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Tai chi chuan exercises improve functional outcomes and quality of life in patients with primary total knee arthroplasty due to knee osteoarthritis

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ABSTRACT

Background and purpose: Postoperative rehabilitation plays an indispensable role for a successful total knee arthroplasty (TKA) and the optimal exercises programs are not known. A single-centre, single-blind, randomised controlled trial was designed to explore whether tai chi chuan (TCC) exercises can improve the functional outcomes and the quality of life (QOL) in patients with primary TKA due to knee osteoarthritis (OA).

Materials and methods: One hundred seven participants with primary TKA for end-stage knee OA were enrolled from January 2014 to January 2017. Patients were treated for 12 weeks either with TCC exercises (intervention) or traditional physical exercises (control). Outcomes including western ontario and mcMaster universities arthritis index (WOMAC), 6-min walk test (6 MWT), knee range of motion (ROM), and short form (36) health survey (SF-36) were assessed. The adverse events related to TCC exercises or TKA were recorded.

Results: Before the intervention, the two groups were comparable after examining the general descriptions of patients. Compared with the control group (CG), the TCC group (TG) had significantly better scores in the WOMAC physical function score, 6 MWT, SF-36 physical component score (PCS), and the mental component score (MCS) ($P < 0.05$) after the 12-week intervention. Nevertheless, there were no significant differences in WOMAC pain score and knee ROM. There were no adverse events related to the TCC exercise program. In the CG, three patients reported one fall each, but those falls did not lead to a further problem.

Conclusion: The TCC exercises improve the physical function and the QOL in patients with primary TKA without additional risks.

1. Introduction

The increasing age of the population is leading to more people manifesting knee osteoarthritis (OA); therefore, the demand for total knee arthroplasty (TKA) is growing. For a successful TKA, the surgical aspect of TKA is just one part of the total process. The type and quality of postoperative rehabilitation play an indispensable role in outcomes [1]. Despite substantial pain relief, a long-term study indicates the persistence of impairment and functional limitation after TKA [2]. Functional limitations after TKA include reduced muscle strength [3], reduced postural stability and impaired balance [4], and difficulties with walking long distances and climbing stairs for several months [5]. All those functional limitations show that patients after TKA may not necessarily achieve the desired functional outcomes. Rehabilitation after TKA is expected to avoid impairment persistence and to optimise functional recovery [6]. Notably, muscle weakness and functional deterioration are reported in TKA patients who developed loosening of the knee components [7]. Hence, postoperative rehabilitation is of utmost importance for patients with TKA.

Tai chi chuan (TCC), a traditional Chinese sport, has become popular around the world in recent years [8]. Many studies prove that TCC improves medical outcomes [9–11]. The benefits of TCC exercises for the elderly have been extensively studied [12], and include benefits for the musculoskeletal system [13], cardiopulmonary effects [14], falls [15], balance [16], quality of life (QOL) [17], self-efficacy [18], psychological symptoms [19], and immune- and inflammation-related responses [20]. To our knowledge, the gains of TCC exercises in functional outcomes and QOL have not been investigated in patients with TKA. The objective of this study was to evaluate the effect of TCC exercises in functional outcomes and QOL for patients with TKA.

2. Materials and methods

This single-blind randomised controlled trial was designed to

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explore the effect of TCC exercises on outcomes for patients with TKA at the Affiliated Hospital of Jining Medical University from January 2014 to January 2017. The study protocol was ratified by the Institutional Review Board of the Affiliated Hospital of Jining Medical University (Approval No.20130572). Informed consent was obtained from each participant before enrolment in the study.

