of credibility indicating causality followed in rigor by quasi-experiments, cohort studies, case-control studies, cross-sectional studies and, lastly, ecological studies. (Figure 1)

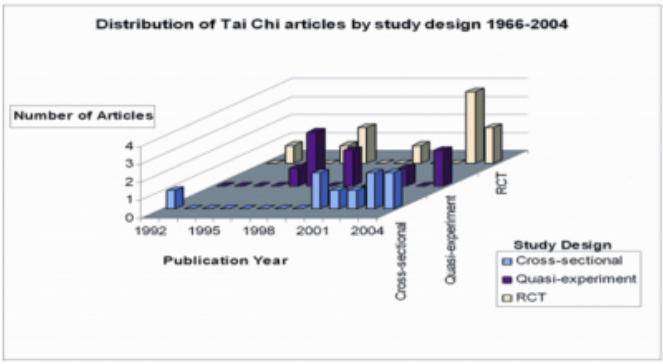
Figure 1



Among twenty-nine studies included in this review, we identified ten cross-sectional studies,[8910111213141516 17] nine quasi-experiments[18192021222324252 6] and ten randomized trials.[27282930313233343536] No cohort and case-control studies with respect to Tai Chi are found in this review. Figure 2 illustrated the distribution of scientific studies assessing the effect of Tai Chi on balance and fall prevention by study design between 1966 and 2004. While the overall number of articles is increasing over time, there is an encouraging trend in the number of RCTs published within the literature relatively recently.

Figure 2

Figure 2. The distribution of published studies assessing the effect of Tai Chi on balance and fall prevention by study design between 1966 and 2004



Although the results from RCTs are considered the most reliable form of scientific evidence, the cross-sectional design still appeals to many researchers; it is relatively easy, quick and inexpensive to conduct compared to other study designs. In a typical cross-sectional design, researchers compare the balance ability between Tai Chi practitioners to sedentary elderly or people engaging in other exercises, at one point in time. Many people use this design to gain a general picture when starting a new study and to generate new hypotheses for further investigations. Moreover, with a cross-sectional design, one can study people who already practice Tai Chi with people who do not. Hence, there is no need to assign anyone to practice Tai Chi when they do not want to, which is always an ethical concern in conducting RCTs. It is also believed that the longer time people practice Tai Chi, the greater benefits they can gain from it. When the primary study interest is long-term effects of Tai Chi, cross-sectional study may be an easier option to provide some preliminary data because one can look at the difference between short-term and long-term Tai Chi practitioners at the same time. For example, by comparing 28 male long-term Tai Chi practitioners with 30 sedentary men, Hong et al[16] found that long-term Tai Chi practitioners achieved statistically significant better scores in a single leg standing test, along with trunk and hamstring flexibility tests than did the sedentary controls. This implied the beneficial effects of long-term regular Tai Chi practice on balance control and flexibility. However, it may take years for researchers to follow and study a group of subjects when either a cohort study or experimental study design is used to answer the same research question.

Although cross-sectional study has some obvious advantages over other study designs, its inherent limitations cannot be easily ignored. Most importantly, associations identified in a cross-sectional study do not meet a key requirement of causality: temporal relationship between Tai Chi practice and the improvement in balance. If practicing Tai Chi is believed to cause the improving balance in an individual, then an individual must have started practicing Tai Chi before the improvement in balance was achieved. However, in a cross-sectional study, the balance test is measured and compared between people who already practice Tai Chi and people who do not, at the same point of time, hence, it is difficult to rule out alternative explanations of observed better balance control among Tai Chi practitioners. For example, in the study conducted by Hong et al[16], one could argue that Tai Chi practitioners already have had better balance ability even before they started doing Tai Chi because of genetic factors. Another alternative explanation is that many of the Tai Chi practitioners were also doing yoga or other exercises which may potential improve their balance and flexibility as well. Therefore, any claim from a cross-sectional study that Tai Chi practice can improve balance is weak.

