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Authors: Emily Taylor, Ruth E. Taylor-Piliae

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Title: The Effects of Tai Chi on Physical and Psychosocial Function among Persons with Multiple Sclerosis: A Systematic Review

Author Names: Emily Taylor[a], Ruth E. Taylor-Piliae,[b]

[a]*College of Nursing, University of Arizona, Tucson, AZ, USA*

1305 N. Martin, PO BOX 210203, Tucson, AZ 85721-0203, USA

Email: etaylor2@email.arizona.edu

[b]*College of Nursing, University of Arizona, Tucson, AZ USA*

1305 N. Martin, PO BOX 210203, Tucson, AZ 85721-0203, USA

Email: rtaylor@nursing.arizona.edu

Corresponding Author: Emily Taylor, MS, RN, PhD Student

College of Nursing, University of Arizona, 1305 N. Martin, PO BOX 210203, Tucson, AZ 85721-0203, USA

Email: etaylor2@email.arizona.edu

Phone: 520-626-4881

Fax: 520-626-4062

Highlights

- Tai Chi is likely a safe physical activity for individuals with Multiple Sclerosis, including those with clinically isolated syndrome, relapsing-remitting Multiple Sclerosis, and secondary progressive Multiple Sclerosis.
- Tai Chi may provide physical and psychosocial benefits for individuals with Multiple Sclerosis.
- Current Tai Chi research among those with Multiple Sclerosis is limited to standing forms of Yang style Tai Chi, and among those with lower levels of Multiple Sclerosis associated disability.

Abstract

Objectives: Conduct a systematic review to evaluate the effects of Tai Chi on physical and psychosocial function among individuals with Multiple Sclerosis.

Methods: An electronic literature search of 12 databases using controlled vocabulary function and keywords from inception through August 2016. All Tai Chi intervention studies assessing physical and psychosocial function among persons with Multiple Sclerosis were included. Study quality was scored using an established tool examining 16 study elements (range=0-32).

Results: A total of 91 articles were retrieved, with 3 additional articles identified through reviewing bibliographies of relevant articles. A total of 8 studies (randomized controlled trials, n=3; quasi-experimental, n=5) enrolled 193 participants with Multiple Sclerosis. Studies were

conducted in the USA (n=3), Europe (n=3), Iran, (n=1), and India (n=1). A total of 3 studies reported using the Yang style of Tai Chi (not specified, n=5 studies). The Tai Chi intervention averaged 27 sessions over 11 weeks. Study quality scores for the randomized controlled trials had a mean score of 23 (range 19-26), while quality scores for quasi-experimental studies had a mean score of 20 (range 13-26). Overall, participants enrolled in Tai Chi had better balance, gait and flexibility, less fatigue and depression, and better quality of life after the intervention; though mixed results were reported.

Conclusion: The results indicate that Tai Chi is likely safe and may provide physical and psychosocial benefits in individuals with Multiple Sclerosis. Further research is needed using more rigorous study designs to assess the benefits of Tai Chi for individuals with Multiple Sclerosis.

Keywords: Multiple Sclerosis, Tai Ji, postural balance, fatigue, depression, review

1. Introduction

Multiple Sclerosis (MS) is a chronic, long-term, autoimmune disease that is characterized by destruction of the myelin in the central nervous system.[1] Prevalence and incidence of MS is increasing worldwide, with an estimated 2.3 million people affected.[2, 3] The average age of the development of the first symptoms is 29 years and the average age of diagnosis is 37 years.[4] Women are more likely to be diagnosed with MS, than men.[2, 5, 6] The etiology of MS is believed to be a combination of genetic and environmental factors.[1, 2, 5]

In clinical practice, the McDonald criteria are used for diagnosis with two or more lesions noted on Magnetic Resonance Imaging (MRI), presence of oligoclonal bands or elevated

Immunoglobulin G index in Cerebrospinal Fluid, and presentation of patient-reported symptoms consistent with MS that last greater than 24 hours.[7] Four types of MS classifications exist: Clinically Isolated Syndrome (CIS), Relapsing-Remitting MS (RRMS), Secondary Progressive MS (SPMS), and Primary-Progressive MS (PPMS).[8] CIS is characterized by a single clinical episode consistent with demyelination; RRMS is characterized by a relapse of symptoms and a full recovery to baseline; SPMS is diagnosed by an original relapsing course of the disease and as the disease gradually progresses the symptoms remain present; PPMS is characterized by a continual worsening of symptoms without remission.[8]

Common psychosocial symptoms associated with MS are depression,[9, 10] fatigue,[4, 9, 10] anxiety,[11] and cognitive impairment.[9, 12] The most common comorbidity at diagnosis is depression.[11] Common physical symptoms associated with MS include impaired mobility,[4, 9] falls,[13] visual impairment, impaired bowel and bladder function, sensory impairment, spasticity, and pain.[9]

