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Research Article

# Cost-Effectiveness of a Therapeutic Tai Ji Quan Fall Prevention Intervention for Older Adults at High Risk of Falling

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## Abstract

**Background:** Data on the cost-effectiveness of proven fall prevention exercise interventions are limited. We aimed to establish the cost-effectiveness of Tai Ji Quan: Moving for Better Balance (TJQMBB) compared with a conventional exercise intervention for older adults at high risk of falling.
**Methods:** We conducted a trial-based cost-effectiveness analysis involving 670 older adults who had a history of falling or impaired mobility. Participants received one of three interventions—TJQMBB, multimodal exercise, or stretching exercise (control)—each of which was implemented twice weekly for 24 weeks. The primary cost-effectiveness measure was the incremental cost per additional fall prevented, comparing TJQMBB and multimodal exercise to Stretching and TJQMBB to multimodal exercise, with a secondary measure of incremental cost per additional quality-adjusted life-year (QALY) gained. The intervention was conducted between February 2015 and January 2018, and cost-effectiveness was estimated from a health care system perspective over a 6-month time horizon.
**Results:** The total cost to deliver the TJQMBB intervention was $202,949 (an average of $906 per participant); for multimodal exercise, it was $223,849 ($1,004 per participant); and for Stretching, it was $210,468 ($903 per participant). Incremental cost-effectiveness ratios showed that the multimodal exercise was cost-effective ($850 per additional fall prevented; $27,614 per additional QALY gained) relative to Stretching; however, TJQMBB was the most economically dominant strategy (ie, having lower cost and being clinically more efficacious) compared with multimodal and stretching exercises with regard to cost per additional fall prevented and per additional QALY gained. TJQMBB had a 100% probability of being cost-effective, relative to Stretching, at a threshold of $500 per each additional fall prevented and $10,000 per additional QALY gained. Sensitivity analyses showed the robustness of the results when extreme cases, medical costs only, and missing data were considered.
**Conclusions:** Among community-dwelling older adults at high risk for falls, TJQMBB is a cost-effective means of reducing falls compared with conventional exercise approaches.
**Trial Registration:** Clinicaltrials.gov (NCT02287740).

**Keywords:** Exercise, Evidence-based interventions, Physical activity, Quality of life

Falls among community-dwelling older adults are of growing public health concern worldwide. In the United States, approximately one in four adults 65+ years of age living in the community reports falling annually; an estimated 38% of these falls result in injuries (1) that lead to emergency department visits, hospital admissions, or death (2,3). Recent national estimates show a significant increase in

the death rate from falls by an average of 3.0% annually between 2007 and 2016 (4). Medical treatments of fall-related injuries are costly (2,5,6). In 2015, the total medical costs for falls in older adults totaled more than $50 billion, an increase of nearly 32% over 2013 (7). Therefore, falls and falls injuries among older adults impose an increasing economic burden on the health care system (7,8).

Evidence generated from randomized controlled fall prevention intervention trials has led to the consensus that exercise can reduce the risk and incidence of falls among older adults (9–11) while still being cost-effective (12,13), making it highly appropriate and relevant in clinical practice as a primary resource for the prevention of falls. However, not all proven programs are equal in their resource requirements, cost-effectiveness, or monetary savings (14,15). Therefore, identifying optimal program choices from among currently available proven interventions is urgently needed and relevant from the perspectives of public health and the integration of evidence-based programs into clinical practice. Such efforts are likely to benefit organizations and health care planners/providers in evaluating, planning, and making informed decisions about the effective use of resources in relation to the dissemination and implementation of evidence-based interventions in broader community contexts (8,16).

Using data from a previous comparative effectiveness trial (17), the objective of this study was to determine the comparative costs and effects of the evidence-based Tai Ji Quan: Moving for Better Balance (TJQMBB) intervention relative to multimodal exercise (Multimodal), another proven intervention (18), and a control condition (Stretching), in older adults at high risk of falling.

## Methods

### Study Design

The study was a trial-based cost-effectiveness analysis. Details on the original trial design, methodologies, and intervention protocols have been described elsewhere (17). Briefly, the study involved a randomized clinical trial in which participants were randomly assigned to one of three exercise interventions: TJQMBB, Multimodal, or stretching exercises. The protocol required that participants in each intervention participate in a 60-minute exercise session twice weekly for 24 weeks. The intervention was conducted between February 2015 and January 2018.

