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ORIGINAL

THE THERAPEUTIC EFFECTS OF INTERNET-BASED TAI CHI ON KNEE OSTEOARTHRITIS IN CHINESE ATHLETES: A RANDOMIZED CONTROLLED TRIAL PROTOCOL

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ABSTRACT

Background: Knee osteoarthritis (KOA) is a prevalent chronic degenerative disease, especially among athletes due to their high physical demands. While community-based Tai Chi is recommended for KOA rehabilitation, its feasibility is often limited by external factors like weather and logistics. Internet-based Tai Chi could offer a more accessible alternative. This study aims to compare the therapeutic effects of Internet-based Tai Chi with community-based Tai Chi in athletes with KOA and to explore the underlying mechanisms of Tai Chi's therapeutic action. **Methods and Analysis:** In this parallel randomized controlled trial, 96 athletes with KOA in China will be randomly assigned to either an Internet-based or a community-based Tai Chi group in a 1:1 ratio. The intervention consists of 60-minute Tai Chi sessions, conducted twice weekly for 12 weeks. Primary outcome measures include the Western Ontario and McMaster University Osteoarthritis Index. Secondary outcomes encompass the 20-meter walk test, Timed Up and Go test, Osteoarthritis Self-Efficacy Scale,

SF-36 health survey, and assessments of muscle strength and ultrasound echo intensity in quadriceps, hip abductors, and core muscles, along with lateral trunk lean angle. Attendance rates and adverse events will also be documented. Assessments will occur at baseline, 3 months, and 6 months. Data will be analysed on both intention-to-treat and per protocol bases. **Conclusion:** This trial will provide insights into the viability and efficacy of Internet-based Tai Chi as a therapeutic option for athletes with KOA, comparing it against the traditional community-based approach. It will also contribute to the understanding of Tai Chi's therapeutic mechanisms in managing KOA, potentially offering an innovative, accessible rehabilitation strategy for athletes.

KEYWORDS: Tai Ji; Knee; Osteoarthritis; Internet-Based Intervention

1. INTRODUCTION

Knee osteoarthritis (KOA) is a chronic degenerative disease affecting the entire joint of knee, characterized by injury to the local articular cartilage, narrowing of the joint space, and remodeling of the subchondral bone, as well as alterations of the synovium, ligaments, and surrounding muscles (Bennell, Hinman, Wrigley, Creaby, & Hodges, 2011). Knee osteoarthritis tends to occur in middle-aged and elderly people, with pain and limited mobility as typical clinical features. Because it is not curable, non-pharmacy treatment was recommended as the fundamental intervention for individuals with KOA. It is worth noting that as a mind-body exercise, Tai Chi was highly recommended for KOA rehabilitation by the American College of Rheumatology (Kolasinski et al., 2020).

A meta-analysis suggested that community-based Tai Chi exercise may be effective in alleviating pain, relieving stiffness, and improving physical function in patients with KOA(Li et al., 2020), A randomized controlled trial has shown that the community-based Tai Chi intervention can improve gait outcomes of older Chinese women with knee osteoarthritis, such as gait velocity, step length, initial contact angle, and maximal angle4. Furthermore, the Tai Chi group showed a significant improvement in Western Ontario and McMaster University Osteoarthritis Index (WOMAC) scores and Short Physical Performance Battery (SPPB) scores(Zhu et al., 2016).

However, there are still some disadvantages to community-based Tai Chi. First, the instruction of community-based Tai Chi is usually conducted outdoors, such as public parks or squares, so severe weather may be an obstacle to the implementation of the Tai Chi instruction. Transferring the Tai Chi instruction indoors may overcome this problem, but it may increase the teaching costs. Second, community-based Tai Chi instruction is not friendly to people living far from the teaching station, which can lead to poor compliance by the learners. Third, community-based Tai Chi was usually implemented at the appointed time;

it is a lack of flexibility in time, which is not beneficial to the popularization and application of Tai Chi to individuals with KOA. Finally, with the arrival of the post-pandemic era, a large crowd of practitioners in the public territory may not be recommended and the community-based Tai Chi instruction mode may be susceptible to epidemics.

How can we overcome these problems? With the development of the Internet technology, Tai Chi instruction can be implemented and supervised on the Internet. Exploring a pattern of Internet -based Tai Chi instruction mode, which allows a group of individuals and their Tai Chi instructor to exercise together live and interact together, is of great significance.

Although meta-analysis has confirmed that Tai Chi is effective in improving pain, stiffness, and physical function of KOA, it is still unknown whether Internet -based Tai Chi has the same therapeutic effects on KOA. A similar study has confirmed that telecommunication-based tai chi exercise is as effective as traditional community-based tai chi exercise in improving balance function in older adults at high risk of falls, and in addition, it is an effective, affordable and acceptable choice of exercise for older adults(Wu, Keyes, Callas, Ren, & Bookchin, 2010).

Thus, we hypothesized that the therapeutic effectiveness of Internet -based Tai Chi exercise in KOA is not inferior to traditional community-based Tai Chi exercise in improving the WOMAC score of pain, stiffness, and physical function, and the adherence rate of Internet -based Tai Chi exercise is also not inferior to traditional community-based Tai Chi exercise. Subsequently, to date, as far as we know, there is little research exploring the therapeutic mechanism of Tai Chi on KOA from the holistic view of biomechanics, the etiology of osteoarthritis is multifactorial, involving mechanical, structural, genetic, and environmental factors(K. R. Vincent, Conrad, Fregly, & Vincent, 2012), above all, the mechanical factor is the most direct factor influencing the onset and progression of KOA.

