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Online Unsupervised Tai Chi Intervention for Knee Pain and Function in People With Knee Osteoarthritis
The RETREAT Randomized Clinical Trial

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IMPORTANCE Tai chi is a type of exercise recommended for knee osteoarthritis, but access to in-person tai chi can be limited.

OBJECTIVE To evaluate the effects of an unsupervised multimodal online tai chi intervention on knee pain and function for people with knee osteoarthritis.

DESIGN, SETTING, AND PARTICIPANTS The RETREAT study was a 2-group superiority randomized clinical trial enrolling participants who met clinical criteria for knee osteoarthritis in Australian communities from August 2023 and November 2024.

INTERVENTIONS Participants in the control group received access to a purpose-built website containing information about osteoarthritis and exercise benefits. Participants in the intervention group received the *My Joint Tai Chi* intervention comprising access to the same website plus tai chi information, a 12-week unsupervised video-based Yang-style tai chi program, and encouragement to use an app to facilitate program adherence.

MAIN OUTCOMES AND MEASURES Changes in knee pain during walking (Numeric Rating Scale; range 0-10 with higher scores indicating greater pain) and difficulty with physical function (Western Ontario and McMaster Universities Osteoarthritis Index; range 0-68 with higher scores indicating greater dysfunction) during 12 weeks. Secondary outcomes included another knee pain measure, sport and recreation function, quality of life, physical and mental well-being, fear of movement, self-efficacy, balance confidence, positive activated affect, sleep quality, global improvement, and oral medication use.

RESULTS Of 2106 patients screened, 178 met inclusion criteria and were randomized, 89 (mean [SD] age, 61.0 [8.7] years; 66 female [74%] and 23 [26%] male participants) to the control group and 89 (mean [SD] age, 62.1 [7.3] years; 59 [66%] female and 30 male [34%] participants) to the tai chi intervention. Of the total, 170 (96%) completed both of the primary outcomes at 12 weeks. The tai chi group reported greater improvements in knee pain (control, −1.3; tai chi, −2.7; mean difference, −1.4 [95% CI, −2.1 to −0.7] units; $P < .001$) and function (control, −6.9; tai chi, −12.0; mean difference, −5.6 [95% CI, −9.0 to −2.3] units; $P < .001$) compared to the control group. More participants in the tai chi than in the control group achieved a minimal clinically important difference in pain (73% vs 47%; risk difference, 0.3; 95% CI, 0.1 to 0.4; $P < .001$) and function (72% vs 52%; risk difference, 0.2; 95% CI, 0.1 to 0.3; $P = .007$). Between-group differences for most secondary outcomes favored tai chi, including another knee pain measure, sport and recreation function, quality of life, physical and mental well-being, global improvement, pain self-efficacy, and balance confidence. No associated serious adverse events were reported.

CONCLUSIONS AND RELEVANCE This randomized clinical trial found that this unsupervised multimodal online tai chi intervention improved knee pain and function compared with the control at 12 weeks. This free-to-access web-based intervention offers an effective, safe, accessible, and scalable option for guideline-recommended osteoarthritis exercise.

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Visual Abstract

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Supplemental content

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Knee osteoarthritis (OA) is a leading cause of chronic pain and long-term disability in adults, with a global prevalence of 365 million in 2019, and is projected to rise by 75% by 2050.[1,2] All current clinical guidelines[3,4] recommend exercise as the cornerstone of knee OA management. Among the recommended exercise options, tai chi is strongly endorsed.[3,4] Systematic reviews of in-person group tai chi classes have demonstrated benefits for pain, function, stiffness, mobility, and mental health in OA,[5] with effects comparable to other forms of exercise.[6]

People typically undertake tai chi in person by attending group classes led by instructors. However, accessing in-person tai chi classes can be challenging due to geographical, financial, and service availability barriers. With 5.4 billion people using the internet globally in 2023,[7] including 75% of those 65 years and older,[8] alongside growing interest in digital health resources,[9] an online unsupervised tai chi program could offer an accessible and scalable option for access to therapeutic exercise at home. Although evidence supports online tai chi programs for other chronic health conditions, such as dementia, cystic fibrosis, or mobility impairment,[10-16] these have typically involved some form of clinician oversight and the associated costs. Additionally, to our knowledge, none were specifically designed for people with knee OA.

To address this gap, we developed a multimodal online tai chi intervention, *My Joint Tai Chi*,[17] that comprises educational information plus a 12-week unsupervised tai chi program, and an app, My Exercise Messages,[18] to encourage and facilitate tai chi adherence. This study aimed to assess the effectiveness of the tai chi intervention compared with online education alone. We hypothesized that the tai chi intervention would lead to greater improvement in the primary outcomes of knee pain during walking and physical function at 12 weeks.

Key Points

Question Can a 12-week unsupervised multimodal online tai chi intervention improve knee pain and physical function in people with knee osteoarthritis (OA)?

Findings This randomized clinical trial of 178 adults with clinically diagnosed knee OA found that a 12-week unsupervised online tai chi program with a mobile app to encourage adherence and online OA educational information improved participants' knee pain on walking and physical function more than online OA educational information alone.

Meaning These findings indicate that this freely available online tai chi intervention provides an effective, safe, accessible, and scalable option for improving access to a guideline-recommended exercise modality for knee OA.

