Effect of quadriceps strengthening exercises alone and in combination with Baduanjin qigong on older adults with knee osteoarthritis: a quasi-experimental study

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Abstract

Background: Exercise is recommended as a core treatment for individuals with KOA. However, the optimal exercise program to promote long-term compliance for KOA patients is not clear. The aim of this study is to compare the effects of the combination exercise program (quadriceps strengthening exercises (QSE) plus Baduanjin qigong) versus QSE alone on older adults with knee osteoarthritis (KOA).

Methods: A two-arm, quasi-experimental trial with repeated measurements was used. As a cluster randomized trial, participants from one community center were assigned to combination exercise group while participants from the other center were assigned to QSE group. We assessed pain intensity, physical function, self-efficacy, and HRQoL with standardized instruments at baseline, 3 and 6 months.

Results: 87 participants with KOA who aged above 60 completed the study. Over the 6 months, there were significant time by group interaction effects on pain intensity (F = 44.419, p < 0.001), physical function (F = 46.904, p < 0.001) and self-efficacy (F = 49.754, p < 0.001), as well as in the physical component summary (F = 15.205, p < 0.001) and mental component summary of SF-12 (F = 19.205, p < 0.001), with the combination exercise group exhibiting significantly greater improvements in all outcomes than QSE group.

Conclusions: Combination exercise treatment is more effective than QSE for relieving pain, increasing physical functioning, and improving self-efficacy, and quality of life in community-dwelling KOA older adults. Also, it could promote long-term compliance for KOA community patients.

Trial registration: Chinese Clinical Trails Registry number ChiCTR2000033387 (retrospectively registered). Registered 30 May 2020

Keywords: knee osteoarthritis, Baduanjin qigong, quadriceps strengthening exercises
Background

Osteoarthritis (OA), as the third risk factor for disability in the elderly, could lead to pain, loss of function, and reduced quality of life (QoL) [1]. With the aging of the global population, the number of elderly with OA is gradually increasing in both low- and high-income countries[2]. Globally, knee osteoarthritis (KOA) accounts for more than 80% among OA patients[3]. In US, KOA affects about 37% of American adults aged 60 and older[4]. In China, the years lived with disability (YLDs) for KOA per 100,000 population was 968 in 2012, and 60% of YLDs were contributed from individuals aged 60 years and older[5].

Until now, since there is no way to cure KOA[1], the treatment goal of KOA mainly focuses on pain reduction and improvement of physical function and quality of life (QoL) [6, 7]. Exercise therapy is one of the most effective non-pharmacologic treatments for KOA due to its high safety, low-cost, and easy operation[7, 8]. According to the KOA clinical guidelines issued by the American College of Rheumatology, exercise interventions, such as aerobic exercise, resistance exercise, and aquatic exercise, are strongly recommended [9].

Among the recommended exercise programs, quadriceps strengthening exercises (QSE) has been widely used for KOA patients. Previous studies show that QSE have better short-term effects on relieving joints’ pain or stiffness and improving the QoL[7, 10, 11]. However, the long-term adherence to exercise becomes a barrier to widespread use and implementation[11, 12]. A study reports that 44.2% of KOA patients withdrew from the exercise intervention due to time, economic pressures or other reasons[10]. Moreover, the type of exercise favored by the patients and the way of exercise delivered by the clinicians may have effects on adherence[12]. Thus, it is necessary to find the optimal way to promote long-term adherence to exercise for KOA patients.

In current, mind-body exercises such as Tai Chi, Yoga, Baduanjin and Qigong have become increasing popularity for pain management[13]. In the management of KOA, Tai Chi is recommended as one of the most appropriate exercise interventions[9]. Baduanjin, as one of well-known traditional Chinese Qigong, is similar to Tai Chi but requires fewer movements and shorter durations[14]. Studies show that Baduanjin has physiological and psychological effects on patients with
various diseases, for example, it reduced the symptoms of morning stiffness, spinal pain and fatigue for patients with ankylosing spondylitis[15], alleviated musculoskeletal pain in older people with chronic low back pain and neck pain[16, 17], and improved mental conditions for a variety of participants[18]. A recent review evaluating the effectiveness and safety of Baduanjin for KOA identified only three randomized controlled trials[14]. Results from this review revealed that Baduanjin is a simple and suitable aerobic exercise for elderly people with KOA, while the effect of Baduanjin on improving OA symptoms needs further investigation.