One of the most devastating and widespread sequela of MS is disability, which is generally measured with the Expanded Disability Status Scale (EDSS). The EDSS is used to determine the impact on a person's functional systems and level of impairment.[14] Functional systems include pyramidal, cerebellar, brain stem, sensory, bowel and bladder, visual, cerebral functions, and ambulation. Healthcare providers evaluate functional systems and assign a score from 0 (normal neurological exam) to 10 (death due to MS) to indicate level of disability. An EDSS score of 3 indicates moderate disability in one functional system, but the individual is fully ambulatory; while a score of 5 indicates that an individual can walk 200 meters without an aide, but the individual has limitations with daily activities.[14]

Level of disability is a major predictor of activity level and exercise in individuals with MS over the age of 55.[15] Physical activity recommendations for individuals with MS include 20 to 60 minutes of aerobic exercise 3 to 5 times weekly.[16] Among individuals with MS, 80% are not meeting physical activity recommendations.[17, 18] An increase in quality of life (QOL) has been identified when individuals with MS engage in exercise.[19] Improvements in MS-associated symptoms, including fatigue, depression, and anxiety, have been noted among individuals engaged in a 6-month exercise program.[20] Exercise is associated with improvements in aerobic capacity and muscular strength,[21] and a decrease in relapse symptoms with 4.6% of individuals that exercise reporting relapses, compared to 6.3% for controls.[22] One type of physical activity that may provide physical and psychosocial benefits for individuals with MS is Tai Chi.

Tai Chi is a low impact exercise and multiple studies conducted among older adults without MS indicate that Tai Chi decreases depressive symptoms,[23] reduces falls,[24-26] improves aerobic endurance,[25] decreases perceived stress,[27] and improves sleep quality.[27] Tai Chi has also been associated with improved executive function in older adults.[28] Tai Chi has been studied in individuals with a variety of chronic diseases including Chronic Obstructive Pulmonary Disease (COPD),[29] Osteoarthritis of the knee[30] and hip,[31] Stroke,[32] Diabetes Mellitus,[33] Parkinson's Disease,[34] Cancer,[35] and Cardiovascular disease.[36] Before Tai Chi can be recommended as an adjunctive therapy for MS patients, it is important to first evaluate the current body of research evidence for potential benefits. Therefore, the purpose of this systematic review was to evaluate the effects of Tai Chi on physical and psychosocial function among individuals with Multiple Sclerosis.

2. Methods

A comprehensive electronic literature search was conducted with the assistance of a medical librarian. Databases searched included: PubMed, CINAHL, PsycINFO, Web of Science, Embase, Academic Search Complete, AMED, Proquest Dissertations and Abstracts, clinicaltrials.gov, SPORTDiskus, PROSPERO, and Google Scholar; using controlled vocabulary function and keywords including "Tai Chi" or "Tai Ji" and "Multiple Sclerosis" (See Appendix A). The literature search included all studies from inception through August 30, 2016 that were published in English. Abstracts of the studies were reviewed to determine if a Tai Chi intervention was offered among persons with MS and if physical or psychosocial function was assessed. The following types of articles were rejected: abstracts, reviews, commentaries, case-reports, book chapters, and studies not-related to the topic. Data abstracted from the studies meeting the inclusion criteria were: country of study origin, study design, participant details (e.g., type of MS, MS duration, age, gender, EDSS), Tai Chi style and length of the intervention, physical and psychosocial function variables measured, study results, intervention adherence rates, attrition, and serious adverse events. Physical function was defined as balance, gait, flexibility, and strength. Psychosocial function was defined as fatigue, quality of life, disease symptoms, perception of disease, and mood.

2.1 Study Quality

Study quality was determined with an established tool[37] that examines 16 study elements. Study elements assessed included: the purpose of the study, sample selection technique, description of study participants, subject allocation to groups, comparability of groups, pre- and post-intervention data collection, procedure details, independent variable, dependent variables, intervention details, follow up at end of study, instrument validity and reliability, inferential and descriptive statistics, and clinical and statistical significance. Each study element could be scored

0 to 2, (0=not defined, 1=incomplete definition, and 2=clearly defined), with scores ranging from 0-32. Discrepancies in scores were rechecked and consensus achieved by discussion.