Methods

The RETREAT study was a parallel-group, superiority pragmatic randomized clinical trial approved by The University of Melbourne Human Research Ethics Committee and registered prospectively with the Australian New Zealand Clinical Trials Registry (ACTRN12623000780651). The trial protocol is available in Supplement 1 and has been published elsewhere.[19] There were no major changes to the trial methods. Informed consent was obtained electronically from each participant. Reporting aligns with the Consolidated Standards of Reporting Trials (CONSORT)[20]; the CONSORT-EHEALTH[21]; and the Template for Intervention Description and Replication (TIDieR) reporting guidelines.[22]

Participants

Participants were recruited from the community nationwide in Australia from August 2023 to November 2024 via online advertisements, social media, and printed flyers placed around the University of Melbourne, Melbourne, Australia. Interested individuals completed an online screening questionnaire to ascertain their eligibility and provided information regarding the trial, including the Plain Language Statement in REDCap (Research Electronic Data Capture).[23,24] Individuals who were deemed eligible underwent a final telephone screening of additional eligibility questions and to confirm their prior responses. Then, informed consent was obtained through an online consent form. The main inclusion criteria were: (1) OA based on clinical criteria from the National Institute for Health and Care Excellence[25] including age 45 years or older, activity-related knee joint pain, and either no morning knee stiffness or stiffness of only 30 minutes or less; (2) history of knee pain of 3 months or longer; (3) knee pain on most days during the past month; (4) knee pain of 4 or more on an 11-point Numeric Rating Scale (NRS) in the past week during walking; and (5) having a home internet connection and a device with access to the internet. All inclusion and exclusion criteria are available in the trial protocol in Supplement 1. Demographic information, including ethnicity, was collected via self-reported questionnaire on REDCap.

Randomization, Allocation Concealment, and Blinding

Eligible and consented participants were randomly assigned in a 1:1 ratio using permuted blocks of sizes 2 and 4. The randomization list was computer generated by an independent biostatistician and concealed in password-protected software (REDCap) by a researcher not involved in the study. After randomization, the study coordinator (S.J.Z.) sent an email to participants describing their allocated website and access details and a request to access the website within 3 days. No other reminders to access the websites were sent to either group. Due to the nature of the intervention, participants were unblinded to study groups, with participants aware that we were testing a tai chi intervention. As primary and secondary outcomes were self-reported, the participants are deemed assessors, and therefore, by default the outcome assessment was unblinded. An a priori statistical analysis plan (Supplement 2) was written and published on our center's website while blinded. Biostatisticians (P.L., A.P.D.S.) were blinded to group names while analyzing data.

Tai Chi Intervention

A detailed description of the My Joint Tai Chi multimodal online intervention (https://myjoint-taichi.org/) has been

published elsewhere[17,19]; its key features are summarized in eTable 1 in Supplement 3. Its style and dosage aligns with other in-person tai chi trials for lower limb OA, where Yang style is the most common, typically delivered 2 to 3 times weekly over 8 to 24 weeks.[26,27] The My Joint Tai Chi program comprised 12 prerecorded 45-minute tai chi videos (1 video per week, performed 3 times weekly for 12 weeks) led by an experienced tai chi instructor (J.H.). Each video included warm up and cool down periods, with a modified 10-form Yang-style tai chi routine tailored for people with knee OA and little prior experience. The program commenced with simple tai chi movements and introduced new movements weekly to increase its difficulty. Participants were encouraged to download and use the previously developed, exercise behavioral change theory–informed My Exercises Messages mobile app[18] that was designed for people with knee OA to facilitate adherence to an already-prescribed exercise program. The app itself does not prescribe or deliver specific exercise instructions, but instead delivers behavior change messages designed to motivate exercise and overcome general exercise barriers. Examples of the messages are found in eTable 2 in Supplement 3. Participants were also encouraged to read the educational content on the website about tai chi, OA, treatment options, and the benefits of exercise.

Online Education Alone

The control group received access to purpose-built website containing the same educational information about OA and exercise as the My Joint Tai Chi website. However, control participants were not offered any of the tai chi information or videos nor the mobile app.

Primary and Secondary Outcomes

Outcomes were collected via online surveys at baseline and 12 weeks after randomization. If the follow-up survey was not initiated after 3 emails and 3 text reminders (sent over a period of 6 days), the researcher (S.J.Z.) telephoned participants to obtain primary outcome measures verbally. To ensure consistency and minimize potential measurement bias, each question was read verbatim, identically to the online questionnaire, without rewording or prompting. Participants who fully completed the 12-week survey were compensated with a A$ 50 (approximately US$ 34) gift voucher (2024 average exchange rate, US$ 1.00 = A$ 1.51).

Primary outcomes were 12-week changes in widely used, reliable, and valid pain[28] and physical function,[29] measures that are recommended for knee OA clinical trials.[30,31] Overall average knee pain severity during walking in the previous week was assessed using an 11-point NRS with terminal descriptors of 0 (no pain) and 10 (worst pain possible).[28] Limitation with physical function during the past week was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC; Likert, version 3.1)[29] function subscale, with scores ranging from 0 (no dysfunction) to 68 (maximum dysfunction). The prespecified minimal clinically important differences (MCIDs) were 1.8 units for pain[32] and 6.0 units for function.[33]

Secondary outcomes included (1) Knee Injury and Osteoarthritis Outcome Score (KOOS) pain[34]; (2) KOOS function in sport and recreation[34]; (3) KOOS knee-related quality-of-life subscales[34]; (4) Short Form 12 (SF-12) physical component score[35]; (5) SF-12 mental component score[35]; (6) Brief Fear of Movement Scale for Osteoarthritis (BFOM)[36]; (7) Arthritis Self-Efficacy Scale (ASES) pain subscale[37]; (8) Activities-Specific Balance Confidence Scale (ABC-6)[38]; (9) International Positive and Negative Affect Schedule–Short form (I-PANAS-SF) (positive affect subscale)[39]; (10) participant-perceived overall change in knee condition since baseline; (11) sleep quality (modified from Pittsburgh Sleep Quality of Index)[40,41]; and (12) use of oral pain medications.