To determine cost-effectiveness, the present study compared TJQMBB and multimodal exercise with stretching exercise and TJQMBB with multimodal exercise. Data for the comparisons of costs and effectiveness were derived from the clinical measures of falls and quality of life and resource use obtained from trial group- and person-level data, with the incremental cost-effective analysis performed from a health care system perspective (19) over a 6-month time horizon. Study outcome assessors were blinded to group allocation.

### Participants

The target population was community-dwelling adults aged 70 years of age and older. To be eligible, participants were required to have fallen at least once in the preceding 12 months and have a health care provider's referral indicating the participant was at risk of falls or to show impaired mobility (a Timed-Up-and-Go (20) result of >13.5 seconds) (21). We excluded individuals if they (a) were physically active, (b) had cognitive impairment (defined as a Mini-Mental State Examination (22) score ≤ 20), or (c) had major medical or physical conditions.

### Interventions

The three active group-based exercise interventions were delivered, with nonoverlapping class schedules, in 15 community sites (encompassing seven urban and suburban cities across three counties in Oregon) including senior/community centers, churches, medical clinics, and nonprofit organizations. Exercise classes within each intervention arm varied in size, with a range of 9–21 participants. Interventionists delivered the interventions after being trained for an equal amount of time in their respective protocols. TJQMBB instructors were trained by the first author prior to the intervention, and the instructors who delivered Multimodal and Stretching were community instructors who all had a background in exercise science and equivalence in teaching experience.

The exercise protocol in each of the three interventions was standardized with regard to exercise frequency, duration, and intensity, and was produced as a manual for the purpose of replicability (17). Specifically, all three interventions involved a 60-minute exercise session conducted twice weekly for 24 weeks, with each consisting of a 10-minute warm-up, 40–45 minutes of core exercise components, and a 5-minute cool-down activity. Attendance at each session was recorded by the class instructor, and exercise intensity in each intervention arm was monitored through a subjective measure of perceived exertion. During the first 10 weeks, participants in TJQMBB and multimodal exercise participated at a level of exertion that was characterized as being "Light to Moderate" (equivalent to 2–4 on the 0–10 Borg CR10 scale) and progressed to "Moderate to Strong" and "Strong" (equivalent to 5–6 on the 0–10 scale) after 10 weeks of intervention. Intensity in the Stretching control group, however, was kept constant at a level of between "Very Light" (1) and "Light" (2) throughout the 24-week active intervention period. No additional in-home or between-sessions exercises were assigned for any of the three interventions during the study period.

#### Tai Ji Quan: Moving for Better Balance

This intervention involved practice of a core 8-form routine with built-in variations and a subroutine of therapeutic exercises (17,23). The protocol focused primarily on practicing self-initiated Tai Ji Quan-based forms and exercise activities integrated with synchronized breathing. The intervention included movements that emphasized controlled center of gravity displacement, unilateral weight-bearing and weight-shifting, trunk and pelvic rotation, ankle sway, and eye–head–hand movements. Exercises were progressive during practice with a gradual increase in movement complexity over time.

#### Multimodal exercise

This intervention consisted of a multimodality exercise program adapted from a previous study (24). The program includes a mix of exercises, including aerobic (eg, long strides, heel–toe walking, narrow- and wide-based walking, and sidestepping), strength (eg, ankle dorsiflexors, knee extensors, and hip abductors), balance (tandem foot-standing, heel–toe and line walking, single-leg standing, alternation of the base of support, weight transfers, and various reaching and stretching movements away from the center of gravity), and flexibility or stretching (eg, major upper- and lower-body muscle groups). At 4 months, use of gym-based equipment, such as hand and ankle weights, resistance tubing, and balance foams, was integrated into the strength and balance exercises. Training was progressive, with increasing challenges made with respect to movement pace, patterns and coordination, and joint range of motion.