3. Results

A total of 91 articles were retrieved electronically (see Figure 1). Duplicates were removed and 64 articles remained. Articles were reviewed to determine if a Tai Chi intervention was offered to individuals with Multiple Sclerosis and if physical or psychosocial function was assessed. Three additional articles were found from reviewing bibliographies of published relevant articles. Reviews (n=16), commentaries (n=15), case reports (n=1), abstracts (n=4), book chapters (n=1), and articles not related to the topic (n=18) were excluded. The study selection process is shown in the PRISMA[38] flow diagram (Figure 1). A total of 8 studies were included in this review (see Table 1). Study designs included randomized controlled trials (RCT) (n=3)[39-41] and quasi-experimental studies (n=5).[42-46]

3.1 Study Characteristics

The studies reviewed were conducted in the USA (n=3),[42, 44, 46] Europe (n=3),[41, 43, 45] Iran (n=1),[39] and India (n=1)[40]; published between 1999 and 2015. A total of 193 participants with MS were enrolled. Across studies, demographics were missing for 28 participants. The participants had a variety of types of MS, including RRMS (n=90), SPMS (n=36), CIS (n=1), chronic progressive (n=5), and unknown type of MS (n=61). It is unknown if chronic progressive referred to PPMS or SPMS. MS duration ranged from less than 6 years[39] to 22 years,[45] though MS duration was not reported for two studies.[42, 46] The majority of participants were women (79%) with an average age of 46 years old. EDSS was not reported consistently across studies. An inclusion criteria of an EDSS less than 5 was used for two studies.[39, 43]

3.2 Tai Chi Intervention

The Yang style of Tai Chi was performed for three studies (37.5%).[39, 42, 43] Tai Chi style was not specified for the remaining five studies (62.5%).[40, 41, 44-46] Tai Chi interventions comprised on average 27 sessions (range=6 to 50 sessions), over 11 weeks (range=3 to 25 weeks). The study that offered six sessions had participants keep an exercise diary and their practice averaged 221 minutes per week over a 2-month period.[45] Attrition ranged from 5.6% to 43%. Intervention adherence was reported at 60% for one study,[43] though the remaining studies did not report intervention adherence rates. None of the studies reported serious adverse events. In addition, only one study reported that they did not observe any adverse events.[43]

3.3 Comparison Groups

Three of the RCT's[39-41] and two of the quasi-experimental studies[43, 44] included comparison groups. Four of the studies provided a comparison group that received treatment as usual and were instructed to not participate in Tai Chi or meditation during the course of the study.[39-41, 43] One study had both groups participate in a Tai Chi classes. Both groups attended 20 sessions of a 40-minute Tai Chi class. One group practiced an additional 20-minute mental practice. The mental practice was at the beginning of class and was a visualization of the Tai Chi forms that were to be performed during class.[40]

3.4 Study Quality

A quality score was assigned to each of the research studies included in this review. Scores for the RCTs obtained 72% of the possible points (average score=23, range=19-26), while scores for the quasi-experimental studies obtained 63% of the possible points (average score=20, range=13-26) (see Table 2).

3.4 Effect of Tai Chi on Physical Function

3.4.1 Balance

Three RCT's assessed balance[39-41] and reported significant within group improvements in balance post-intervention ($p<0.05$). A total of three quasi-experimental studies assessed balance[42, 43, 45] with two of the studies finding significant within group improvements in balance post-intervention ($p<0.05$).

The study conducted by Averill[42] reported mixed results. Averill[42] assessed both static and dynamic balance. Static balance with quiet stance and standing meditation without arm movements did not significantly improve post-intervention ($p>0.05$). However, significant changes post-intervention were reported for tandem stance and standing meditation with arm movements ($p<0.05$).[42]

Different tests were used to assess balance including the Berg Balance Scale (BBS),[39] Modified Clinical Test of Sensory Organization and Balance (mCTISB), Functional Reach,[40] single leg standing test,[41, 45] a 14-task balance test,[43] and Center of Pressure (CoP) velocity, net excursion, Time to Contact (TcT), and tandem stance.[42]

3.4.2 Gait, Flexibility, and Strength

One of the RCT's assessed gait[40] while two of the quasi-experimental studies assessed gait.[42, 46] Kaur et al.[40] reported significant within group improvements in gait speed post-intervention ($p<0.05$). Husted et al.[46] reported a 21% increased walking speed. Averill (2014) reported non-significant changes in walking speed ($p>0.05$). The tests used to measure gait included the dynamic gait index, timed up and go[40] and 25-foot walking speed test.[42, 46]

Two quasi-experimental studies assessed flexibility.[42, 46] Averill (2014) reported a significant increase in flexibility ($p<0.05$); while Husted et al.[46] reported a 28% improvement in hamstring flexibility. Tests used to assess flexibility included foot tapping test[42] and hamstring flexibility.[46]

One quasi-experimental study assessed lower-body strength[42] and reported significant improvements post-intervention ($p<0.05$). Strength was assessed with time to complete five chair rises.[42]