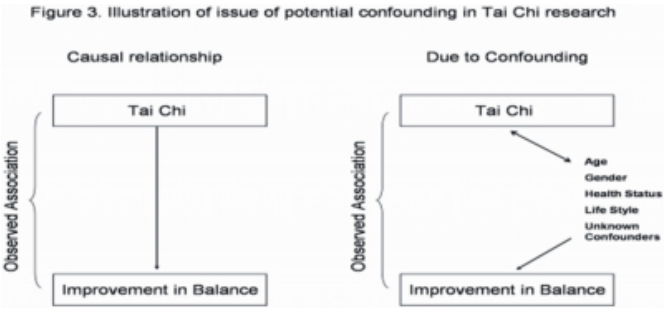
In addition, cross-sectional study is vulnerable to many errors or biases. As a result, the observed better balance control among Tai Chi practitioners may be due to factors other than the fact that they practice Tai Chi. Using posturography and EMG to test the postural stability between 15 elderly Tai Chi practitioners and 13 sedentary controls, (all females), Hsiao-Wecksler et al[14] found that the Tai Chi group had better stability than the controls under the dynamic condition. However, since no baseline demographic data were collected, people in the Tai Chi group may differ from people in the control group in many ways, such as health status. Therefore, the better stability in the Tai Chi group may be explained as the stronger and healthier people in the group as opposed to the benefit of Tai Chi practice itself. This kind of error in choosing individuals who are not comparable called selection bias.

Because of many methodological limitations of cross-sectional study, some researchers have to resort to quasi-experiments to demonstrate causality between Tai Chi training and improvement in balance. Quasi-experimental studies can use measurements before starting Tai Chi training and after Tai Chi training along with non-randomly selected control groups. For example, Hain et al[24] concluded that Tai Chi training improves balance; he compared results from posturography, Romberg test, reach test and two questionnaires before and after 2-month Tai Chi training among 22 people in three age groups. One can also determine whether Tai Chi can improve balance by

comparing people who receive Tai Chi training to people who either do not exercise at all, or engage in other exercises over a period of time. Jacobson et al[21] selected 12 people each for two groups: 12-week Tai Chi training or 12-week without any balance or resistance training, and compared pretest and posttest results. Statistically significant differences were found between groups in lateral body stability, kinesthetic sense at 60 degrees, and strength of the dominant knee extension. Nonetheless, since in a quasi-experiment, balance ability is measured after Tai Chi training is given to an individual, better temporal sequence can be established. Hence, much stronger causal argument can be made based on quasi-experiment than cross-sectional study.

Unfortunately, like cross-sectional study, the lack of random assignment is the major weakness of the quasi-experimental design. Without random assignment, the internal validity of the study is endangered by potential bias and confounding variables, especially unknown confounding variables. A variable or a factor is a confounding variable if it is associated with the Tai Chi training and is also related to balance ability of an individual (Figure 3).

Figure 3



The confounding variable leads to a situation where a causal relationship between Tai Chi training and improvement in balance is observed as a result of the influence of the confounding variable. For instance, in the quasi-experiment conducted by Hain et al[24], the goal was to demonstrate the 8-week Tai Chi training improves balance among 22 people with mild balance disorders. Although the author excluded patients with many conditions associated with poor balance, there are a number of important potential confounding variables, such as medication use and the cognitive level of the patients that may change in the pretest and posttest time period. These confounding variables would be difficult if not near impossible to measure and control. However, these variables, along with many other potential confounding variables that we could not even recognize can be properly controlled by the randomized assignment of subjects to intervention and control groups in RCTs.

Another potential threat to the internal validity of a quasi-experiment is regression toward the mean.[37] This statistical phenomenon happens when repeated measurements are made on the same sample; extreme measurements tend to be followed by normal measurements or measurements that are closer to the mean. Unfortunately, in a poorly designed quasi-experimental study, the observation of changes between extreme and normal measurements could lead to the wrong conclusion that an effect is due to the intervention when in reality it is purely by chance. For example, in a study conducted by Shih,[23] the velocity of sway was measured in static and dynamic conditions among 11 volunteers before and after 16-week Tai Chi training program. Based on the statistical significant difference found in the average velocity of sway in the dynamic condition, the author concluded that the increased postural stability is due to Tai Chi training which could reduce the risk of falling. Unfortunately, the finding could be also explained as regression toward to the mean. If the pretest score is really just an extreme high observation that is still within the normal range of the velocity of sway in the dynamic condition of this sample, according to the statistical theory, these measurements will tend to decline even without the Tai Chi training program. Thus, the finding of the benefits of Tai Chi in this study is not conclusive.

Nonetheless, RCTs should be used whenever possible because their ability to provide evidence against confounding and regression toward the mean as alternate explanations for observed associations. Unfortunately, RCTs usually require resources, expertise and time. In addition, some ethical concerns may prevent a researcher from choosing RCTs. In such cases, well-designed quasi-experiments could be used. For example, in Shih's study, adding a second pretest before the Tai Chi training helps provide evidence that can be used to refute the phenomenon of regression toward the mean. If both pretest scores were high this would imply that it was unlikely that posttest is lower due to chance. Thus, a little improvement in the study design could yield more convincing evidence. Harris et al[37] has reviewed different quasi-experimental study designs and the relative hierarchy of these designs related to their ability to establish causality. Future investigators could use the review as a guide in designing a quasi-experiment to evaluate the effect of Tai Chi.