### Stretching exercise

This intervention was an exercise stretching routine (25) that consisted of breathing, stretching, and relaxation activities, with the majority of the stretches performed in a seated position. The core part of the exercise protocol consisted of a variety of combined seated and standing stretches involving the upper body (neck, arms, upper back, shoulders, and back and chest) and lower extremities (quadriceps, hamstrings/calves, and hips), along with slow and gentle trunk rotations. Also included were abdominal breathing and progressive relaxation exercises of major upper- and lower-extremity and trunk muscle groups.

## Measures

### Primary and secondary outcomes

The primary clinical end point was the reduction in the incidence of falls at 6 months. The number of falls during the trial was ascertained by a daily "fall calendar" (17,25). A fall was defined as "when you land on the floor or the ground, or fall and hit objects like stairs or pieces of furniture, by accident." Falls ascertainment started with the first intervention class and continued until the end of the 24 weeks, or until a participant withdrew, died, or was lost to follow-up. Over the 6-month falls surveillance period, 664 (99%) of the 670 participants provided full follow-up data on falls, and the average follow-up time on falls was 5.98 months (median: 6.0 months).

The secondary end point was the change in the EuroQol (EQ-5D-3L) measure of health-related quality of life (26), administered at baseline and 6 months (at termination of the intervention). The EQ-5D assesses health status in five domains: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each domain was measured at three levels: no problems (coded as 1), some problems (2), and extreme problems (3). An EQ-5D utility score at baseline and 6 months for each participant was calculated based on the U.S. population-based (preference-weighted) health index scores on a scale ranging from 0.0 (worst health state) to 1.0 (best health state/healthy) (27). The average utility score was subsequently used for calculating quality-adjusted life-years (QALYs) by multiplying the index score by the duration of the intervention to derive the corresponding QALYs. At 6 months, 633 (94%) of the participants provided complete data on EQ-5D. If an EQ-5D value was missing for a participant at 6 months, the baseline score of that participant was used.

### Measures of health service utilization costs

For the cost-effectiveness analysis, a survey of health-related utilization expenses was used to record health service utilization expenses incurred during the 6-month intervention period. The survey (available in the Supplementary Material) consisted of six general medical services that participants may have received (eg, physical therapy/chiropractic, health care home visits, medical treatment on falls-related injuries, feet or ankle joint problems, and knee or hip replacement) and included the associated costs, both insured and out-of-pocket expenses, related to each service received. The survey was administered at two equivalent recall periods, the first at the beginning of the fourth month (covering costs from baseline to the end of the third month) and then at 6 months (covering costs from the beginning of the fourth month to the end of the sixth month). Where available, medical insurance/Medicare billing statements were obtained from each participant. In situations where cost information was not available (eg, physical therapy or home visits), expenses were estimated from the number of sessions/visits reported multiplied by the salary estimates obtained from the 2016–2017 U.S. Department of Labor, Bureau of Labor Statistics.

## Statistical Methods

### Analysis of outcomes

The original study (17) was designed to detect a difference, with 80% power and a 35% reduction, between two negative binomial rates resulting from the 6-month intervention between the two exercise interventions (TJQMBB and multimodal exercise) relative to Stretching, with a sample size of 666 and taking into account a 15% attrition rate. Power was not calculated between TJQMBB and Multimodal due to the lack of a priori effect size estimates.

We compared the number of falls (a count variable) ascertained during the trial period across the three intervention groups using a negative binomial regression model from which we derived incidence rate ratios (IRRs) with their corresponding 95% confidence intervals (CIs) comparing TJQMBB and Multimodal with Stretching and between TJQMBB and Multimodal. In each model, we ran the analysis with and without baseline covariates (ie, age, sex, health status, history of falls); results from the unadjusted analyses are presented. For the secondary outcome, we analyzed changes from baseline in the EQ-5 utility scores (a continuous variable) with a linear mixed-effect model. The model was run with and without the covariates indicated previously. We used intention-to-treat and two-sided statistical tests at a significance level of 0.05 for all analyses. Analyses were conducted using Stata (Stata Corp LP, release 13).