The Ottawa panel clinical practice guidelines for the management of KOA points out that aerobic exercise in combination with strengthening exercises showed significant improvement for pain relief and physical function [19]. However, relatively little robust research has been conducted on Baduanjin combined with QSE in patients with KOA. The aim of this study was to explore the effects of a combination of Baduanjin with QSE on older adults with KOA. Our hypothesis was that the combination exercise program could not only relieve pain, improve physical function, thus improving self-efficacy and QoL; but also promote long-term compliance to exercise.

Methods
Study design
This was an assessor-blinded quasi-experimental trial with two parallel groups and repeated measurements. The study was conducted in two community (community A and community B) health care centers in Tangshan city, China. Post-test data were collected at 3 months and 6 months from baseline.

Participants
This study recruited community-dwelling elderly patients with KOA by print and social-media advertisements. After the research assistants registered volunteers with KOA from the community centers, the doctors screened them, according to the inclusion and exclusion criteria, and determined who could participate in the study. The study involved participants who were: aged more than 60 years; clinically diagnosed with KOA; experiencing knee pain on most days of the past month with an
average knee pain in the last week between 3 and 7 on an 11-point numeric rating scale (NRS); and had no regular Baduanjin qigong training or quadriceps muscle strength exercise before the day of agreement to enter the trial. The exclusion criteria were: having severe/uncontrolled comorbidities (such as myocardial ischemia, unstable angina pectoris, mental illness) or neurological disorders affecting the lower extremities; having had joint replacement surgery or acute trauma of knee joint; having severe deformity of lower limbs; having received intraarticular injection within the past 3 months; having a long history of regular exercise before the day of agreement to enter the trial.

**Randomization and blinding**

In order to avoid contamination effects among participants in the same community, this study adopted randomization by community. The two communities were randomized by drawing lots. Four sheets of paper of the same size read “QSE intervention in community A,” “QSE intervention in community B,” “QSE plus Baduanjin intervention in community A,” and “QSE plus Baduanjin intervention in community B” respectively. These four sheets of paper were placed in four opaque envelopes. After the recruitment, one of the envelopes was selected randomly and opened by a research assistant. Prior to interventions, all researchers received professional training to provide QSE and Baduanjin instruction to the participants. To ensure the quality of the study, the assessor and statistician were blinded to participant allocation and were not involved in the recruitment and intervention process.

**Sample size**

Power Analysis and Sample Size (PASS 11) software set for the repeated measures was used to calculate the sample size. The primary outcome was change in the pain dimension of the Western Ontario and McMaster Universities Arthritis Index (WOMAC) between the two groups at the end of 3 months and 6 months. Assuming a mean difference and standard deviation (SD) between the groups based on previous similar study on community-dwelling KOA patients[20], a minimum of 30 participants per group would be required to achieve a medium effect size at a power of 80% and a significance level of 0.05. Given a projected dropout rate of 15%, we aimed to include 50 participants per group.
**Interventions**

**Intervention group**

The participants in this group engaged in QSE plus Baduanjin training program at least three times weekly over 6 months. They were instructed to complete a brief exercise diary in order to record the number of exercises per day. The QSE plus Baduanjin training program consisted of two phases, face-to-face conducting phase (0–6 weeks) and follow-up phase (6 months). In face-to-face conducting phase, participants were required to attend a 2-h class conducted by the trained researchers twice a week for 6 weeks. The trained researchers explained the main points of QSE and Baduanjin and provided step-by-step instruction in class. Each class, which was conducted in groups of 10–15 participants, included an hour for QSE and an hour for Baduanjin exercise. Outside of the class, participants were encouraged to practice what they learned by themselves. In the follow-up phase, participants were required to practice QSE at home and practice Baduanjin in groups, at least three times per week until the end of the treatment. The scheduled telephone follow-up calls were implemented by research assistants weekly during weeks 7 through 12 and then monthly during weeks 13 through 24. Research assistants telephoned participants to discuss their progress, identify their barriers, and encouraged them to adhere to the exercise program. Participants were also encouraged to contact the researchers if there were concerns or questions.