STUDY SAMPLES

The potential effect of age, gender and health status on the benefit of Tai Chi on balance or fall prevention has been explained in detail in Wu's review. In fact, these factors along with life style are the most common confounding variables in any exercise-related epidemiological studies and should be carefully described and controlled. Unfortunately, this has not been done in some studies reviewed here.[2021]

In addition, selection bias is common but has not been recognized.[2425] In many studies, subjects were recruited through local advertisement or on a voluntary basis.[182432333438] However, volunteers may differ from the target population (people with high fall risk factors) or even the general population. These volunteers usually tend to be better educated, more health conscious, healthier, and pay more attention to Tai Chi training. As a result, the effect of Tai Chi may be overestimated. In addition, the results from these studies may have very limited generalizability or external validity.

Moreover, previous Tai Chi experience was not indicated by many quasi-experimental studies.[2021232425] Naïve volunteers may need more time to follow the instruction and also it takes more time for them to achieve the same benefit of Tai Chi as non-naïve volunteers. Since the Tai Chi training time in quasi-experiments is relatively short, the results might be underestimated or overestimated, depending on the proportion of naïve volunteers in the study group.

Lastly, the choice of comparison groups is crucial with respect to interpreting the effects of Tai Chi exercise. In fact, any exercises may improve body function (physically and mentally). Therefore, if the Tai Chi group were compared to a sedentary group, the results of positive improvement in the Tai Chi group would be obvious. There were cross-sectional studies[1213] that used golfers and swimmers/runners as well as the sedentary elderly as controls. All three exercise groups showed better improvement in proprioceptive tests than the sedentary control group. The significant differences in knee joint proprioceptive tests were not found when comparing between the Tai Chi group and the golfers group, and also between the Tai Chi group and swimmers/runners group. This may suggest that sedentary people are not an ideal control in order to show the effectiveness of Tai Chi on balance.

INTERVENTIONS

In her review, Wu hypothesized different types of Tai Chi (Chen, Yang, Wu, Sun or others), the overall amount, and the intensity of Tai Chi training, may affect the outcome of balance control and fall reduction.[7] Nonetheless, there are many other factors could potentially confound the effect of Tai Chi training and introduce error or bias to the studies. Thus, it is important for future investigators to recognize these factors and clearly present them in a study report. These factors include: 1) center-based Tai Chi training and/or home self-practice, 2) major components of Tai Chi emphasized during the intervention, 3) specific Tai Chi movements used in the study, 4) the composition of a Tai Chi training session in the study, 5) the experience of Tai Chi instructors and the evaluation of Tai Chi training and/or the instructor by study subjects, and 6) study compliance. Each of these factors will be discussed in turn. (See Table 1 and 2)

First, Tai Chi is very different from traditional western exercise. Unlike many western exercises, Tai Chi is not a set of repetitions of simple movements. A Tai Chi routine consists of a series of slow, rhythmic movements emphasizing trunk rotation, weight shifting, coordination and a gradual narrowing of lower extremity stance.[39] Many movements are not intuitive for western people. This could potentially pose a challenge to deliver Tai Chi intervention in a study. Previous Tai Chi studies focused on center-based – participants had to come to a center to learn and practice Tai Chi with instructors several times a week.[1118192021222324252627282930313233343536] However, Tai Chi could also be learned with instruction sheets, video tapes and books or a combination of center-based and home practice. In the center-based settings, direct supervision from the instructors could facilitate individuals to learn Tai Chi movements. If different Tai Chi skill is associated with different gain in balance, then people who receive center-based Tai Chi training may gain better balance control within a shorter period than people who learn Tai Chi at home. Future studies are needed to quantify Tai Chi learning in individuals and find optimal way to teach Tai Chi.

Second, original Tai Chi practiced in China usually involves a series of slow, movements, along with deep breathing and meditation. This requires long-term, usually many years of, practice for an individual to be able to integrate these techniques. Since keeping balance is a complicated process that requires coordination of multiple systems, the three components of Tai Chi may have different impact on human balance control and stability. Thus Tai Chi interventions emphasizing different components may provide different

benefits for improving balance to study participants.