Descriptive measures and medication use were collected at baseline. Adverse events (defined as problems related to trial participation requiring treatment/medication or causing negative symptoms lasting ≥2 days) were self-reported at 12 weeks via a custom survey. Adherence to tai chi exercise was self-reported using the Exercise Adherence Rating Scale, section B,[42] and as the number of days tai chi was performed per 14-night period. Acceptable adherence was defined as 2 or more days per week, averaged from weeks 2 and 12, based on other trials of exercise in knee OA.[43-45] Process measures at 12 weeks included recommendation likelihood and overall satisfaction, both assessed via NRS (range, 0 to 10, with 0 indicating not at all likely/satisfied and 10 indicating extremely likely/satisfied), and website analytic data about intervention and control website access. Additional process measures and a qualitative evaluation will be reported separately.

Sample Size

We aimed to detect a difference in change between groups that met or exceeded the MCID on either of the primary outcomes. Significance was set to $P < .025$, with a conservative Bonferroni correction for 2 primary outcomes. To obtain 80% power with a 2-sided 2.5% significance level, assuming equal between-participant SDs of 2.5 for pain and 13.0 for function, a correlation between pre- and postmeasurements of 0.25 for pain and 0.40 for function,[44] and 15% loss to follow-up, 178 participants (89 per group) were required. In all, we screened 2106 patients (**Figure**).

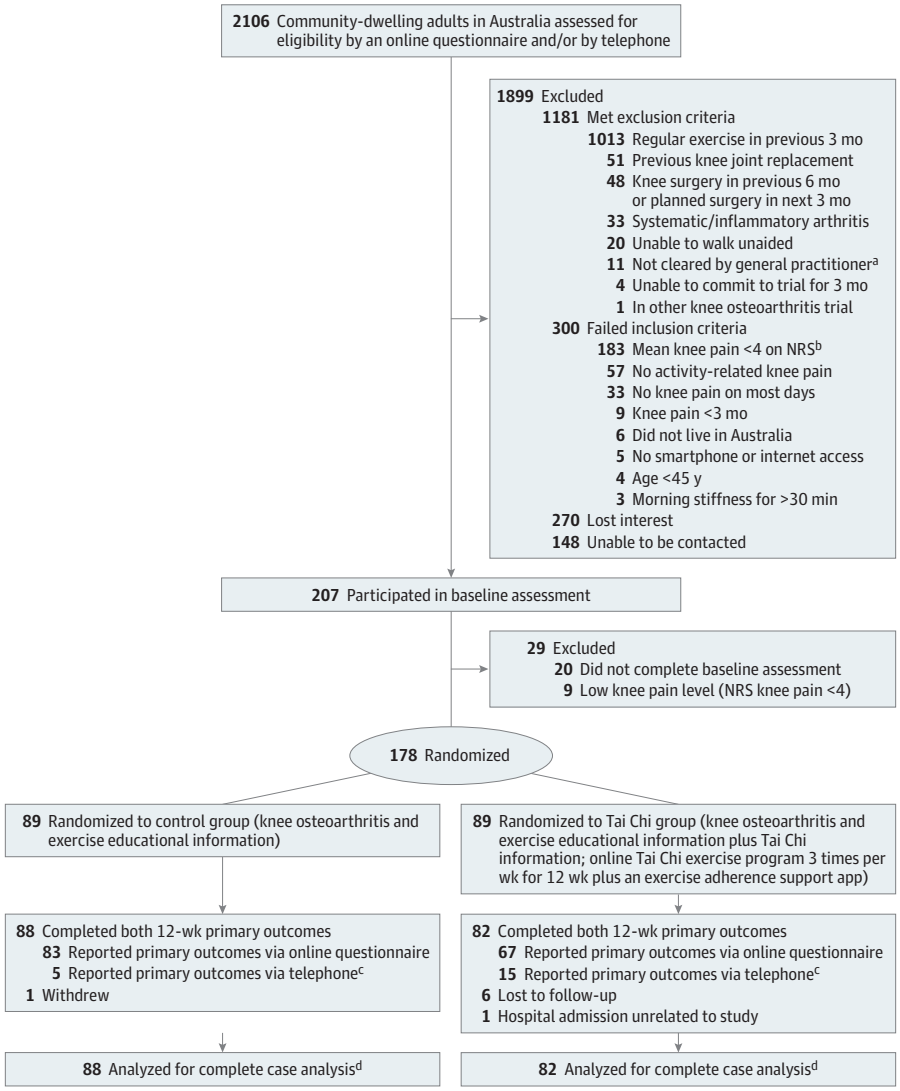
Patient and Public Involvement

The intervention was iteratively codeveloped by tai chi instructors, people with OA, physiotherapists, and OA researchers to ensure it was appropriate, safe, and practical for people with knee OA. The process is detailed elsewhere.[17] One experienced tai chi instructor (J.H.) joined the research team and appeared in the program videos. Usability testing with 5 people with knee OA was conducted using a *think aloud* process, with feedback informing subsequent website revisions.

Statistical Analysis

Primary outcomes were compared between groups using separate linear regression models adjusted for baseline levels of respective outcomes to obtain the estimated between-group mean difference and corresponding 2-sided 95% CIs and *P* values (Bonferroni-adjusted for 2 primary outcomes). We considered tai chi effective if at least 1 primary outcome showed a significant between-group difference. Number needed to treat

Figure. CONSORT Flow Diagram of Participants



NRS indicates Numeric Rating Scale.