3.5 Effect of Tai Chi on Psychosocial Function

3.5.1 Fatigue

Three quasi-experimental studies assessed fatigue.[42-44] Results were mixed across studies. One study reported significantly improved cognitive and psychosocial fatigue scores ($p<0.05$).[44] Another study reported stable fatigue for the Tai Chi group and significant worsening of fatigue for the control group ($p<0.05$).[43] The final study reported non-significant changes in fatigue ($p>0.05$).[42] Measures used to assess fatigue include the Fatigue Severity Scale (FSS),[42] Fatigue Scale of Motor and Cognitive Functions (FSMC),[43] and the Modified Fatigue Impact Scale (MFIS-5).[44]

3.5.2 Quality of Life

Two quasi-experimental studies assessed quality of life.[43, 46] Husted et al.[46] reported improvements in vitality (15%), mental health (5%) and social functioning (13%), while physical function and general health both declined 10%. Burschka et al.[43] reported the Tai Chi group had significant improvements in life satisfaction scores, compared to controls ($p<0.05$). Measures used to assess quality of life include the SF-36[46] and the Questionnaire of Life Satisfaction (QLS).[43]

3.5.3 Disease Symptoms

One RCT[41] and one quasi-experimental[45] study assessed self-reported MS disease symptoms. Improved participant rating of symptoms were reported immediately post-

intervention ($p<0.05$)[41, 45] and at 3-months post-intervention follow-up ($p<0.05$).[41] Symptoms were assessed with a symptom rating questionnaire.

3.5.4 Perception of Disease

One RCT[40] and one quasi-experimental study[42] assessed perception of disease. Averill[42] reported significantly improved well-being and psychological scores ($p<0.05$), though non-significant changes in physical scores ($p>0.05$) were observed. Kaur et al.[40] reported significantly better perceived level of confidence related to balance and gait ($p<0.05$). Perception of disease was assessed with the Multiple Sclerosis Impact Scale (MSIS-29)[42] and the Activities Balance Confidence (ABC) scale.[40]

3.5.5 Mood

Two quasi-experimental studies assessed negative mood.[43, 45] Burschka et al.[43] reported the Tai Chi group had significant reductions in depressive symptoms, compared to controls ($p<0.05$); while Mills et al.[45] reported significantly lower depression scores post-intervention ($p<0.05$). Mood was measured with the Profile of Mood States (POMS)[45] and the Center for Epidemiological Studies Depression Scale (CES-D).[43]

4. Discussion

This systematic review evaluated the effects of Tai Chi on physical and psychosocial function among individuals with Multiple Sclerosis. Significant improvements included better balance, gait, flexibility, less fatigue and depression, and better quality of life after the Tai Chi intervention; though mixed results were reported.

Tai Chi is a promising form of physical activity for persons with Multiple Sclerosis to manage physical and psychosocial symptoms. These findings are similar to other studies that have offered Tai Chi as an intervention for persons with a chronic condition including breast

cancer, rheumatoid arthritis, cardiovascular disease, hypertension, or osteoporosis with effectiveness consistently reported for improvements in physical or psychological health.[47]

One of the challenges with this review is that these studies used different styles of Tai Chi, and offered various session durations as well as length of the interventions making comparisons across studies difficult. The majority of studies failed to report the type of Tai Chi used. Only one study offered a detailed description of the intervention.[43] Three of the studies (37.5%) offered a mixture of Tai Chi with meditation or Qigong. Kaur et al.[40] offered a Tai Chi intervention and a Tai Chi plus mental practice intervention. The Tai Chi group participated in a 40-minute session with six Tai Chi forms practiced. The Tai Chi plus mental practice group participated in a 20-minute mental practice followed by the same 40-minute session of six Tai Chi forms. In addition to the small sample size, the two intervention groups may have been too similar, as the authors were unable to detect a statistically significant difference between groups post-intervention. Tavee et al.[44] offered a 90-minute intervention. The intervention class was comprised of three forms of mediation in 30-minute sessions. The three parts consisted of walking meditation, moving meditation, and sitting meditation. The moving meditation part included common Tai Chi forms and Qigong. Mills et al.[45] and Mills and Allen[41] offered an intervention with Tai Chi forms and Qigong. The interventions in the studies conducted by Tavee and Mills and colleagues included Qigong and may not be comparable to other interventions that offer Tai Chi only. Future Tai Chi studies conducted among persons with MS need to specify the Tai Chi style and the intervention dose to allow replication of findings. Health benefits have been noted with other forms of Tai Chi, including Wu, Chen, and Sun styles and use of these styles may produce positive results.[48]

One of the most notable omissions from these studies is the lack of measurement of the effects of Tai Chi on cognitive ability. Cognitive impairment is frequently reported among individuals with MS.[9] The only measure of cognitive function used was the Modified Fatigue Impact Scale (MFIS) 5-item questionnaire.[44] This scale assesses cognitive impairments related to fatigue.[49] A systematic review of Tai Chi studies conducted among older adults reported improvements in executive function, compared to controls.[28] These findings shed light on potential cognitive improvements for the MS population, though further research is needed.