### Economic evaluation

Our primary economic analysis focused on incremental costs per additional fall prevented, comparing the TJQMBB and Multimodal interventions with the Stretching intervention. We took a health care system perspective (19) by including health utilization services of the participants and resource use costs that are necessary to implement a public-health-based fall prevention program for community-dwelling older adults. All unit costs (in U.S. dollars) were calculated for the 2016–2017 financial year (base year), and no discount was applied because the intervention lasted only 6 months. The analytic time horizon for which cost data were collected and analyzed was confined to the 6-month trial timeframe. Our valuation on resource use incorporated costs incurred during the 6-month intervention period with the following components: (a) intervention-related costs, including the resource costs for running each intervention and participant travel expenses to and from classes, and (b) participant health service utilization costs. Program development costs and other research costs related to the clinical trial implementation and evaluation were excluded.

### Cost-effectiveness analysis

In our planned base-case economic evaluation, we first compared the costs and cost-effectiveness of TJQMBB and Multimodal relative to Stretching at 6 months, followed by a comparison between TJQMBB and Multimodal. We calculated the incremental cost-effectiveness ratio (ICER), which provided an estimated incremental cost per additional fall prevented by dividing differences in average costs by differences in effects of intervention and comparators. Our total costs included intervention-related costs and health service utilization costs. Through a similar analytic approach, we estimated ICERs in cost per additional QALYs gained between TJQMBB and Multimodal relative to Stretching, and between TJQMBB and Multimodal via calculation

of the difference in average costs divided by the difference in the average utility estimates in the QALY measure.

**Sensitivity analysis**

We generated cost-effectiveness acceptability curves from the base-case analysis, through bootstrapping of our trial data ($n$ = 1,000, $n$ = 5,000, $n$ = 10,000) related to mean costs and effects, to describe the probability that TJQMBB or Multimodal is cost-effective compared with Stretching at varying incremental thresholds for cost per additional fall prevented (Supplementary Material). We used a low threshold of $10,000, which approximates recently published values of $9,389 (5) to $9,463 (2) for a fall-related injury, and a high threshold of $30,000 (2) for hospital costs of a fall injury that the U.S. health system might be willing to pay for an additional fall prevented. For QALYs, we used the United States-recommended $50,000-per-QALY threshold (28). We also conducted three additional sensitivity analyses, recalculating our ICERs by (a) removing extremely high-cost cases on health utilization (ie, the top 5th percentile), (b) taking a narrow health care perspective (by including health care [medical] costs borne by third-party payers and paid out of pocket by participants), and (c) using multiple imputation of data, under the assumption of missing at random, for participants who did not provide any information on health utilization.

For economic evaluation, we used SPSS (version 23; IBM Corp, Armonk, NY) and Microsoft Excel (Microsoft Office Professional Plus 2016).

## Results

### Participant Characteristics

A total of 1,147 individuals were screened for eligibility, of which 670 participants were qualified and enrolled in the interventions (17). Participant characteristics were found to be similar in terms of demographic descriptors and comorbidities at baseline (see Supplementary Table 1).

### Effectiveness

At 6 months, there were fewer falls in TJQMBB ($n$ = 152, mean fall rate = 0.68, $SD$ = 1.27) compared with Stretching ($n$ = 363, mean = 1.63, $SD$ = 3.93) and Multimodal ($n$ = 218, mean = 0.98, $SD$ = 1.80). Both the TJQMBB and Multimodal groups had a lower IRR (IRR = 0.42, 95% CI: 0.31, 0.56, $p$ < .001 for TJQMBB; IRR = 0.60, 95% CI: 0.45, 0.80, $p$ = .001 for Multimodal) compared with the Stretching group. In addition, the TJQMBB group showed a significantly lower IRR compared with the Multimodal group (IRR = 0.69, 95% CI: 0.52, 0.94, $p$ = .01). With respect to QALYs, there was a 0.04 (95% CI: 0.02, 0.06) difference in mean health state utility scores of EQ-5 between TJQMBB and Stretching ($p$ < .001) and 0.02 (95% CI: 0.01, 0.04) between Multimodal and Stretching ($p$ = .005), favoring the TJQMBB and Multimodal groups, respectively. The TJQMBB group also scored better than the Multimodal group ($p$ = .04, 95% CI: 0.01, 0.03). In all primary and secondary outcome analyses, inclusion of baseline covariates did not change the results significantly.