[a]Clearance from a general practitioner was obtained for participants who reported a fall in the previous 12 months, were housebound due to immobility, or indicated they had a health condition that might compromise exercise safety on the Exercise and Sports Science Australia stage 1 pre-exercise screening questionnaire.

[b]An 11-point NRS was used to report average walking pain over the previous week (range, 0-10, with 0 indicating no pain and 10 indicating worst pain possible).

[c]Sensitivity analysis was performed excluding 20 participants (15 in tai chi; 5 in control) who reported primary outcomes via telephone at 12 weeks.

[d]Complete case analyses were performed as primary analyses due to less than 5% missing data for each primary outcome.

(NNT) for clinically meaningful improvement in knee pain and physical function was calculated. Continuous secondary outcomes were analyzed similarly. Binary secondary outcomes were compared between groups using log-binomial regression, adjusting for the outcome at baseline if available, and reported as relative risk and risk difference with corresponding 95% CIs and *P* values. Model assumptions were assessed using standard diagnostic plots.

Additionally, exploratory subgroup analyses were planned to assess potential moderation of baseline characteristics selected a priori on the primary outcomes using separate linear regression models, with an interaction term between group and the potential moderator included in the model. A sensitivity analysis was performed to estimate the average tai chi effect assuming acceptable adherence to the tai chi intervention using 2-stage least-squares model, adjusting for the baseline outcome. Unplanned post hoc analyses estimated between-group differences for primary outcomes after excluding participants reporting the primary outcomes via telephone at 12 weeks. Due to 18% missing at least 1 secondary outcome, further post hoc analyses were performed to assess the sensitivity of the primary and secondary outcomes to missingness at random and not at random. Data were analyzed using Stata, version 18.0 (StataCorp).[46] Main comparative analyses included all participants according to their randomized group and were based on complete case data due to less than 5% missing primary outcome data. Detailed methods for handling missing data are provided in the eMethods in Supplement 3.

Results

Study Participants

Of 2106 patients screened, 178 met inclusion criteria and were randomized, 89 (mean [SD] age, 61.0 [8.7] years; 66 female [74%] and 23 [26%] male participants) to the control group and

89 (mean [SD] age, 62.1 [7.3] years; 59 [66%] female and 30 male [34%] participants) to the tai chi intervention (Figure). All baseline characteristics were generally similar between groups (**Table 1**). At 12 weeks, 170 of 178 participants (96%) provided both primary outcomes, with some differences between those who did and did not provide them (eTable 3 in Supplement 3). The mean (SD) delay in 12-week survey completion was 2.4 (9.0) days. Specifically, missing primary outcomes were more frequent in the tai chi group (8%) than in the control (1%), and more missing secondary outcomes occurred in the tai chi group (27%-28%) than in the control (6%-8%; eTable 4 in Supplement 3; baseline differences presented in eTable 5 in Supplement 3). Twenty participants completed primary outcomes via telephone at 12 weeks, including 15 (75%) from the tai chi group and 5 (25%) from the control (eTable 6 in Supplement 3). Adherence to tai chi is shown in **Table 2**. In all, 64 tai chi participants (72%) completed process measures with baseline characteristics and primary outcomes comparable between those who did and did not complete these (eTables 7 and 8 in Supplement 3). Among respondents, the reported weekly mean (SD) was 2.5 (1.0) tai chi sessions, with 82% of participants achieving acceptable adherence (≥2 days/week). Tai chi participants were highly satisfied (median [IQR], 9.0 [7.0-10.0]) and likely to recommend the program (9.0 [8.0-10.0]; Table 2).

Primary Outcomes

Compared with the control at 12 weeks, tai chi intervention led to greater improvements in knee pain during walking (control, −1.3; tai chi, −2.7; mean difference in change, −1.4 [95% CI, −2.1 to −0.7] units; $P < .001$) and in WOMAC function (control, −6.9; tai chi, −12.0; mean difference in change, −5.6 [95% CI, −9.0 to −2.3] units; $P < .001$; **Table 3**). More participants in the tai chi group than in the control reached MCIDs in pain during walking (73% vs 47%; risk difference, 0.3; 95% CI, 0.1 to 0.4; $P < .001$) and in function (72% vs 52%; risk difference, 0.2; 95% CI, 0.1 to 0.3; $P = .007$) at 12 weeks (**Table 4**). For knee pain, the NNT for achieving the MCID was 4 (95% CI, 3 to 9), and for physical function, the NNT was 6 (95% CI, 4 to 20).

Secondary Outcomes

At 12 weeks, the tai chi intervention led to greater improvements than the control in most secondary outcomes including all KOOS subscales (pain, sports/recreation function, and quality of life), physical and mental health (SF-12), pain self-efficacy (ASES pain), and balance confidence (ABC scale; Table 3). More tai chi participants than control participants reported global overall knee improvement (82% vs 39%; risk difference, 0.4; 95% CI, 0.3 to 0.6; $P < .001$; Table 4).

Exploratory Analysis

Preidentified potential moderators (pain self-efficacy and treatment expectations) did not moderate tai chi effects on primary outcomes at 12 weeks (eTables 9-11 in Supplement 3). Due to the absence of participants with past tai chi experience in the control group, we were unable to conduct planned subgroup analyses for this variable.