Most of the studies in this review (n=6)[39-43, 45] assessed balance with improvements reported post-intervention. However, these studies did not assess self-reported falls pre- and post-intervention to determine if there was a reduction in fall rates. Concerns of falling and self-reported falls are common among individuals with MS.[13] Prior studies conducted among older adults report decreased falls with Tai Chi practice.[24] This is another area that could be researched among persons with MS.

Among individuals with MS, an EDSS is used to assess level of disability in individuals with MS. EDSS was not reported for three studies.[41, 45, 46] One study used a self-reported EDSS.[42] Another study allowed individuals with an upper limit of 6.5 for EDSS, but the average EDSS was 3.[44] An EDSS less than 5 was an inclusion criteria for two studies.[39, 43] When conducting physical activity interventions among individuals with MS, it is important to know the level of disability and have established cut off scores. Most physical activity studies conducted among individuals with MS limit enrollment to those with mild to moderate disability.[21] However, the use of a sitting form of Tai Chi would allow the inclusion of MS individuals with greater disability, or those that have difficulty standing for prolonged periods. Sitting forms of Tai Chi are appropriate for individuals with difficulty standing.[50] Sitting Tai Chi

is associated with improved sitting balance,[51, 52] handgrip strength,[51] and eye-hand coordination.[52]

4.1 Limitations

Serious adverse events were not reported for any of the studies included in this review, indicating that Tai Chi is safe for persons with MS to perform. Only one study reported that participants did not experience adverse events.[43] Adverse events reported during Tai Chi practice may include musculoskeletal pain, but reporting of adverse events is often lacking in the literature.[53]

Study quality scores among the studies reviewed were not ideal, indicating that more rigorous study designs are essential. The range of quality scores for the RCT's was 19-26 with an average score of 23. The range of quality scores for quasi-experimental studies was 13-26 with an average score of 20. Sampling technique was not described for one study[42] and the remaining studies obtained participants through convenience sampling. The sample sizes were small with only one study providing details of a power analysis to determine sample size, likely impacting the results reported.[39] Random sampling was not used for any of the studies. Across studies, dependent variables were not adequately defined and a blinded rater was not used for study assessments. Instruments used were known to be reliable, but only one study presented reliability estimates for all measures used.[39] Clinical significance of statistical results was only provided for one study.[40] Since this was the first systematic review examining the effects of Tai Chi on physical and psychosocial function among persons with MS, it was important to examine the state of the science and all published intervention studies were included, regardless of study quality scores.

Each of the studies reviewed performed pre- and post-intervention within group statistical analyses. Among the RCT's (n=3), only one of the studies performed between group comparisons.[39] Among the quasi-experimental studies (n=5), only one study assessed between group comparisons.[43] Averill (2014) performed multiple statistical t-tests without post hoc corrections, thus the risk for Type I error is high and may have impacted their findings.

Intervention adherence was reported as 60% for only one study.[43] The remaining studies did not report adherence and may limit the ability to interpret the effectiveness of the intervention. Finally, one study did not report attrition.[46] The attrition rates ranged from 5.6% to 43% and this is another factor that limits the ability to interpret the effectiveness of the intervention.

One limitation in conducting this review was the inclusion of English language publications only. It is possible that there are studies published in other languages that were not included. The study published by Averill[42] was a thesis and did not undergo the formal peer review process. Interpretation of the results are limited as most of the studies only performed within group analysis of the beneficial effects of Tai Chi in individuals with Multiple Sclerosis.

5. Conclusions

This review examined the effects of Tai Chi on physical and psychosocial function among individuals with Multiple Sclerosis. Despite quality scores for the studies, the results indicate that Tai Chi is likely safe and may provide benefits. Collectively, the studies reported statistically significant improvements in balance, gait, flexibility, fatigue, depression, and quality of life. These findings offer a promising alternative for MS symptom management with the use of Tai Chi. Further research is needed using more rigorous study designs, detailed intervention descriptions, larger sample sizes, adequate Tai Chi exercise doses, and carefully chosen outcome

measures that assess the mechanisms, as well as the effects of Tai Chi, before widespread recommendations can be made.