2.1. Patients

The inclusion criteria for patients who agreed to participate were as follows: (a) clinical and radiographic evidence diagnosed with end-stage knee OA according to the diagnosis criteria [21] and scheduled for primary unilateral TKA surgery; (b) 65–74 years of age; (c) no history of significant cardiovascular, pulmonary, metabolic, musculoskeletal, or other chronic diseases; (d) fully informed consent about the program; (e) a partner to oversee the entire exercise process to ensure safety; and (f) a normally active lifestyle. Patients were excluded if they had the following conditions: (a) a history of knee infection, a lesion involving bilateral knees, or any intra-articular hyaluronic acid injections in the 6 months prior to assessment; (b) serious medical conditions that limited his/her ability to safely participate in either the TCC or physical therapy programs; (c) inability to walk at least 150 m in 6 min due to some serious diseases (e.g., epilepsy, diminished mental capabilities); (d) previous experience with TCC or exercised regularly with other similar types of complementary and alternative medicine such as qi gong or yoga; or (e) inability to complete the study (e.g., not Chinese-speaking or intended to move out of the region).

The candidates were enrolled from consecutive patients diagnosed with end-stage knee OA and scheduled for TKA at the Affiliated Hospital of Jining Medical University. The participants were randomly assigned to two groups by sealed envelopes that contained random numbers generated by a computer program. Odd and even numbers represented the TCC group (TG) and the control group (CG), respectively.

Postoperative pain management, which was standard in both groups, included the following: (a) preoperative oral administration of cyclooxygenase-2 (COX-2) inhibitors; (b) intraoperative periarticular multimodal drug injection using opioids and long-acting local anaesthetic agents combined with peripheral nerve block under epidural anaesthesia; (c) an oral analgesic protocol consisting of extended- and short-release oxycodone or tramadol postoperatively.

2.2. Measurements

All candidates were assessed at 3 days preoperatively, at the end of week 2 postoperatively (discharge day), and at the end of week 14 postoperatively. The outcome measurements were completed at the Department of Joint Surgery of the Affiliated Hospital of Jining Medical University by two orthopaedic surgeons who were not the study coordinator. Complications related to the TCC exercises or TKA were recorded.

2.2.1. The western ontario and mcMaster universities arthritis index

The western ontario and mcMaster universities arthritis index (WOMAC) was developed for use among patients with knee and/or hip OA to assess pain, stiffness, and physical function. The WOMAC has been extensively used in both observational and epidemiological studies and to examine changes following treatments including pharmacotherapy, arthroplasty, exercises, physical therapy, knee bracing, and acupuncture. Chinese WOMAC has demonstrated acceptable psychometric properties in patients with severe knee OA [22]. The WOMAC consists of 24 items divided into three subscales: pain (5 items, score range 0–20), stiffness (2 items, score range 0–8), and functional status (17 items, score range 0–68). Higher scores reflect worse physical functioning.

2.2.2. The 6-min walk test

The original purpose of the 6-min walk test (6 MWT) was to test exercises tolerance in chronic respiratory disease and heart failure. The test has since been used as a performance-based measure of functional exercises capacity in other populations including healthy older adults, people undergoing knee or hip arthroplasty [23], fibromyalgia, and scleroderma. The 6 MWT measures the distance an individual can walk over a total of 6 min on a hard, flat surface. The goal is for the individual to walk as far as possible in 6 min. The individual is allowed to self-pace and rest as needed as they traverse back and forth along a marked walkway.

2.2.3. Knee range of motion

Knee range of motion (ROM) refers to the range of extension and flexion of the knee joint. It is measured by goniometry, and is accurate to 1°. The landmarks employed in the measurements are the greater trochanter of the femur, the proximal head of the fibula, and the lateral malleolus. Specific measurement methods were applied in a previous literature [24].

2.2.4. The short form (36) health survey

The short form (36) health survey (SF-36) [25] is one of the most widely accepted generic health status measures. It contains eight domains: Physical Functioning, Role-Physical, Bodily Pain, General Health, Vitality, Social Functioning, Role-Emotional, and Mental Health. Each subscale ranges from 0 to 100, and higher scores represent better health status. A physical component summary (PCS) score and a mental component summary (MCS) score have also been derived from factor analytic methods. To achieve this, responses on 10 items are recoded before being added to the other items on the same scale. The raw scale scores are then transformed to a 0–100 scale. Scales are set up so that a higher score indicates better health.