Third, as mentioned in Wu's review, Tai Chi is practiced in many styles and forms. Each style has up to a hundred or more different movements. In quasi-experiments and randomized trials, study subjects could not learn all these movements due to relative short study duration. Tai Chi training used in previous studies was a combination of a few Tai Chi movements. Therapeutic elements have been identified for different movements in Yang style.[7] This implies that training programs which combine different Tai Chi movements could have different impacts on balance control for an individual. Therefore, it is important to not only identify the style and form of Tai Chi taught in the study but also specify each movement used. An illustration of these movements in an appendix of future study will be extremely helpful.

Fourth, in previous studies, some Tai Chi training sessions also had some adjunct exercise. For example, in one study,[36] the 1-hour Tai Chi training consisted of 10- to 15-minute warm-up, 35 to 45 minutes of Tai Chi practice, and a 5-minute cool-down. Since additional exercise may play a role in the improvement of balance and body function as well, clearly document the composition of a typical Tai Chi training session is important to rule out alternative explanation of the contribution of other exercise to the gain in balance.

Fifth, qualifications of Tai Chi instructors and the evaluation of Tai Chi training program by study subjects may potentially affect study outcomes. An experienced Tai Chi instructor may facilitate the learning process, ensure safety and improve compliance during the study. However, the evaluation of an exercise program by study participants could indicate how the intervention is received and be used to assess the effectiveness of Tai Chi intervention from another perspective. Therefore, it is necessary to identify and control both factors in the future.

Sixth, an important factor related to both intervention and outcome measurement is the level of compliance with the intervention. It is important to know the reason why an individual does not complete a study. It is more important to identify the difference between people who are compliant with the study and those who are not. Otherwise, selection bias may occur and internal validity of the study is affected. For example, in a quasi-experimental study, Taggart et al[26] measured balance ability and functional mobility among 69 healthy women at baseline, after the 3-month control period, and after the 3-month Tai Chi intervention and reported significant improvement in all outcome variables. However, only 65% participants completed the study and the author failed to compare people who completed the study to people who dropped out in the middle. One may argue that when those frail people dropped out the study, a distorted positive association would result. Therefore, in future study, the compliance rate should be carefully documented and an analysis should be conducted whenever it is possible. This evaluation of compliance will help readers to interpret the study accurately. The results of the review are shown in Table 1 and 2.

Figure 4

Table 1. Summary of Quasi-experimental Studies on Tai Chi (TC) promoting balance and preventing falls, published between 1966 and 2004

Author	Schaller[23]	Shih[23]	Jacobson et al[22]	Forrest[22]	Ross et al[22]	Hain et al[24]	Taggart[26]	Thornton et al[18]	Tsang et al[2]
Year	1996	1997	1997	1997	1999	1999	2002	2004	2004
Study design	Quasi	Quasi	Quasi	Quasi	Quasi	Quasi	Quasi	Quasi	Quasi
Volunteer Bias recognized (Y/N)	Y	N	N	N	N	N	N	N	N
Previous TC experience is identified (Y/N)	N	N	Y	Y	N	N	N	Y	Y
Type of Control	Sedentary Control	No control	Sedentary Control	No control	No control	No control	No control	Sedentary Control	Education control and TC practitioner control
Intervention types*	Combined	Combined	Center-based	N/A	Center-based	Combined	Center-based	Center-based	Center-based
Major components of TC emphasized in the trial is identified (Y/N)	N	N	N	N	N	Y	N	N	N
Illustration of TC movements provided (Y/N)	N	N	N	N	N	N	N	N	N
The composition of a typical Tai Chi training class provided (Y/N)	N	Y	Y	N	Y	N	N	Y	Y
Qualification of TC instructor described (Y/N)	N	N	Y	N	Y	N	N	Y	N
Evaluation by subjects provided (Y/N)	N	N	N	N	N	N	N	N	N
Any evaluation of Compliance (Y/N)	N	N/A (No drop-out)	N/A (No drop-out)	N/A (No drop-out)	N	N	N	N	N