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Figure 1: PRISMA Study Selection Process

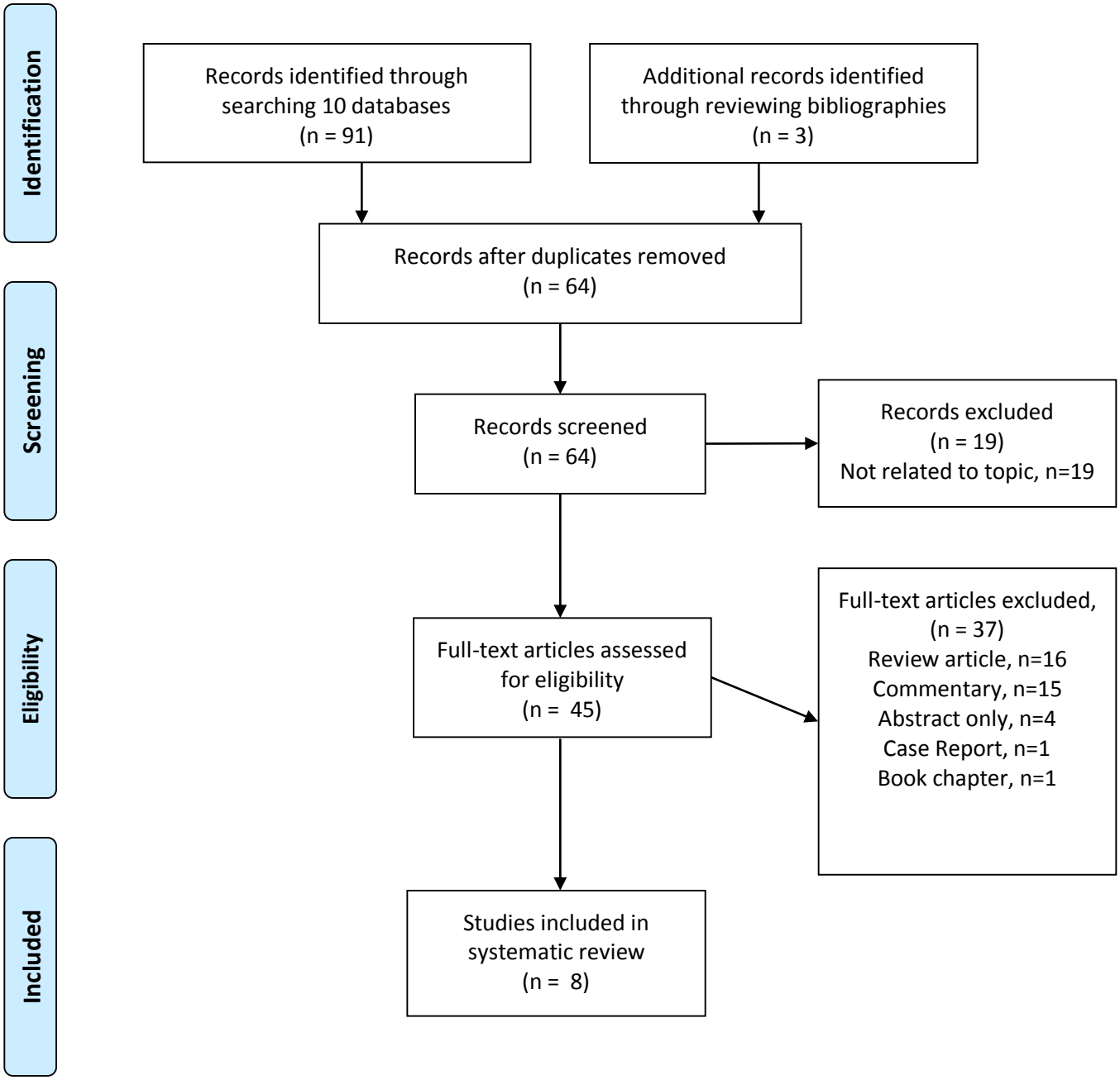

Table 1: Summary of Tai Chi Intervention Studies among Individuals with Multiple Sclerosis

First Author, Yr. Location	Participant Details	N	Intervention/ Control Details	Study Variable/ Measures	Results	Quality Index
Randomized Controlled Trials						
Azimzadeh, 2015 Iran	RRMS (n=36) MS Duration Range: Less than 6 years=26% 6-10 years=26% More than 10 years=44% Age Range: 20-30=35% 31-40=35% 41-50=26% 51-60=3% EDSS<5 Women=100%	36	Tai Chi, n=18 Yang style, 6 forms 24 Sessions, 12 weeks Control (treatment as usual), n=18	*Physical* Balance (BBS)	No significant between group differences ($p>0.05$), post-intervention. Tai Chi group had significant within group improvements in balance ($p<0.05$), post-intervention. Attrition=5.6% SAE= Not reported Intervention adherence= Not reported	26
Kaur, 2014 India	RRMS (n=16) Unknown type (n=9) MS Duration mean=8.25 years Mean Age =36.75 years EDSS=3.19	25	<u>Group 1</u> N=8 Tai Chi style=not specified, 6 forms 10-12 weeks, 20 sessions, 60 minutes Tai Chi + mental practice	*Physical* Balance (mCTISB) Dynamic Gait Index Functional Reach (FR)-lateral and forward Timed up and go (TUG)	Between group differences not reported. Both Tai Chi only and Tai Chi + mental practice groups had significantly better within group scores on Dynamic Gait Index, Functional Reach,	23