**Quadriceps strengthening exercises (QSE):** The QSE program, which was created based on a literature review[21, 22], clinical practice, and consultation with experts has been proven to be safe, effective and easy for KOA patients to practice. A list of QSE programs in our study can be found in *Additional file 1*. The participants with KOA were recommended to practice QSE 30–40 min per day at least 3 days per week.

**Baduanjin qigong:** The entire set of Baduanjin exercises in this study, recommended by Chinese Health Qigong Association in 2003, consisted of eight postures[14]. It was recommended to practice Baduanjin one time a day, two sets each time[14, 15]. It takes about 20 minutes to complete a full set of Baduanjin. The participants were required to practice Baduanjin in a group-based form at least three days per week, except for a few participants who could not go out to practice so did it at home. Participants were advised that the exercises should be performed within a
tolerable level of pain. If the participants have any discomfort during their exercise, researchers would conduct a re-assessment and adjust previous plans based on participants’ physical functioning and knee symptoms.

**Control group**

The participants in this group trained with similar QSE and telephone follow-ups as for the intervention group. During the entire trial period, the participants in QSE group were not allowed to practice Baduanjin, nor were they allowed to practice other qigong exercises, such as Wu Qin Xi, Tai Chi, etc., but their daily activities were not restricted.

**Outcome measurement**

The participants were assessed by the same research assistants who were blind to intervention allocation to complete the same set of outcome measures at baseline, 3 months, and 6 months. Demographic variables included age, gender, height and weight (body mass index, BMI), disease duration, and social circumstances.

**Primary outcome measures.**

The primary outcomes were pain intensity and physical function related to KOA, measured by WOMAC[23]. The WOMAC was originally designed for use in clinical trials of patients with osteoarthritis of the hip and knee. It includes five items on pain and 17 items on physical function that are rated on a 0–4 Likert scale. Higher scores reflect greater pain and stiffness and more difficulty in physical function. The internal reliability of the Chinese version of the WOMAC, as measured by Cronbach’s alpha, is 0.67–0.82 for its three subscales[24].

**Secondary outcome measures**

Participants’ confidence in managing symptoms of arthritis was measured by the 8-item version of the Arthritis Self-Efficacy Scale (ASES-8)[25]. It consists of eight items with no subscales. Responses were averaged to yield a score ranging from 1 (very uncertain) to 10 (very certain) (higher = greater self-efficacy). The internal consistency of the Chinese version of the ASES-8, as measured by Cronbach’s alpha, is 0.942[26].

HRQoL was measured by Short Form-12 item health survey questionnaire (SF-12), which consists of 12 items with two domains: physical component summary (PCS) and mental component summary scores (MCS)[27]. Higher scores indicate better physical and mental health[28]. The SF-12 has been widely used to assess the
HRQoL of patients with various conditions, including KOA disease, and demonstrated good reliability and validity[29]. The Chinese version of SF-12 indicates good internal consistency with a Cronbach's α of 0.86[28].

**Statistical analysis**

The data were analyzed using SPSS version 23.0. Descriptive statistics including means and SDs, as well as frequencies and percentages, were used to describe the participants’ demographic and clinical characteristics. For intervention effects, repeated measures analysis of variance was used to determine the significance of the differences in pain, physical function, self-efficacy, and HRQoL over six months between the two groups. The interaction effect (group × time) was used to assess the differential change of the outcome variable across three time points between the two groups. The statistical significance level was set at 0.05.