Table 1. Baseline Characteristics of Participants by Study Group

Characteristic	Group, No. (%)	
	Control	Tai chi
Participants, No.	89	89
Age, mean (SD), y	61.0 (8.7)	62.1 (7.3)
Sex		
Female	66 (74)	59 (66)
Male	23 (26)	30 (34)
Gender		
Man/male	24 (27)	30 (34)
Woman/female	65 (73)	57 (64)
Nonbinary	0	2 (2)
Height, mean (SD), m	1.7 (0.1)	1.7 (0.1)
Body mass, mean (SD), kg	87.9 (18.8)	87.8 (21.7)
BMI, mean (SD)	31.3 (6.2)	31.0 (7.7)
Ethnicity		
Australian/New Zealander	66 (74)	67 (75)
Aboriginal and Torres Strait Islander	4 (4)	1 (1)
European	11 (12)	8 (9)
Asian	7 (8)	9 (10)
Other Oceanian	1 (1)	0
North African or Middle Eastern	0	1 (1)
Other	0	3 (3)
Education level		
Did not complete primary school	0	1 (1)
Secondary/high school	11 (12)	14 (16)
Trade/trade certificate	9 (10)	7 (8)
University/tertiary institute	48 (54)	52 (58)
Higher university degree	21 (24)	15 (17)
Currently in paid employment	49 (55)	54 (61)
Geographic location		
Major cities	49 (55)	54 (61)
Inner regional	30 (34)	27 (30)
Outer regional	8 (9)	6 (7)
Remote	1 (1)	2 (2)
Very remote	1 (1)	0
Most painful knee		
Right knee	45 (51)	45 (51)
Left knee	44 (49)	44 (49)
Knee symptom duration, median (IQR), y	6 (3-15)	7 (2-25)
Concerns in other joints		
Non–study knee	30 (34)	24 (27)
Upper body	24 (27)	30 (34)
Back and neck	27 (30)	29 (33)
Hip	24 (27)	20 (22)
Foot/ankle	16 (18)	20 (22)
Joint replacement		
Non–study knee	2 (2)	2 (2)
Hip(s)	1 (1)	4 (4)

(continued)

Table 1. Baseline Characteristics of Participants by Study Group (continued)

Characteristic	Group, No. (%)	
	Control	Tai chi
Comorbid conditions		
≥1 Comorbid condition	85 (96)	80 (90)
Heart disease	3 (3)	6 (7)
High blood pressure	31 (35)	30 (34)
Lung disease	5 (6)	4 (4)
Diabetes	10 (11)	4 (4)
Ulcer or stomach disease	2 (2)	2 (2)
Kidney disease	1 (1)	1 (1)
Liver disease	0	0
Anemia or other blood disease	3 (3)	0
Cancer	4 (4)	3 (3)
Depression	17 (19)	10 (11)
Back pain	25 (28)	33 (37)
Other medical problems	26 (29)	22 (25)
Current oral medication use for knee pain[a]		
≥1 Medication used	71 (80)	64 (72)
Analgesia/paracetamol combinations	64 (72)	56 (63)
Anti-inflammatory tablets or capsules	46 (52)	39 (44)
Oral corticosteroids	2 (2)	1 (1)
Oral opioids	3 (3)	0
Treatment for knee in previous 3 mo, No./total No. (%)		
≥1 Treatment	49/89 (55)	46/89 (52)
Massage/manual therapy	32/89 (36)	34/89 (38)
Gait aid	18/89 (20)	8/87 (9)
Electrotherapy[b]	10/89 (11)	5/89 (6)
Joint injections	1/89 (1)	5/89 (6)
Acupuncture	5/89 (6)	8/87 (9)
Information/education course	6/88 (7)	10/88 (11)
Herbal therapies	11/88 (12)	14/89 (16)
Past experience with tai chi	1/89 (1)	6/89 (7)
Physical activity level, median (IQR), h/wk[c]	21 (12-32)	20 (12-28)
Tai chi expectations[d]		
No effect at all	0	0
Minimal improvement	12 (13)	6 (7)
Moderate improvement	53 (60)	51 (57)
Large improvement	24 (27)	31 (35)
Complete recovery	0	1 (1)
Health professional consultation[e]		
General practitioner	40 (45)	43 (48)
Physiotherapist	20 (22)	18 (20)
Exercise physiologist	1 (1)	4 (4)
Dietician	1 (1)	2 (2)
Psychologist	4 (4)	0
Pharmacist	24 (27)	20 (22)
Podiatrist	8 (9)	6 (7)
Occupational therapist	1 (1)	2 (2)
Rheumatologist	0	0
Sports and exercise physician	0	0
Orthopedic surgeon	5 (6)	3 (3)
Other	7 (8)	5 (6)

(continued)

Table 1. Baseline Characteristics of Participants by Study Group (continued)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

[a] Defined as ≥1 time per week over the last 4 weeks.

[b] Electrotherapy includes transcutaneous electrical nerve stimulation, low-level laser, and ultrasound therapy.

[c] Measured using an incidental and planned exercise questionnaire with 10 questions regarding frequency and duration of incidental and planned walking, sport, and recreational activities over the past 7 days. Scores were calculated as product of the frequency and duration scores to create a total duration for the week score, where higher scores indicate higher levels of activity.

[d] Scored from a question asking about expectation of study treatment outcomes, with scores on a 5-point Likert scale from 1 (no effect at all) to 5 (complete recovery).

[e] Reported yes/no if any of the listed health professionals were visited for knee condition in the previous 3 months.

Assuming acceptable adherence (eTable 12 in Supplement 3), tai chi led to even greater improvements in knee pain during walking (mean difference, −2.4 ; 95% CI, −3.5 to −1.3; $P < .001$) and in WOMAC function (mean difference, −9.9; 95% CI, −14.9 to −4.8; $P < .001$) than control.

Despite the unequal missing primary and secondary outcomes across groups, results remained consistent with the primary analyses when various missingness-not-at-random assumptions were applied regarding differences between participants who did and did not provide these outcomes, with some differences only in extreme assumptions (eTables 13 and 14 in Supplement 3), and when excluding participants who completed the primary outcomes via telephone (eTable 6 in Supplement 3).