*Center-based, home practice, or combined

Figure 5

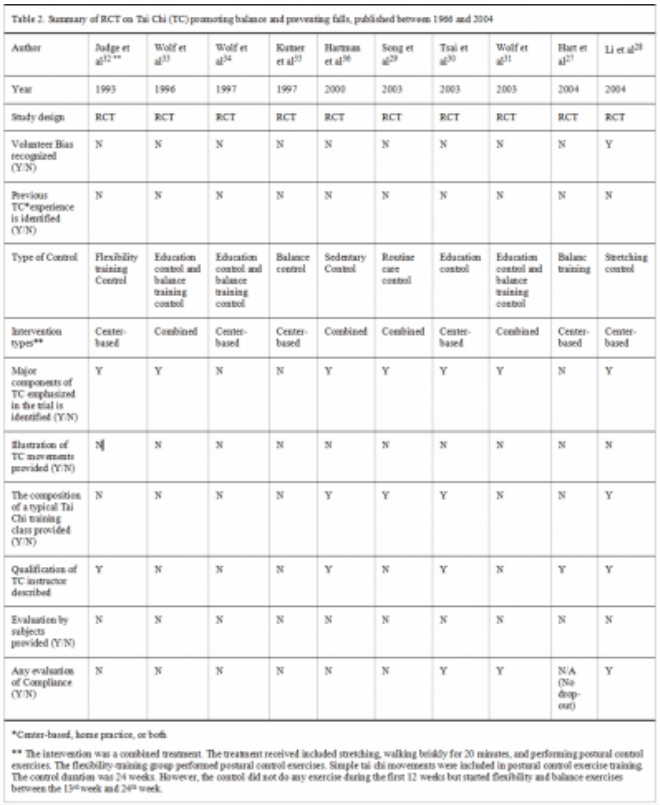


Table 2. Summary of RCT on Tai Chi (TC) promoting balance and preventing falls, published between 1966 and 2004

Author	Judge et al[32] **	Wolf et al[33]	Wolf et al[34]	Kutner et al[35]	Hartman et al[36]	Song et al[29]	Tsai et al[30]	Wolf et al[31]	Hart et al[27]	Li et al[28]
Year	1993	1996	1997	1997	2000	2003	2003	2003	2004	2004
Study design	RCT	RCT	RCT	RCT	RCT	RCT	RCT	RCT	RCT	RCT
Volunteer Bias recognized (Y/N)	N	N	N	N	N	N	N	N	N	Y
Previous TC*experience is identified (Y/N)	N	N	N	N	N	N	N	N	N	N
Type of Control	Flexibility training Control	Education control and balance training control	Education control and balance training control	Balance control	Sedentary Control	Routine care control	Education control	Education control and balance training control	Balanc training	Stretching control
Intervention types**	Center-based	Combined	Center-based	Center-based	Combined	Combined	Center-based	Combined	Center-based	Center-based
Major components of TC emphasized in the trial is identified (Y/N)	Y	Y	N	N	Y	Y	Y	Y	N	Y
Illustration of TC movements provided (Y/N)	N	N	N	N	N	N	N	N	N	N
The composition of a typical Tai Chi training class provided (Y/N)	N	N	N	N	Y	Y	Y	N	N	Y
Qualification of TC instructor described	Y	N	N	N	Y	N	Y	N	Y	Y
Evaluation by subjects provided (Y/N)	N	N	N	N	N	N	N	N	N	N
Any evaluation of Compliance (Y/N)	N	N	N	N	N	N	Y	Y	N/A (No drop-out)	Y

*Center-based, home practice, or both

** The intervention was a combined treatment. The treatment received included stretching, walking briskly for 20 minutes, and performing postural control exercises. The flexibility-training group performed postural control exercises. Simple tai chi movements were included in postural control exercise training. The control duration was 24 weeks. However, the control did not do any exercise during the first 12 weeks but started flexibility and balance exercises between the 13th week and 24th week.

SUMMARY

Although Tai Chi has been practiced in China for centuries, scientific evaluation of its potential benefits just began in the last two decades. Many observational and experimental studies reported that Tai Chi was associated with improvement in balance control and reduction in risks of falls. Unfortunately, many limitations exist in their research methodology and have been discussed in this review. As a result, the internal validity of these studies is questionable and the evidence based on existing studies is less convincing. Future studies should focus on how to minimize these limitations, and hence the internal validity would be greatly improved. Future Tai Chi investigators should choose RCT design, when feasible, because of its potential to eliminate bias, as well as to control known and unknown confounding variables. In situations when it is unethical or logistically impractical to conduct a randomized trial, high-level quasi-experiments should be used. In addition, attention should be given to selection of study samples to improve both internal and external validity. Lastly, in quasi-experiment and randomized trial, intervention, including training given to intervention and control groups, should be described thoroughly. Details of the interventions intended for each group and how they are actually administered should be provided. This will help other researchers to evaluate the validity of the results and replicate the study.

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