**Results**

A total of 120 eligible participants were assessed from two community centers, of which 23 were excluded for the following reasons: not meeting criteria (n = 13), not wishing to participate (n = 10). A total of 97 participants who met the study criteria agreed to participate in the study, with 50 in intervention group and 47 in control group. Until the end of the intervention, 10 of the 97 participants were lost to follow-up (10.3%), as shown in Fig. 1.

**Participant characteristics**

The demographic characteristics of the participants are shown in Table 1. The mean age was 65.63 (SD= 3.31), range 60–72. There were more female than male patients, at 85.1% and 14.9% respectively. The mean symptom duration was 8.11 (SD =3.86), range 2–16. In total, 33.3% of participants had two affected knees. There were no significant differences in demographic and clinical data between the two groups at baseline (Table 1). At 6 months, there were five participants (11.4%) exercising less than three times per week in intervention group and 13 participants (30.2%) in control group. There were significant differences between the two groups ($\chi^2 = 4.719, P = 0.036$).

**Effects on WOMAC pain intensity and physical function**

No significant group differences were found in pain intensity or physical function at baseline (see Table 2). At the third month of follow-up, significant group
differences were found in physical function (t = 2.223, P = 0.029). At the sixth month of follow-up, there were significant differences between groups in pain (t = 3.730, P < 0.001) and physical function (t = 3.317, P = 0.002).

Repeated measures ANOVA was performed to test the time by group interaction effects on pain intensity and physical function for the entire duration of the study and results are presented in Table 2. The analysis indicated significant time by group interaction effects on pain (F = 44.419, p < 0.001) and physical function (F = 46.904, p < 0.001).

Figures 2 and 3 illustrate time by group interaction effects and the trends of pain and physical function respectively, across the three time points of the study. In both groups, the score pain and physical function at the end point of follow-up were significantly lower than the value obtained at the time of baseline measurements, with the intervention group exhibiting significantly larger reductions in outcomes on both measures than the control group.

Post-hoc multiple comparison of changes in pain and physical function at different time intervals of the study is presented in Table 3. For the intervention group, there were significant reductions in pain intensity and physical function at the time intervals of baseline/month 3 of follow-up (pain:2.205(CI, 1.882 to 2.528), physical function: 4.727(CI, 4.229 to 5.226)), baseline/month 6 of follow-up (pain:3.182 (CI, 2.838 to 3.526), physical function: 6.545(CI, 5.630 to 7.461)), and month 3 of follow-up/month 6 of follow-up (pain:0.977(CI, 0.645 to 1.300), physical function: 1.818(CI, 0.909 to 2.737)). In the control group, significant reductions of both measurements were also observed at the same time intervals as in the intervention group, except at month 3 of follow-up/month 6 of follow-up (pain: -0.070(CI, −0.396 to 0.257), physical function: -0.140(CI, −1.069 to 0.789)).

**Effects on self-efficacy and HRQoL**

Table 4 shows the results for self-efficacy and HRQoL. There were no significant group differences in any of the outcomes at baseline. At the time point of month 3 of follow-up, significant group differences were found in self-efficacy (t = −2.658, P = 0.009). At the time point of month 6 of follow-up, there were significant differences between groups in self-efficacy (t = −4.870, P < 0.001), as well as in the PCS (t = −2.764, P = 0.007) and mental component summary (t = −2.635, P = 0.010) of SF-12.
The analyses of time by group interaction effects on self-efficacy and HRQoL for the entire duration of the study are presented in Table 4. The analysis indicated significant time by group interaction effects on self-efficacy ($F = 49.754, p < 0.001$), as well as in the physical component summary ($F = 15.205, p < 0.001$) and mental component summary ($F = 19.205, p < 0.001$).

**Discussion**

Since there is no cure for OA[1], lifestyle change, particularly exercise and activity are the key to managing knee OA[10, 11]. Therefore, it is important to develop an effective exercise intervention program to facilitate long-term use by people with KOA.

The findings of our study are that compared with an intervention that only involved QSE, a program combining QSE and Baduanjin was more effective in reducing pain intensity in elderly KOA patients, and improving their physical functioning, self-efficacy, and HRQoL. Importantly, the combination exercise program resulted in a better compliance (Figure 2,3).