Adverse Events and Co-Interventions

No serious related adverse events occurred, and nonserious events (mostly musculoskeletal pain) were few and comparable across groups. Co-interventions were similar between groups (Table 2).

Discussion

A 12-week unsupervised multimodal online tai chi intervention was more effective in improving pain during walking and physical function at 12 weeks than an online education control for people with knee OA. Although the between-group mean differences were just below our prespecified MCIDs for pain and function, the confidence intervals included the MCIDs. In addition, more tai chi than control participants achieved the MCIDs, suggesting that the benefits may be clinically relevant.

Table 2. Adverse Events (AEs), Nondrug Co-Interventions, Program Adherence, and Process Measures

Measure	No./total No. (%)	
	Control group	Tai chi intervention group
Participants, No.	89	89
Participants reporting AE[a]		
Discontinued trial due to related AE	0/82	0/64
Serious related AEs[b]	0/82	0/64
Nonserious related AEs[c]	3/82 (4)	3/64 (5)
Nonserious related AEs, No.	3	4
Shoulder pain	0	1
Increased knee pain	1	1
Lower back pain	1	0
Foot pain	0	1
General pain (unspecified)	1	1
Nondrug co-interventions[d]		
≥1 Treatment	82/84 (98)	58/64 (91)
Massage/manual therapy	39/84 (46)	28/64 (44)
Gait aid	19/84 (23)	3/64 (5)
Electrotherapy[e]	10/84 (12)	7/64 (11)
Joint injections	1/84 (1)	2/64 (3)
Acupuncture	8/84 (10)	4/64 (6)
Arthroscopic surgery	0/84	0/64
Knee joint replacement	2/84 (2)	0/64
Information/education course	51/84 (61)	34/64 (53)
Herbal therapies	21/84 (25)	14/64 (22)
Tai chi (excluding study intervention)	5/82 (6)	1/64 (2)
Other exercise		
Muscle strengthening exercise (including pilates)	42/84 (50)	23/64 (36)
Aerobic exercise (eg, walking, cycling, stepper)	54/84 (64)	47/64 (73)
Hydrotherapy (eg, warm water exercises)	8/84 (10)	5/64 (8)
Yoga	13/84 (15)	10/64 (16)
Adherence and process measures		
No. of days tai chi performed per wk, mean (SD)[f]		
Weeks 1-2	NA	2.4 (1.1)
Weeks 3-4	NA	2.6 (1.3)
Weeks 5-6	NA	2.5 (1.3)
Weeks 7-8	NA	2.7 (1.3)
Weeks 9-10	NA	2.4 (1.3)
Weeks 11-12	NA	2.4 (1.3)
No. of days tai chi performed per wk over weeks 1-2 and 11-12, mean (SD)[g]	NA	2.5 (1.0)
Classified adherent from data collected at 2 wk and 12 wk[h]	NA	47/57 (82)
Exercise Adherence Rating scale section B[i]	NA	20.0 (13.0-23.5)
Use of My Exercises Messages app[j]	NA	48/64 (75)
Likelihood of recommending program[k]	NA	9.0 (8.0-10.0)
Overall satisfaction with the program[l]	NA	9.0 (7.0-10.0)
Access to website[m]	83/89 (93)	86/89 (97)

Abbreviations: NA, not applicable; NRS, Numeric Rating Scale.

[a] Any problem in study knee or elsewhere due to trial participation and causing negative/adverse symptoms/effects for ≥2 days and/or requiring treatment or medication. Denominator was participants completing AE section.

[b] Any medical occurrence associated with death, was life threatening, requiring hospitalization, led to substantial disability, or requiring medical/surgical intervention.

[c] Participants could report more than 1 adverse event.

[d] Having tried the co-intervention for knee pain in the previous 12 weeks (not study intervention) except for other exercise, defined as ≥ 1 time per week for ≥4 weeks (number is participants reporting).

[e] Included transcutaneous electrical nerve stimulation, laser, and ultrasonography.

[f] Self-reported throughout questionnaire sent at 2, 4, 6, 8, and 10 weeks; 67 respondents at 2 weeks, 62 at 4 weeks, 58 at 6 weeks, 56 at 8 weeks and 10 weeks, and 64 at 12 weeks.

[g] At 2 weeks and 12 weeks; 57 respondents.

[h] Adherence defined as tai chi performed on average ≥2 days/week.

[i] Scores range from 0-24 (higher scores were better adherence); 64 respondents.

[j] Participants were asked, "Did you use the My Exercises Messages app at all in the past 3 months?" (yes/no); 64 respondents.

[k] Likelihood of recommending program was scored on an 11-point numeric rating scale, with 0 indicating not at all likely and 10 indicating extremely likely; 65 participants responded.

[l] Overall satisfaction with the program was scored on an 11-point numeric rating scale (0 was not at all satisfied and 10 extremely satisfied); 66 respondents.

[m] Data from website analytics showing number of participants accessing >1 time.

In further support, analyses assuming acceptable adherence to tai chi yielded benefits that greatly exceeded the MCIDs. Most secondary outcomes also consistently favored tai chi. This unsupervised intervention can be considered safe with no serious related adverse events reported. Participants were highly satisfied with the program and likely to recommend it to others.