### Intervention-Related Costs

Full intervention-related cost data were available on the three intervention groups. The total intervention delivery cost, including program promotion, recruitment, class instruction, equipment, and intervention classroom rental, was $590,510, corresponding to an average cost of $847 per participant for TJQMBB, $946 for Multimodal, and $852 for Stretching (Supplementary Table 2). With the inclusion of participant travel costs, the total cost increased to $628,266, with an average cost of $906 per participant for TJQMBB, $1,004 per participant for Multimodal, and $903 per participant for Stretching. We found no significant differences among the three groups in terms of the average cost related to participant travel expenses ($p$ = .21), health utilization ($p$ = .48), or average total costs ($p$ = .50).

### Health Service Utilization Costs

Information on health utilization services was available for 219 (98%) of 224 participants in TJQMBB, for 206 of 223 (93%) participants in Multimodal, and for 212 (95%) of 223 participants in Stretching. Descriptive individual-level health service utilization data, by cost categories, from the study participants across the three intervention groups are shown in Supplementary Table 3. The total health utilization cost per participant in TJQMBB was $1,958, compared with $2,583 in Multimodal and $2,131 in Stretching.

### Cost-Effectiveness

TJQMBB emerged as the economically dominant strategy for reducing the incidence of falls (ie, having lower cost and being clinically more efficacious) among the three intervention groups, showing the lowest average cost ($2,864) and fall rate (0.68) compared with Multimodal ($3,587, fall rate = 0.98) and Stretching ($3,035, fall rate = 1.63), generating an ICER of –$2,410 and –$180, respectively (Table 1). Costs were higher ($3,587), but the outcome (fall rate = 0.98) was better in the Multimodal group compared to the Stretching group (cost $3,035, fall rate = 1.63), generating an ICER of $850 per additional fall prevented. Because TJQMBB was the lowest in cost and most effective in improving QALYs, it again was the dominant strategy over the Stretching and Multimodal intervention groups. The ICER of Multimodal relative to Stretching was $27,614 per additional QALY gained.

### Sensitivity Analyses

The cost-effectiveness acceptability curves (Figure 1 Panel A, see also Supplementary Tables 4A and 4B) showed that the probability of TJQMBB being cost-effective, relative to Stretching, was 100% if a decision maker was willing to pay $500 and at the current threshold of $9,389–$9,463 for each additional fall prevented. In contrast, the Multimodal intervention showed an 80% probability of cost-effectiveness at a willingness-to-pay threshold of $20,000 to prevent a fall. Results on QALYs showed that TJQMBB was 100% cost-effective compared with Stretching if decision makers were willing to pay $10,000 per additional QALY gained (compared with 68% for Multimodal). Both TJQMBB and Multimodal showed a high probability (>90%) of being cost-effective compared with Stretching at the willingness-to-pay threshold of $50,000 (Figure 1 Panel B). Sensitivity analyses showed a similar pattern of results, indicating that, under all three evaluation scenarios, TJQMBB was a dominant strategy over Stretching and Multimodal with respect to cost per additional fall prevented and per additional QALY gained (Supplementary Table 5).

## Discussion

In this study of community-dwelling older adults at high risk of falling, we found that both TJQMBB, a therapeutically tailored

**Table 1.** Cost-Effectiveness at Base Case (Intervention-Related Costs + Health Service Utilization Costs)[a], 2015–2017

| Analysis on Primary Outcome: Falls | | | | | |
|---|---|---|---|---|---|
| Group | Total Costs US$/ Participant ($) | Average Number of Falls | Incremental Cost ($) | Incremental Effectiveness | ICER[b] Cost per Additional Fall Prevented ($) |
| Stretching | 3,035 | 1.63 | — | — | — |
| Multimodal[c] | 3,587 | 0.98 | 552 | 0.65 | 850 |
| TJQMBB[d] | 2,864 | 0.68 | −171 | 0.95 | −180 |
| Secondary analysis: falls | | | | | |
| TJQMBB[e] | 2,864 | 0.68 | −723 | 0.30 | −2,410 |
| Analysis on Secondary Outcome: QALYs | | | | | |
| Group | Total Costs US$/ Participant ($) | Average QALYs Scores | Incremental Cost ($) | Incremental Effectiveness | ICER[b] Cost per Additional QALY Gained ($) |
| Stretching | 3,035 | 0.46 | — | — | — |
| Multimodal[c] | 3,587 | 0.48 | 552 | 0.02 | 27,614 |
| TJQMBB[d] | 2,864 | 0.50 | −171 | 0.04 | −4,269 |
| Secondary analysis: QALYs | | | | | |
| TJQMBB[e] | 2,864 | 0.50 | −723 | 0.02 | −36,151 |