2.3. Interventions

The medical team including clinicians, nurses, anaesthesiologists, and licensed physiotherapists discussed and designed the postoperative intervention protocol. Within two weeks postoperatively, the intensity and forms of the 24 TCC movements were closely monitored by certified TCC instructors to ensure that each movement would be applied correctly and safely to patients. Moreover, at the end of each month during the intervention period, the TCC instructors would further guide and correct the movements of patients in TG to make it meet the standard. All patients were asked to complete traditional physical exercises during the hospital stay. From the end of 2 weeks to the end of 14 weeks postoperatively, the participants in the TG received 45 min of TCC training for 5 days per week, whereas the participants in the CG received 45 min of traditional physical exercises for 5 days per week.

Each TCC session included 5 min of warm-up exercises, at least 35 min of the TCC exercises, and 5 min of cool-down exercises. The knee could flex more than 90° through the initial ROM exercises, so that all patients could practice TCC at low stances. The 24 TCC exercises included the following: (a) part wild horse's mane, 3 times; (b) white crane spreads its wings (east); (c) brush knee and twist step, 3 times (east); (d) play guitar (east); (e) repulse monkey, 4 times (west); (f) grasp bird's tail (ward off, roll back, press, push); (g) single whip (east) (left style); (h) cloud hands, 4 times (east); (i) single whip (east) (left style); (j) high pat on the horse (east); (k) kick with right foot; (l) punch phoenix's ears; (m) turn counter clockwise and kick with left heel (west); (n) extended single whip (west) (left style); (o) snake creeps down (west) (right style); (p) golden cock stands on one leg (west) (left style-on left leg); (q) extended single whip (west) (right style); (r) snake creeps down (west) (left style); (s) golden cock stands on one leg (west) (right style-on right leg); (t) fair lady weaves the shuttles 2 times; (u) pick the needle at sea bottom (west); (v) open the fan (west); (w) snake puts out tongue and step forward, downward deflect, parry and punch

(east); and (x) close the door (east). The 24 forms of TCC were applied according to the previous literature [26].

The traditional physical exercises included strengthening exercises and ROM exercises for the knee. The strengthening exercises included the following: (a) keep the affected leg straight while tightening the leg muscles for 5–10 s; repeat the movement 10 times in 2 min, then rest for 1 min; and (b) raise the affected knee on the bed slightly and hold for 5–10 s, then put down slowly. The ROM exercises for the knee included the following: (a) flex the affected knee while keeping the feet on the bed; hold for 5–10 s at the maximum flexion and then straighten the knee; and (b) hang the affected lower leg off the end of the bed slowly and then hold for 5–10 s at the maximum knee flexion. The traditional physical exercises would take 45 min per day for patients in the CG.

2.4. Data analysis

All continuous data were examined statistically for normality of distribution (the Kolmogorov–Smirnov test). After examining whether the data accorded with normality test, all continuous data in current study had a normal distribution. The results were expressed as the number, mean ± standard deviation (SD) (a normal distribution), as appropriate. The Chi-square test was used to analyse differences between groups with respect to categorical data. After examining whether the data accorded with the normality test, continuous data were analysed using one-way analysis of variance (ANOVA) (a normal distribution). All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, Chicago, IL) version 21.0. Statistical significance was set at $P < 0.05$.

2.5. Ethical considerations

Written informed consent was obtained from each participant prior to the intervention, and they were ensured of their right to withdraw from the study at any time. Results would be disseminated in a peer-review journal. The aim of this study was to examine the effect of TCC exercises in functional outcomes and QOL for patients with TKA.