Table 3. Summary Measures and Estimated Between-Group Mean Differences for Continuous Outcomes Using Complete Case Data

Measure	Mean (SD)						Difference in change[a] between groups at 12 wk, tai chi vs control	
	Baseline		12 wk[b]		Within-group change (12 wk minus baseline)			
	Control (n = 89)	Tai chi (n = 89)	Control (n = 88)	Tai chi (n = 82)	Control (n = 88)	Tai chi (n = 82)	Mean (95% CI)	*P* value
Primary outcomes								
Knee pain during walking (NRS)[c,d]	6.1 (1.3)	6.1 (1.2)	4.8 (2.0)	3.5 (2.2)	−1.3 (2.1)	−2.7 (2.2)	−1.4 (−2.1 to −0.7)	<.001
Physical function (WOMAC)[c,e]	29.6 (10.0)	28.5 (8.5)	22.8 (10.7)	16.6 (10.5)	−6.9 (11.6)	−12.0 (9.8)	−5.6 (−9.0 to −2.3)	<.001
Secondary outcomes								
Knee pain (KOOS)[f,g]	49.7 (11.5)	50.3 (10.6)	60.4 (16.0)	70.2 (16.2)	10.6 (14.5)	19.9 (14.9)	9.4 (4.8 to 14.1)	NA
Sport and recreation function (KOOS)[f,g]	28.8 (21.1)	28.2 (19.8)	36.5 (24.5)	48.2 (22.2)	8.3 (22.4)	20.7 (23.4)	12.1 (5.2 to 18.9)	NA
Knee-related quality of life (KOOS)[f,g]	34.7 (16.3)	32.2 (15.5)	40.4 (17.0)	52.1 (19.4)	6.3 (14.7)	20.0 (19.8)	12.9 (7.7 to 18.1)	NA
Physical health (SF-12)[f,h]	34.1 (7.4)	35.8 (8.9)	37.1 (9.2)	44.5 (8.6)	2.9 (8.2)	8.2 (7.9)	6.1 (3.6 to 8.6)	NA
Mental health (SF-12)[f,h]	51.2 (12.1)	51.8 (10.2)	50.3 (10.8)	53.9 (8.8)	−1.1 (10.6)	1.5 (10.9)	3.2 (0.3 to 6.0)	NA
Fear of movement (FOMOA)[c,i]	13.0 (4.0)	13.5 (3.8)	12.5 (3.6)	12.1 (4.0)	−0.6 (4.0)	−1.5 (3.0)	−0.7 (−1.8 to 0.3)	NA
Arthritis self-efficacy pain (ASES)[f,j]	5.9 (1.8)	6.4 (1.7)	6.2 (1.9)	7.0 (2.2)	0.3 (2.1)	0.8 (1.8)	0.6 (0 to 1.2)	NA
Balance confidence (ABC scale)[f,k]	64.1 (20.2)	67.5 (21.8)	61.9 (21.3)	75.9 (21.2)	−1.6 (18.4)	5.9 (19.2)	9.9 (4.3 to 15.6)	NA
Positive activated affect (I-PANAS-SF)[f,l]	16.1 (3.9)	17.2 (4.0)	16.7 (3.8)	18.2 (4.5)	0.5 (3.2)	1.0 (4.2)	0.8 (−0.3 to 1.9)	NA

Abbreviations: ABC scale, Activities-Specific Balance Confidence scale-6; ASES, Arthritis Self-Efficacy scale pain subscale; FOMOA, Brief Fear of Movement scale for osteoarthritis; I-PANAS-SF, International Positive and Negative Affect Schedule–short form; KOOS, Knee Dysfunction and Osteoarthritis Outcome score; MCID, minimal clinically important difference; NA, not applicable; NRS, numeric rating scale; SF-12, Short Form-12; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

[a] For the primary outcomes, 2-sided 95% CIs and *P* values were multiplicity adjusted (α = .025).

[b] Knee pain (KOOS): 84 in control group; 65 in tai chi group. Sport and recreation function (KOOS), knee-related quality of life (KOOS), physical health (SF-12), mental health (SF-12): 84 in control group; 64 in tai chi group. Fear of movement (FOMOA), arthritis self-efficacy pain (ASES), balance confidence (ABC scale), positive activated affect (I-PANAS-SF): 82 in control group; 64 in tai chi group.

[c] For change within groups, negative changes indicate improvement. For difference in change between groups, negative differences favor tai chi.

[d] NRS, range 0-10, with 0 indicating no pain and higher scores indicating more pain; the MCID was 1.8 units.

[e] WOMAC, range 0-68, for physical function with higher scores indicating more physical dysfunction; MCID = 6 units.

[f] For change within groups, positive changes indicate improvement; for difference in change between groups, positive differences favor tai chi

[g] KOOS, 0-100, with lower score indicating worse symptoms.

[h] SF-12, mental and physical component scores are calculated separately, each ranging from 0-50, with higher scores indicating better functioning.

[i] FOMOA, range of 6-24 with higher scores indicating greater fear of movement.

[j] ASES, range 1-10, with higher scores indicating greater self-efficacy.

[k] ABC-6, range 0%-100%, with higher scores indicating greater balance confidence.

[l] I-PANAS-SF, range of 5-25, with higher scores indicating higher levels of positive effect.

Table 4. Binary Outcomes and Adjusted Relative Risks and Risk Differences (95% CI) Using Complete Case Data

Outcome	No./Total No. (%)		Relative risk (95% CI)[a]	Risk difference (95% CI)[a]
	Control	Tai chi		
Achieved MCID in knee pain walking (NRS)[b]	41/88 (47)	60/82 (73)	1.6 (1.2 to 2.0)	0.3 (0.1 to 0.4)
Achieved MCID in function (WOMAC)[c]	46/88 (52)	59/82 (72)	1.4 (1.1 to 1.8)	0.2 (0.1 to 0.3)
Global knee improvement[d]	33/84 (39)	53/65 (82)	2.1 (1.6 to 2.8)	0.4 (0.3 to 0.6)
Good sleep quality[e]	55/82 (67)	49/64 (77)	1.1 (1.0 to 1.3)	0.1 (0 to 0.2)
Use of oral medications for knee pain[f]	59/84 (70)	37/64 (58)	0.9 (0.7 to 1.1)	0 (−0.2 to 0.1)

Abbreviations: MCID, minimal clinically important difference; NRS, Numeric Rating scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

[a] Relative risks greater than 1 and risk differences greater than 0 favor tai chi intervention.