*Notes:* ICER = incremental cost-effectiveness ratio; QALY = quality-adjusted life-year; TJQMBB = Tai Ji Quan: Moving for Better Balance.

[a]The total intervention-related costs and health service utilization costs are $641,577 for TJQMBB, $799,948 for Multimodal, and $676,790 for Stretching.

[b]For a comparison of TJQMBB versus Stretching, a negative ICER indicates that the TJQMBB intervention is dominant in terms of cost-effectiveness ($Cost_{TJQMBB} - Cost_{Stretching} < 0$; $Effect\_Falls_{TJQMBB} - Effect\_Falls_{Stretching} < 0$, $QALY_{TJQMBB} - QALY_{Stretching} > 0$) compared with Stretching. The same interpretation applies to the comparison of TJQMBB versus Multimodal. In such cases, negative values for ICERs are interpreted to dominate the comparator (ie, TJQMBB saved on costs and was clinically more efficacious).

[c]Using Stretching as a comparator.

[d]Using Stretching as a comparator.

[e]Using Multimodal as a comparator.

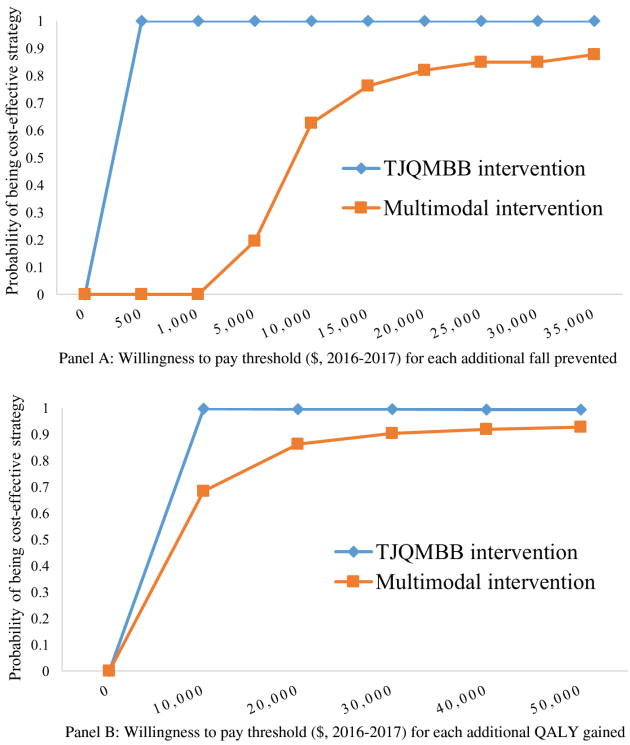


**Figure 1.** Cost-effectiveness acceptability curves showing the probability that interventions (TJQMBB, multimodal) are cost-effective compared with stretching exercise for willingness to pay thresholds for each additional fall prevented (A) and each additional QALY gained (B). TJQMBB = Tai Ji Quan: Moving for Better Balance; QALY = quality-adjusted life-year.

Tai Ji Quan program, and a multimodal exercise program were cost-effective, relative to stretching exercise, in reducing the incidence of falls and improving health-related quality of life. For multimodal exercise, there was a cost of $850 per additional fall prevented and $27,614 per additional QALY gained. However, TJQMBB was found to be the dominant strategy (ie, having lower cost and being clinically more efficacious) when compared with the two alternative exercise interventions (Multimodal and Stretching), with a high probability of being cost-effective at current willingness-to-pay thresholds (2,5), resulting in cost savings for falls prevented and QALYs gained over a 6-month time horizon.