3. Results

Two hundred seventy-one patients with knee OA scheduled for TKA were invited for participation at the Affiliated Hospital of Jining Medical University (Fig. 1). One hundred twenty-one candidates were excluded from the study according to the exclusion criteria. The other 21 patients refused to take part in this trial. There was no statistically significant difference between the patients who refused to participate and the ones enrolled in the study with respect to basic information (detailed data not shown). Ultimately, 107 patients were included in the analysis, 54 in the TG and 53 in the CG, respectively. All patients were diagnosed with end-stage knee OA and underwent primary TKA with a posterior-stabilised implant.

The demographic characteristics of the 107 participants who completed the trial are presented in Table 1. There were no statistically significant differences between the TG and the CG with regard to demographic variables in age, gender, and body mass index (BMI). A baseline comparison of the physical functional and QOL outcomes showed no significant differences between the two groups at 3 days preoperatively and at the end of week 2 postoperatively (discharge day), including WOMAC scores, 6 MWT, knee ROM, and SF-36 ($P > 0.05$). The earliest time point to begin the TCC intervention was at the end of 2 weeks after TKA in the TG. No adverse events related to the TCC exercises or TKA (e.g., wound infections, joint dislocations) were reported in the TG. Whereas, three patients in the CG reported one fall each, although those falls did not lead to a further problem.

TG, tai chi chuan group; CG, control group; BMI, body mass index; WOMAC, Western Ontario and McMaster Universities Arthritis Index; 6 MWT, 6-min walk test; ROM, range of motion; SF-36, Short Form (36) Health Survey; Wk 2, end of 2 weeks postoperatively; PCS, physical component score; MCS, mental component score. Values are expressed as the number, means with standard deviation (SD) in parentheses, as appropriate. P values denote the significance of differences between those two groups.

After the 12-week intervention, the physical function score evaluated by WOMAC in the TG was improved from 50.7 (12.6) to 35.5 (3.2) ($P < 0.01$), and the distance of the 6 MWT was obviously increased from 402.2 (56.3) m to 467.1 (51.4) m ($P < 0.01$). Participants in the TG had significantly improved WOMAC physical function score, 6 WMT, and SF-36 PCS and MCS ($P < 0.05$) compared with the CG (Table 2). However, no significant difference was detected in the WOMAC pain score and knee ROM ($P > 0.05$).

TG, tai chi chuan group; CG, control group; WOMAC, Western Ontario and McMaster Universities Arthritis Index; 6 MWT, 6-min walk test; ROM, range of motion; SF-36, Short Form (36) Health Survey; Wk 14, end of 14 weeks postoperatively; PCS, physical component score; MCS, mental component score. Values are expressed as the number, means with standard deviation (SD) in parentheses. P values denote the significance of differences between those two groups; * indicates significant difference.

4. Discussion

TKA is a reliable cure for treating end-stage degenerative knee OA for pain relief, functional recovery, and substantial improvement in QOL. However, a previous review indicates persistence of impairment and functional limitation after TKA, and the optimal exercise program for rehabilitation is not known [27]. The aim of this study was to explore the effect of TCC on rehabilitation for patients after TKA due to knee OA. Disease-specific and health-related QOL instruments could assess the outcomes of the specific disease and overall patient condition, respectively.

The traditional physical exercises could promote functional rehabilitation of affected limbs, which was consistent with other research findings [5,28]. The results in this study showed that the TCC exercises improved the physical function more than the traditional physical exercises. As a complement to standard medical care, we found that the TCC exercises had potential clinical benefits including enhancement in QOL for patients with TKA. Prior TCC studies [12] also reported improvements in QOL for other population (e.g., asthmatic patients) [17]. The findings in this study expanded the applicable population for TCC exercises to patients with knee OA after TKA. No adverse events related to the TCC exercises were observed, which indicated that the TCC exercises were a safe program for patients after TKA. The TCC exercises seem to be a new form of postoperative rehabilitation exercises.