	average Women=50%		<u>Group 2</u> N=8 Tai Chi style=not specified 10-12 weeks, 20 sessions, 40 minutes Tai Chi only	*Psychosocial* Activities-specific balance confidence (ABC)	Timed Up and Go, and Activities-specific Balance Confidence ($p<0.05$), post-intervention. Attrition rate=36% SAE=Not reported Intervention adherence=Not reported	
Mills & Allen 2000 UK	SPMS (n=24) MS Duration mean=19.6 years EDSS=not reported Mean Age=49.8 years Women=81%	24	Tai Chi, n=12 Tai Chi style=not specified 6 Sessions Control (treatment as usual), n=12	*Physical* Balance (single leg standing test) *Psychosocial* Symptom Rating Questionnaire	Between group differences not reported. Tai Chi group had significant within group improvements in balance, symptoms, and less deterioration post- intervention and at a 3-month follow up ($p<0.05$). Attrition=33% SAE=Not reported Intervention Adherence=Not reported	19
Quasi-Experimental Trials						
Averill, 2014 USA	MS type reported as mild-moderate MS duration=Not reported Mean sEDSS=3.86 Mean PDSS=2.42 Mean Age=50 years	8	Tai Chi, n=8 Yang style, standing and walking 9 sessions, 3 weeks pre-post intervention only	*Physical* Foot tapping test Chair rise test Cutaneous pressure sensation 25-foot walk speed Balance (CoP velocity, net excursion, TcT)	*Physical* Tai Chi group had significantly better muscle strength, foot taps, chair rise time, standing meditation with arm movements and average CoP velocity, tandem stance time to contact CoP to base of support, total wellbeing scores, and	23

	Women=88%			*Psychosocial* Fatigue (FSS) impact of disease (MSIS-29)	psychological score ($p<0.05$), post-intervention. Tai Chi group had no significant change in plantar pressure sensitivity, walking speed, standing balance, standing balance without arm movements, physical score, fatigue level, and leg fatigue score ($p>0.05$), post-intervention Attrition=12.5% SAE=Not reported Intervention Adherence=Not reported	
Burschka, 2014 Germany	RRMS (n=27) SPMS (n=4) CIS (n=1) Unknown type (n=8) MS duration mean=7 years EDSS<5 Mean age=43 years Women=69%	38	Tai Chi, n=21 Yang style, 10 forms 50 sessions, 25 weeks Control (treatment as usual), n=17	*Physical* Balance (14 tasks) Coordination (10 tasks) *Psychosocial* Depression (CES-D) Fatigue (FSMC) Life Satisfaction (QLS)	Tai Chi group had significantly better balance, coordination, fewer depressive symptoms, stable fatigue scores, and improved life satisfaction scores, compared to controls ($p<0.05$). Attrition=16% SAE=none Intervention adherence=60% (median)	26
Tavee, 2011 USA	MS type=not specified MS duration mean=12 years	30*	Tai Chi group, N=19 with MS Tai chi style=not specified	*Physical* Pain (VAS) Disability (PDSS)	Tai Chi group had significant within group improvements in bodily pain, cognitive and psychosocial fatigue scores,	19

	EDSS mean=3 Mean age=46 years Women=77 %		8 sessions, 8 weeks Walking meditation 30 minutes, Moving mediation (includes Tai Chi forms) 30 minutes, Sitting meditation 30 minutes Control (treatment as usual), N=11 with MS	*Psychosocial* Fatigue (MFIS-5)	and mobility ($p<0.05$), post-intervention. Tai Chi group disability scores were not statistically significantly changed (p value not reported), post-intervention. Attrition=43% SAE=not reported Intervention Adherence=not reported	
Mills, 2000 UK	SPMS (n=8) Unknown type (n=4) MS duration mean=22 years Mean age=48 years EDSS=Not reported Women=63%	12	Tai Chi, n=12 Tai Chi style=not specified 6 sessions, supplies videotape, audio tape, and printed handout. Tai Chi homework practice diary pre-post intervention only	*Physical* Balance (single leg standing test) *Psychosocial* Symptom rating questionnaire Profile of mood states (POMS)	Tai Chi group had significantly improved depression score, participant rating of overall symptom change, and balance ($p<0.05$), post-intervention. Homework practice time=average 221 minutes per week Attrition=33% SAE=Not reported Intervention adherence=Not reported	19
Husted, 1999 USA	Chronic progressive (n=5) RRMS (n=11) Unknown type (n=4) Age=not reported	20	Tai Chi, n=19 Tai Chi style=not specified 16 sessions, 8 weeks pre-post intervention	*Physical* 25-foot walk speed Hamstring flexibility *Psychosocial* Quality of Life (SF-	Tai Chi group had increased walking speed 21%, hamstring flexibility 28%, vitality 15%, mental health 5%, and social functioning 13%, post-intervention.	13