Economic evaluation of cost-effectiveness of exercise-based interventions in reducing falls in older adults remains significantly limited. Although differences in study populations, intervention type, costs, delivery mode, and time frame preclude a direct comparison among programs, results of our economic analyses are consistent with those limited reports showing cost-effectiveness of exercise interventions in preventing falls among older adults (12,13,29–31) and people with Parkinson's disease (32,33). Our findings were, however, inconsistent with the evaluation of a study that indicated a lack of strong evidence to support cost-effectiveness of a group-based exercise approach (34). Unlike most other published studies that gauge the overall cost-effectiveness and the broad impacts of interventions, the present study provides indices of both the cost per additional fall prevented and the cost per additional QALY gained across two well-established exercise regimens and a standard exercise control group.

In previous analyses, TJQMBB has been identified as a cost-saving program in terms of reducing falls and increasing return on investment. For example, it was shown that the average cost-effectiveness ratio for a 48-week TJQMBB program, compared with a "doing nothing" base-case alternative, was $917 per fall prevented and $676 per fall prevented for multiple falls (35). A cost–benefit analysis of three evidence-based fall prevention programs revealed TJQMBB to be the most financially prudent option, yielding a net benefit of $529.86 (return on investment of 509%) versus $429.18 (return on investment of 127%) for the Otago Exercise Program and $137.37 (return on investment of 64%) for Stepping On (36). By analyzing first-line data in this cost-effectiveness analysis, we have demonstrated that TJQMBB is also highly cost-effective even at a significantly lower willingness-to-pay value of $500 per additional fall prevented and $10,000 per additional QALY gained. With increasing rates of fall-related deaths (4) and increasing trends and rates of emergency department fall-related visits among older adults (37,38), the estimates from this study indicate that TJQMBB is a superior cost-saving fall prevention strategy for lowering the expenditures of $9,000–$30,000 (2,5) for fall-related injuries for those at high risk of falling.

Underlying the cost savings is the fact that TJQMBB is considered a low-tech exercise modality. The implementation of the program in a community setting is relatively simple in that it requires no special requirements for space or equipment and can be delivered through trained community instructors who are certified through training workshops and refresher courses (35,39). TJQMBB has been shown to be readily implementable in both community and clinical settings, with strong evidence of uptake by service providers and clinicians, resulting in effective reach into target populations, reduced falls, and excellent program fidelity and maintenance (35,39–42). The cost-effectiveness information resulting from this study and others (12,13,36) suggests that health services and fall prevention efforts globally can address the problem of older adult falls through the adoption of a low-cost, accessible, scalable intervention such as TJQMBB.

Our study has limitations that could affect the interpretation of our results. First, we relied primarily on self-reporting in our falls measure and health utilization data, which is subject to recall bias. Future use of objective data, such as national Medicare data, will provide a more accurate account of health utilization. Second, the intervention was limited to a 6-month time horizon, which may have led to an underestimation of long-term costs and effects associated with the intervention. Further research will be required to determine the impact on costs and effects over a longer time frame.

In conclusion, compared with a stretching exercise modality and an evidence-based multicomponent exercise program, our community-based trial provides strong evidence that a 6-month TJQMBB intervention, delivered twice weekly, was most effective in reducing the incidence of falls among older adults at risk of falling, and did so at a lower cost.

## Supplementary Material

Supplementary data is available at The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences online.

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This work was supported by the National Institutes of Health (AG045094).

## Conflict of Interest

F.L. reported that he is the founder and owner of Exercise Alternatives, LLC, a consulting company, and that a voluntary licensing fee for Tai Ji Quan: Moving for Better Balance is paid directly to this company. No other disclosures were reported. The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

## Author Contributions

F.L. had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. F.L. and P.H. contributed to concept and design; acquisition, analysis, or interpretation of data; and statistical analysis. F.L., P.H., and E.E. drafted the manuscript. F.L., P.H., and L.A. obtained funding. F.L. provided administrative, technical, and material support. F.L., P.H., and K.F. were involved in study supervision. All the authors critically revised the manuscript for important intellectual content. We thank the intervention instructors and the research staff for their dedication to this study. Appreciation is also extended to all the volunteers who participated in this project.

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