Although improvement in WOMAC physical function score was seen after the TCC exercises, obvious differences were not detected in the WOMAC pain score and knee ROM at post-test. The results did not show that the TCC exercises could alleviate pain. In postoperative pain management, drug therapy must be dominant. Results on knee ROM showed that the TCC exercises did not offer an advantage over traditional physical therapy. Those results meant that, in TCC intervention, pain management with drugs and traditional physical therapy for knee ROM might be required to attain better outcomes for patients with TKA.

Periprosthesis fracture is one of the serious complications after TKA, and primarily result from an accidental fall [29]. Previous studies have shown the effect of TCC on prevention of falls in elderly people [30,31]. That may explain why the fall event happened in the CG, whereas none was reported in the TG reported. Previous literature confirmed that balance training is import in fall prevention [31], and the TCC exercises could enhance balance capacity [32]. TCC exercises as a safe rehabilitation method might reduce the risk of falls after TKA.

In this study, male patients reported a higher participation of the TCC exercises as routine postoperative functional exercises than did female patients (detailed data not shown). The reasons could be that the

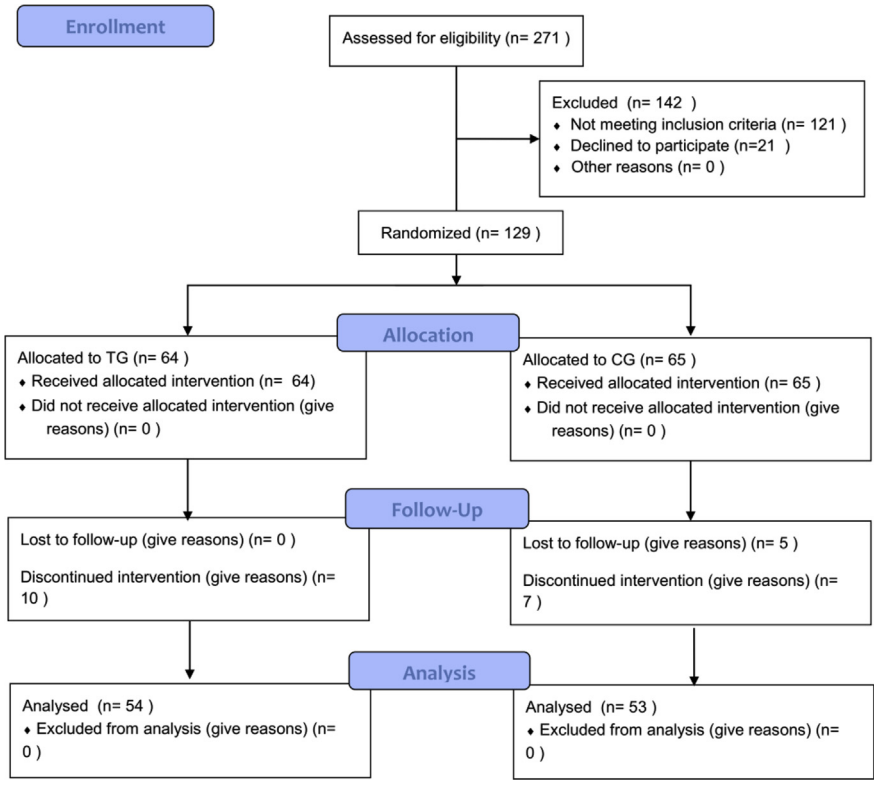

Fig. 1. CONSORT 2010 flow diagram of the study.

Table 1
The demographic characteristics of participants by groups.