Research have shown that the diminished lower limb muscle strength in KOA patients is associated with disease progression, pain, physical dysfunction and reduced quality of life[8, 30]. Therefore, quadriceps strengthening is key in KOA management[22]. QSE as a widely used muscle training method[7, 10, 11], its effect on pain relief and functional improvement in patients with KOA was also demonstrated in our study (Table 2). But the evaluation parameters of pain and physical function of WOMAC in intervention group improved significantly compared with that in control group during follow-up period. The greater beneficial effect of QSE+BDJ on KOA symptoms than traditionally recommended QSE may be related to the direct effect of BDJ on muscle strength of lower limbs and how it affects the perception of pain.

As a low-impact aerobic exercise with soft movements, Baduanjin could stretch and relax musculoskeletal throughout the entire body[16]. Previous studies have reported that Baduanjin can improve fatigue, balance and physical flexibility in older peoples[14, 16]. Importantly, partial Baduanjin poses[14, 31, 32] could especially
enhance the strengthen of lower limb muscles. For example, “drawing the bow on both sides” contracts the hamstring muscles and stretches the quadriceps; “swaying the head and shaking the tail” exercises the adductor and abductor muscles of lower limbs; “bouncing on the toes” enhances the strength of the anterior and posterior muscles of the lower limbs at the same time by putting knees together and lifting heels.

Due to such positive effects of Baduanjin movements on lower limb muscle strength, pain and physical functionality were significantly improved after training in the intervention group (as measured by WOMAC) (Table 2). Especially, WOMAC scores for physical function were significantly improved in the intervention group at the time point of month 3 (Table 3). Maintaining functionality is one of the main goals in OA treatment[9, 33]. Good physical function benefits patients to perform daily activities and social interaction independently[7]. And then, quality of life in these patients improved correspondingly[33]. Our findings support the use of QSE plus Baduanjin interventions in KOA.

As a mind-body exercise, Baduanjin postures can strengthen muscles[16], coupled with breathing regulation and a relaxed state of mind[18], it may help individuals decrease pain sensitivity and change the perception of it. Evidence have demonstrated that Baduanjin training increases the excitation of the middle cerebral cortex, helps to down-regulate anxiety and negative emotions[34], and promotes mental health[35]. In a state of peace of mind, individuals are more likely to make positive and correct decisions in self-management[36], and the impact of discomfort such as pain on the body may also be reduced[37]. These influences may help break the “pain cycle” [15] and enhance patients' confidence in coping with diseases or discomfort[13]. Our findings show that QSE plus Baduanjin intervention has more positive effects on self-efficacy and the QoL of KOA patients (Table 4). This is somehow expected, as previous studies have indicated positive associations between self-efficacy and pain in people suffering from chronic musculoskeletal pain[38].

Veenhof (2006) points out that, in order to ensure good compliance, the ultimate goal of exercise intervention on OA patients is to integrate the exercises into their daily lives [39]. However, how to achieve the goal is the core issue that need to
explore. The reality is that this goal is hardly achieved by simply requiring the patient to perform monotonous exercises repetitively[12]. Thus, it is very essential to mobilize multifaceted support around the patient, such as support and encouragement from peers[40-42].

In our study, participants in intervention group were required to practice Baduanjin in a group-based form, so that they had more chance to share successful personal experience in OA management[42] and to provide mutual encouragement and support[40] compared with the participants in control group who practice QSE alone at home. More importantly, group-based exercise may make patients feel that exercise is not for treating their disease, but just a part of their daily activities, which may help to eliminate their awareness of patients’ role and enhance their initiative in KOA management. Consequently, participants in intervention group showed higher level self-efficacy and better exercise adherence.