	EDSS=not reported MS duration=not reported Women=84%		only	36)	Tai Chi group had 10% declines in physical function and general health. Attrition=Not reported SAE=Not reported Intervention Adherence=Not reported	

*This study included individuals with Peripheral Neuropathy and MS, thus abstracted data/results includes pertains to those with MS only. ABC=Activities-specific Balance Confidence, BBS=Berg Balance Scale, CES-D=Center for Epidemiological Studies Depression Scale, CIS= Clinically Isolated Syndrome, CoP=Center of Pressure, EDSS=Expanded Disability Status Scale, FSMC=Fatigue Scale of Motor and Cognitive Functions, FSS=Fatigue Severity Scale, mCTISB=Modified Clinical Test of Sensory Organization and Balance, MFIS=Modified Fatigue Impact Scale, MIQ-RS=Movement Imagery Questionnaire-Revised second edition, MOS=Medical Outcomes Study, MSIS-29=Multiple Sclerosis Impact Scale, MSQOL-54=Multiple Sclerosis Quality of Life Questionnaire, QLS=Questionnaire of Life Satisfaction, PDSS=Patient-Determined Disease Steps, POMS=Profile of Mood States, RRMS=Relapsing Remitting Multiple Sclerosis, SAE=Significant Adverse Event, sEDSS=self- report Expanded Disability Status Scale, SF-36=36-item Short Form Health Survey, SPMS=Secondary Progressive Multiple Sclerosis, TcT=Time to Contact, TUG=Timed Up and Go

Table 2: Study Quality Scores

Criteria	Azimzadeh (2015)	Kaur (2014)	Mills & Allen (2000)	Averill (2014)	Burschka (2014)	Tavee (2011)	Mills (2000)	Husted (1999)
Purpose of the study	2	2	1	2	2	2	1	2
Sample Selection Technique	1	1	1	0	1	1	1	1
Description of Subjects	2	1	1	2	2	2	2	1
Subject allocation	2	2	2	1	1	1	1	1
Comparability of groups	2	2	2	0	2	1	0	0
Pre/post intervention data collection	2	2	1	2	2	1	2	1
Independent variables	2	1	0	2	2	1	1	1
Dependent variables	1	1	1	1	1	1	1	1
Instrument validity	2	1	1	2	2	1	2	1
Instrument reliability	2	1	1	1	1	1	1	1
Procedures	1	1	1	2	2	1	1	1
Interventions	1	1	1	1	1	1	1	1
Follow-up at conclusion of study	2	1	2	2	2	2	2	0
Descriptive statistics	2	2	2	2	2	0	1	0
Inferential statistics	1	2	1	2	2	2	1	0
Clinical and Statistical Significance	1	2	1	1	1	1	1	1
Total Score	**26**	**23**	**19**	**23**	**26**	**19**	**19**	**13**

Appendix A: Search Strategy

Database	Search Terms
PubMed	(("Multiple Sclerosis"[Mesh] or "multiple sclerosis")) AND ("Tai Ji"[Mesh] or "tai chi")
CINAHL	(("Multiple Sclerosis"[Mesh] or "multiple sclerosis")) AND ("Tai Ji"[Mesh] or "tai chi")
PsycINFO	DE ("Multiple Sclerosis" or “multiple sclerosis”) and ("Tai ji" or "Tai chi")
Prospero	(tai chi or tai ji) and “multiple sclerosis”
Web of Science	(("tai chi" or "tai ji") and "multiple sclerosis")
Embase	multiple sclerosis'/exp AND 'tai chi'/exp
Academic Search Complete	multiple sclerosis AND (tai chi or tai ji)
AMED	(multiple sclerosis and tai chi).af.
Proquest Dissertations and Abstracts	ab("multiple sclerosis") AND ab(("tai chi" OR "tai ji"))
Clinicaltrials.gov	Multiple Sclerosis AND Tai Chi
SPORTDiscus	“Multiple Sclerosis” AND (“Tai Chi” or “Tai Ji”)
Google Scholar	multiple sclerosis "tai chi"