Subscale	TG (n = 54)	CG (n = 53)	P value
Age (years)	69.6 (4.3)	68.5 (3.5)	0.42
Gender (male/female)	26/28	24/29	0.19
BMI (kg/m^2)	23.7 (3.6)	24.2 (2.9)	0.75
WOMAC pain score			
Preoperative	10.5 (2.2)	10.8 (2.4)	0.60
Wk 2	9.4(2.1)	9.5 (2.0)	0.15
WOMAC physical function score			
Preoperative	50.7 (12.6)	46.8 (16.9)	0.29
Wk 2	40.9 (3.2)	43.6 (4.1)	0.18
6 MWT (m)			
Preoperative	402.2 (56.3)	407.5 (53.9)	0.47
Wk 2	417.2 (51.4)	416.5 (47.5)	0.63
Flexion, deg			
Preoperative	105.3 (15.2)	104.9 (14.9)	0.95
Wk 2	109.1 (14.8)	110 (12.9)	0.86
Extension, deg			
Preoperative	4.5 (4.2)	4.1 (3.1)	0.72
Wk 2	2.5 (0.2)	2.2 (0.3)	0.43
SF-36, PCS			
Preoperative	33.5 (1.2)	32.4 (1.1)	0.64
Wk 2	42.1 (1.9)	41.5 (2.1)	0.68
SF-36, MCS			
Preoperative	53.3 (1.3)	51.3 (1.2)	0.77
Wk 2	55.2 (1.7)	53.3 (1.6)	0.65

female patients usually have more family responsibility than the male patients and, thus, less time to devote to postoperative exercise. Hence, in the Chinese population, clinicians should be aware that the use of the TCC exercises for female patients with TKA as a postoperative rehabilitation method may not be as effective as in male patients due to lower participation of female patients.

Table 2
Outcomes comparisons on WOMAC score, 6 MWT, knee ROM, and SF-36 by groups at Wk 14.

Subscale	TG(n = 54)	CG(n = 53)	P
WOMAC pain score	9.1 (2.0)	9.3 (1.9)	0.07
WOMAC physical function score	35.5 (3.2)	41.6 (4.1)	0.03*
6 MWT (m)	467.1 (51.4)	429.2 (47.5)	0.01*
Flexion, deg	112.1 (14.8)	110 (12.9)	0.62
Extension, deg	1.5 (0.3)	1.9 (0.2)	0.59
SF-36, PCS	54.2 (1.5)	45.2 (1.9)	0.01*
SF-36, MCS	58.5 (1.8)	54.1 (1.7)	0.03*

4.1. Study limitations

There were several limitations in this study. The results in this study showed that the TCC exercises can improve the functional outcomes and the QOL. However, due to the lack of designs of multiple groups (e.g., other forms of rehabilitation), whether TCC could compare with other forms of rehabilitation in efficacy is still unknown and requires further research. Although it was a prospective, single-cohort longitudinal study, we were unable to compare these results to patients who may have received a different type of prosthesis (e.g., unicompartmental knee arthroplasty) or different types of fixation (e.g., cementless TKA) than what was used by the authors. Thus, these results may not reflect patients' satisfaction and general health outcomes and trends of patients with other knee components. With a sample of 271 patients, only a small proportion of eligible patients were enrolled in this trial, which could introduce selection bias. In addition, we are unable to provide a definitive physiological mechanism for effects of TCC exercises. Specific trials should be performed for homogeneous subgroups of patients with relevant comorbidities (e.g., neurologic diseases, rheumatoid arthritis, diabetes, arterial diseases) or complications (e.g., nerve injuries, length difference between lower limbs, recurrent dislocations) that may affect the effectiveness of rehabilitation. A further

potential source of variability not investigated was surgical approach. Intensive research should consider these sources of variability by either selecting homogeneous patients for the type of prosthesis and surgical operation, or stratifying participants for these variables in adequately powered trials. Nonetheless, this study provided informative data from the first large-scale clinical trial of the TCC exercises in the OA population after TKA.

5. Conclusions

In conclusion, our study provides preliminary evidence that TCC exercises as a potential form of postoperative rehabilitation exercises can effectively improve the functional outcomes and the QOL for patients with TKA. In the future, studies with direct evidences such as the enhancement of muscle strength will overcome the limitations of current existing dataset and reach the more reliable conclusions. Further studies are needed to explore the underlying mechanisms of TCC exercises.

Conflicts of interest

No conflict of interest declared.

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