A review indicated that choosing the exercise program based on patient preference is effective in increasing adherence to exercise[12]. Baduanjin is very popular with the elderly, but most elderly patients with KOA dare not practice Baduanjin due to their concerns of aggravating joint symptoms[43]. In our study, the participants’ concerns were eliminated through correct action guidance by researchers. The results of our study indicated that practicing Baduanjin was safe for elderly patients with KOA, and the participants in QSE plus Baduanjin group showed better adherence. And adherence to exercise was a key predictor of long-term outcome from exercise[8]. At the beginning of the research design, our concern was that participants in the intervention group may have lower compliance due to more exercise items. However, according to the results of 6 months of follow-up, participants in the intervention group showed better enthusiasm, participation, and adherence.

There were several limitations in our study. First, the participants were only recruited from the urban communities and rural residents did not include in this study. It is suggested that future investigation includes rural residents in diverse study settings, so that more conclusive claims of effectiveness of the program may be shown. Second, patients who agreed to participate in the study might care more about their health. This might the cause of the high completion and low attrition rates of the patients in this study, and finally may achieve better intervention results. In addition,
with regard to safety during practice, the study recruited only elderly patients with mild to moderate pain on NRS. Therefore, future study should include patients with severe pain to confirm whether QSE plus Baduanjin can reduce pain and improve other health outcomes among such patients. Finally, a long period of follow-up should be addressed in the future to test patients’ long-term compliance and/or outcomes. More strictly designed trials are warranted in the future to confirm the findings of the current study.

Conclusions

In conclusion, the exercise programs that combined strengthening exercise and Baduanjin promote a positive lifestyle change with an increase in physical activity. Results have shown that patients with KOA in QSE plus Baduanjin group indicated significantly greater reduction on pain, higher improvement in physical function and self-efficacy, and better physical and mental health status than those in QSE group. Likewise, the outcome improvements in the QSE plus Baduanjin group have been better sustained. Moreover, Baduanjin exercise appears to be safe for patients with KOA when practiced correctly. This study provides evidence for the value of exercise programs for patients with KOA.

Additional files

Additional file 1: The guidelines for practicing quadriceps strengthening exercises and Baduanjin qigong for KOA patients in this study. (DOC 15 kb)

Additional file 2: The dataset supporting the conclusions of this article is included within the article. (XLSX 11 kb)

Additional file 3: CONSORT 2010 checklist of information to include when reporting a randomized trial. (DOC 219 kb)

Abbreviations

OA: Osteoarthritis; KOA: Knee osteoarthritis; NRS: Numeric rating scale; BMI: Body mass index; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; ASES-8: Short Form-8 item Arthritis Self-Efficacy Scale; SF-12: Short Form-12 item health survey questionnaire; SF-12 PCS: Physical component summary of SF-12; SF-12 MCS: Mental component summary of SF-12; QSE: quadriceps strengthening exercises;
BDJ: Baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; HRQoL: health related quality of life; BL: baseline; MFU: month of follow-up; CI: confidence interval; SD: Standard deviation.

**Authors’ contributions**

Fenglan Wang participated in the design of the study, performed the data analysis, and drafted the manuscript. Xiaoli Zhang was responsible for the resources and project administration. Xiao Tong performed the statistical analyses and validated the study. Fengmei Xing supervised the study. Min Zhang collected and analyzed patient data. Kun Yang and Nana Jiao performed the assessment and exercise interventions for patients. Zhiguang Duan was a major contributor in the design of this study and revised the manuscript. All authors contributed to and approved the final manuscript.

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**Availability of data and materials**

Data and materials can be accessed through a request to the lead author.

**Ethical approval**

The study protocol was approved by Ethics Committee of North China University of Science and Technology (reference number: 2019073). All participants provided informed, written consent.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare that they have no competing interests.