[b] NRS, 0-10 with higher scores indicating more pain; MCID = an improvement of 1.8 NRS units from baseline.

[c] WOMAC, 0-68 for physical function; MCID = an improvement of 6 WOMAC units from baseline.

[d] Rated using a 5-point scale with terminal descriptors of markedly worsened to markedly improved; those indicating moderately/markedly improved were classified as improved.

[e] Single question from Pittsburgh Sleep Quality of Index, rated using a 4-point scale with terminal descriptors of very good to very bad; those indicating very/fairly good were classified as having good sleep quality.

[f] Participants who used oral pain medication(s) at least once a week for knee pain in the past 4 weeks collected at 12 weeks (including analgesia/paracetamol combinations, anti-inflammatories, corticosteroids and/or opioids).

The mechanisms by which tai chi improves knee OA outcomes remain uncertain but are likely multifactorial. Through slow and controlled movements, tai chi is postulated to improve strength, joint stability, lower limb alignment, and reduce mechanical stress on the knee.[47,48] Its mindfulness and breathing exercises are thought to modulate neurochemical and analgesic pathways, regulate inflammation, and increase pain thresholds.[47,49,50] Psychologically, tai chi also enhances pain coping and self-efficacy, which may improve pain perception.[49-51] It is also possible that more frequent physical activity may have mediated the outcomes; however, we did not measure physical activity at follow-up to determine this.

Our findings are in agreement with systematic reviews and meta-analyses that show in-person tai chi improves pain, function, and quality of life in people with knee OA.[5,52] The clinical relevance of the benefits of in-person tai chi is further supported by a systematic review[53] of 8 RCTs reporting an NNT of 10 or less for improvements in pain and physical function. Furthermore, compared to other types of mind-body exercises, tai chi has consistently been identified as the most effective for improving pain and quality of life for people with knee OA, followed by yoga.[50,54,55]

Our intervention is unique in its fully unsupervised online delivery mode. To our knowledge, only 1 other trial (TAICHIKNEE[56]) is currently investigating remotely delivered tai chi for knee OA. However, in contrast to our program, that tai chi intervention is delivered in real-time by instructors through videoconferencing.[56] Previously, our team developed and evaluated 2 other unsupervised online exercise programs for knee OA—one was a strengthening program[57] and the other was yoga[44]; these were compared with an online education control similar to that of the current study. Significant differences in between-group pain (1.6 [95% CI, 0.9-2.2] units) and function (5.2 [95% CI, 1.9-8.5] units) at 24 weeks were found with the strengthening program[57] comparable to our tai chi results. In contrast, the yoga program achieved smaller benefits in function (4 [95% CI, 1.3-6.8] units) with no association with knee pain at 12 weeks.[44] Notably, both programs have been made freely available to the public and accessed by more than 47 000 users from 123 countries, including 59 countries classified as low- and middle-income. This highlights the global demand for online unsupervised OA resources that allow people to exercise in the comfort of their own homes. The current study adds to this body of work with our tai chi intervention offering another effective, accessible and scalable option to improve patient access to guideline-recommended OA exercise, potentially reducing demand on health professionals and optimizing health care resources.

Strengths and Limitations

Our study has several strengths. We recruited participants nationwide, including 42% from rural or regional areas. We applied broad inclusion criteria, including a clinical diagnosis of OA as recommended by guidelines,[25] to maximize the generalizability of our findings. We tested a tai chi program that had undergone rigorous intervention design, which was evidence-informed and co-developed by tai chi instructors, clinicians, and people with knee OA.[17]

Our study has limitations. We primarily recruited participants from the community through online social media rather than referrals from health professionals, which might have yielded participants with different baseline characteristics to those seeking care. However, results of a systematic review show that various baseline characteristics (eg, body mass index, education) do not moderate the effect of exercise on pain and physical function.[58] As this was a pragmatic trial, participants were unblinded and we did not control for differences in contextual effects between groups. This could have led to bias and overestimated the true tai chi effects. However, a recent large meta-epidemiological study[59] found that estimated treatment effects were similar regardless of whether patients were blinded or not. Follow-up was limited to 12 weeks, so the long-term effect of online tai chi remains unknown. We provided the control group with limited information about OA and exercise, similar to what is currently available or accessible online. Because we tested a combined intervention of tai chi plus the adherence support app, we cannot determine the extent to which either component contributed to the results. We were unable to capture accurate website continu-

ous adherence metrics for the tai chi program, which would have provided a more objective measure of the actual intervention duration. Participants were required to have internet access and own a device, so findings may not fully generalize to populations who are digitally excluded. Lastly, more people in the tai chi group than the control group required telephone follow-up for the primary outcomes and had missing secondary outcomes, which can introduce bias if missing data are related to outcomes. However, post hoc analyses showed our results were robust to a range of missingness not at random assumptions (with the exception of some extreme assumptions), and when excluding participants reporting outcomes via telephone.

Conclusions

This randomized clinical trial found that a 12-week unsupervised multimodal online tai chi intervention improved knee pain and function in people with knee OA when compared with an online educational program alone. The benefits appeared to be of a clinically relevant magnitude. The intervention was safe with no serious adverse events. This free and scalable tai chi intervention could improve patient access to recommended OA exercise and provide clinicians with a resource to support their delivery of evidence-based care.

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