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| Characteristic                          | Total (n=87) | QSE (n=43) | QSE plus BDJ (n=44) | \( \chi^2 \text{/t} \) | \( P \)-value |
|----------------------------------------|--------------|------------|---------------------|----------------|---------------|
| Age, Mean (SD)                         | 65.63±3.31   | 65.70±3.50 | 65.57±3.15          | 0.182 \( ^* \) | 0.856         |
| Gender (n, %)                          |              |            |                     | 0.897 \( ^\# \) | 0.344         |
| Male                                   | 13(14.9)     | 8(18.6)    | 5(11.4)             |               |               |
| Female                                 | 74(85.1)     | 35(81.4)   | 39(88.6)            |               |               |
| Marital status (n, %)                  |              |            |                     | 0.288 \( ^\# \) | 0.592         |
| Married                                | 73(83.9)     | 37(86.0)   | 36(81.8)            |               |               |
| Single/Divorce/Widowed                 | 14(16.1)     | 6(14.0)    | 8(18.2)             |               |               |
| Educational level (n, %)               |              |            |                     | 0.113 \( ^\# \) | 0.990         |
| Primary education or blow              | 19(21.8)     | 9(20.9)    | 10(22.7)            |               |               |
| Secondary education                    | 35(40.2)     | 18(41.9)   | 17(38.6)            |               |               |
| Higher education                       | 23(26.4)     | 11(25.6)   | 12(27.3)            |               |               |
| College or above                       | 10(11.5)     | 5(11.6)    | 5(11.4)             |               |               |
| Monthly income RMB                     |              |            |                     | 0.116 \( ^\# \) | 0.944         |
| ≤¥999                                  | 14(16.1)     | 7(16.3)    | 7(15.9)             |               |               |
| ¥1000~2000                            | 42(48.3)     | 20(46.5)   | 22(50.0)            |               |               |
| ≥¥2000                                 | 31(35.6)     | 16(37.2)   | 15(34.1)            |               |               |
| BMI, Mean (SD)                         | 22.94±1.99   | 24.12±2.13 | 23.83±1.96          | 0.659 \( ^* \) | 0.511         |
| Symptom duration, Mean (SD)            | 8.11±3.86    | 8.16±4.01  | 8.07±3.75           | 0.114 \( ^* \) | 0.910         |
| Number of affected knees               |              |            |                     | 0.500 \( ^\# \) | 0.298         |
| One                                    | 58(66.7)     | 27(62.8)   | 31(70.5)            |               |               |
| Two                                    | 29(33.3)     | 16(37.2)   | 13(29.5)            |               |               |

* independent t-test; \( ^\# \) Chi-square; BMI: body mass index; QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; SD: standard deviation; \( p < 0.05 \) was considered statistically significant.
## Table 2 Comparisons the average score of pain and physical function between the two groups in different time points (n = 87)

| Time | Group 1 (Mean±SD) | Group 2 (Mean±SD) | Between groups (QSE vs. QSE plus BDJ) | Time×Group |
|------|------------------|------------------|--------------------------------------|------------|
|      | BL               | 3rd MFU          | 6th MFU                              |            |
|      |                  | (Mean±SD)        | (Mean±SD)                            | (Mean±SD)  |
|      | QSE(n=43)        | 6.91±2.42        | 5.47±2.20                            | 5.53±2.49  |
|      | QSE plus BDJ(n=44) | 6.86±2.24        | 4.66±2.08                            | 3.88±2.13  |
|      | WOMAC-pain       |                  |                                      |            |
|      | QSE(n=43)        | 18.91±5.36       | 16.74±5.07                           | 16.88±6.49 |
|      | QSE plus BDJ(n=44) | 19.14±4.77       | 14.41±4.72                           | 12.59±6.27 |

† The repeated measures ANOVA was used to test the time by group interaction effects across the 3 time points of the study.

WOMAC: Western Ontario and McMaster Universities osteoarthritis index, pain (0-20), physical function (0-68); QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; BL: baseline; MFU: month of follow-up; SD: standard deviation; p < 0.05 was considered statistically significant.

## Table 3. SIDAK multiple pairwise comparisons of average score of pain and physical function for the QSE and QSE plus BDJ groups at different time points of the study

|                      | BL vs. 3rd MFU | BL vs. 6th MFU | 3rd MFU vs. 6th MFU |
|----------------------|----------------|----------------|---------------------|
|                      | Mean difference (95% CI) | P-value | Mean difference (95% CI) | P-value | Mean difference (95% CI) | P-value |
|                      |                |            |                     |          |                        |         |
| WOMAC-pain           |                |            |                     |          |                        |         |
| QSE(n=43)            | 1.442(from 1.115 to 1.769) | <0.001    | 1.372(from 1.024 to 1.720) | <0.001   | -0.070(from -0.396 to 0.257) | 0.937   |
| QSE plus BDJ(n=44)   | 2.205(from 1.882 to 2.528) | <0.001    | 3.182(from 2.838 to 3.526) | <0.001   | 0.977(from 0.654 to 1.300) | <0.001  |
| WOMAC-physical function |                |            |                     |          |                        |         |
| QSE(n=43)            | 2.163(from 1.659 to 2.667) | <0.001    | 2.023(from 1.098 to 2.949) | <0.001   | -0.140(from -1.069 to 0.789) | 0.977   |
| QSE plus BDJ(n=44)   | 4.727(from 4.229 to 5.226) | <0.001    | 6.545(from 5.630 to 7.461) | <0.001   | 1.818(from 0.900 to 2.737) | <0.001  |

WOMAC: Western Ontario and McMaster Universities osteoarthritis index, pain (0-20), physical function (0-68); QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; BL: baseline; MFU: month of follow-up; SD: Standard deviation; CI: confidence interval; p < 0.05 was considered statistically significant.
Table 4 Comparisons of self-efficacy and HRQoL between the two groups in different time points (n = 87)

|                      | BL (Mean±SD) | 3rd MFU (Mean±SD) | 6th MFU (Mean±SD) | Between groups (QSE vs. QSE plus BDJ) | BL | 3rd MFU | 6th MFU | Time × Group |
|----------------------|--------------|-------------------|-------------------|--------------------------------------|----|---------|---------|-------------|
| SF-12 PCS            |              |                   |                   |                                      |    |         |         |             |
| QSE (n=43)           | 41.35±9.17   | 45.21±9.23        | 44.33±10.03       |                                      | -0.333 | 0.740 | -1.835 | 0.070 | -2.764 | 0.007 | 15.205 | <0.001 |
| QSE plus BDJ (n=44)  | 42.05±10.21  | 49.43±12.01       | 51.42±13.38       |                                      | -0.216 | 0.829 | -1.976 | 0.051 | -2.615 | 0.010 | 19.205 | <0.001 |
| SF-12 MCS            |              |                   |                   |                                      | -0.350 | 0.727 | -2.658 | 0.009 | -4.870 | <0.001 | 49.754 | <0.001 |
| QSE (n=43)           | 44.77±11.81  | 48.33±11.38       | 47.45±13.97       |                                      | -0.350 | 0.727 | -2.658 | 0.009 | -4.870 | <0.001 | 49.754 | <0.001 |
| QSE plus BDJ (n=44)  | 45.31±11.68  | 52.98±10.39       | 54.61±11.25       |                                      | -0.350 | 0.727 | -2.658 | 0.009 | -4.870 | <0.001 | 49.754 | <0.001 |

† The repeated measures ANOVA was used to test the time by group interaction effects across the 3 time points of the study.

ASES-8: short form-8 item arthritis self-efficacy scale; SF-12: short form-12 item health survey questionnaire, SF-12 PCS: physical component summary, SF-12 MCS: mental component summary; QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; BL: baseline; MFU: month of follow-up; SD: standard deviation; p < 0.05 was considered statistically significant.
Figure 1. Flowchart of the study participants

QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong.
Figure 2. Trends of pain intensity for the QSE and QSE plus BDJ group participants at the 3 time points of the study

WOMAC: Western Ontario and McMaster Universities osteoarthritis index; QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; MFU: month of follow-up.
Figure 3. Trends of physical function for the QSE and QSE plus BDJ group participants at the 3 time points of the study

WOMAC: Western Ontario and McMaster Universities osteoarthritis index; QSE: quadriceps strengthening exercise; BDJ: baduanjin qigong; QSE plus BDJ: a combination of quadriceps strengthening exercise and baduanjin qigong; MFU: month of follow-up.