Research on the pathophysiology of osteoarthritis has indicated that the morphology and spatial distribution of mechanical components of knee cartilage in healthy subjects have been accommodated to joint load during the load-bearing period, which allows certain areas of cartilage to respond better to load, while other areas are vulnerable to joint loading (K. R. Vincent et al., 2012). Alterations in knee kinematic patterns can cause a shift from normal articular contact areas to articular areas that are not frequently loaded, which can contribute to the onset of KOA(K. R. Vincent et al., 2012).

A previous study has confirmed that the loading deviation in the coronal plane is a vital pathogenesis of KOA (Gerbrands, Pisters, Theeven, Verschueren, & Vanwanseele, 2017). But what factors lead to the shift of joint

load distribution in the coronal plane? To answer this question, we have reviewed the relative researches in the past and found that there are mainly four factors exerting influence on the shift of joint load distribution in the coronal plane of the knee, they are as follows:

The first factor is the lateral trunk lean, it alters the load distribution of the medial-lateral cartilage of the knee joint during the support stance, which transfers the load of joint from the well-adapted area to the poorly adapted area and may lead to the onset and progression of KOA(Vincent et al.). The second factor is weak core strength, which is significantly associated with improper trunk control, and weak abdominal muscles have been shown to lead to lateral trunk lean (Karthikbabu & Verheyden, 2020), and decreased core stability is associated with a higher risk of knee injury (Borghuis, Hof, & Lemmink, 2008).

The third factor is the weak hip abductor; it can affect the stability of the coronal plane of the pelvis during the single-leg supported period, which can result in lateral trunk lean and abnormal loading of the knee joint in the coronal plane(Elizabeth A Sled, 2010), in addition, it was identified that hip abductor strength is positively correlated with KOA function, KOA progresses faster in people with weak hip abductor muscle(Jianxiong et al., 2019).

The last factor is the weak quadriceps femoris, this can lead to an increase in the asymmetry strength of the quadriceps on both sides, which was significantly associated with the asymmetry of trunk movement, and can increase the lateral trunk lean and affect the load on the knee in the coronal plane (Iijima, Eguchi, Aoyama, & Takahashi, 2019). As described above, we know that core muscle weakness, hip abductor muscle weakness, quadriceps weakness, and increased lateral trunk lean are four factors that contribute to the deviation of the joint load distribution in the coronal plane, and decreased core muscle, hip abductor muscle, and quadriceps strength are highly correlated with lateral trunk lean (CHAKRABORTY, YARDI, & SINDHA, 2020).

But what makes these muscles weak? Animal experiments have confirmed that muscle fat infiltration has an independent effect on muscle contraction and there is a direct relationship between muscle fat infiltration and muscle weakness (Biltz et al., 2020). Furthermore, clinical research has shown that quadriceps femoris weakness and hip abductor muscle weakness are both characteristics of KOA(Iijima et al., 2019), and weakness of both muscles is also related to fatty infiltration of muscles (Addison, Marcus, Lastayo, & Ryan, 2014).

When it comes to the therapeutic mechanism of Tai Chi training in KOA, previous research indicates that KOA can be chronically caused by inappropriate posture and exertion habits, and Tai Chi exercise can relieve the pain of individuals with KOA by correcting the posture of exertion and

strengthening the muscles of the lower limbs (Song, Lee, Lam, & Bae, 2003; Yu et al., 2018), For example, the Tai Chi alignment principle requires “head suspended from above, trunk maintained vertically upright” (S. Wang, Xu, & Li, 2017), keeping the trunk vertical can also reduce the forces required to support the COM of the whole body (Gatts, 2008), in addition, compared to walking, Tai Chi gait has a greater component of lower limb motion in the coronal plane, longer duration of single-leg stance time, larger joint motion hip abduction(Wu, Liu, & Hitt, 2004). These kinematics characteristics contribute to maintaining the stability of the lateral trunk (Song et al., 2003) and maintaining good posture during the stance period (Kirsteins, Dietz, & Hwang, 1991).

Accordingly, we hypothesize that the therapeutic mechanism of Tai Chi exercise in KOA was that Tai Chi exercise can improve the strength of the hip abductor, the quadriceps femoris, and the core muscles, which can reduce the lateral trunk lean and correct the control of the coronal gesture control of KOA individuals, and moreover, the mechanism of muscle strength improvement may be that fat infiltration in these muscles was reduced by Tai Chi exercise.

Thus, we design a randomized controlled trial to compare the effectiveness and adherence of Internet -based Tai Chi exercise with the traditional community-based Tai Chi exercise program, and to explore the therapeutic mechanism of Tai Chi on KOA from the point of view of biomechanics and physiology. The aim of this study is to explore the feasibility of the application of Tai Chi exercise as a long-distance, supervised, home rehabilitation program for the management of KOA.

2. Materials and Methods

2.1 Study Design and Setting

This research is a single-blind parallel randomized controlled trial that compares the Internet-based Tai Chi exercise with community-based Tai Chi exercise, and is designed as a non-inferiority trial, and a total of 96 subjects will be recruited. The duration of the study will be six months including a supervised intervention of three months and a follow-up period of three months, assessments will be conducted at the beginning of the study, 3 months, and 6 months, the WOMAC score will be used to monitor the therapeutic effects of KOA on the last day of every week during the 3-month intervention period.

The research is carried out at the Department of Rehabilitation of Southwest Medical University, Sichuan province, China. the community-based Tai Chi intervention is implemented in Zhongshan Park, Luzhou, Sichuan province, China; Ethics approval was certified by the Clinical Ethics Committee of the Southwest Medical University (Ethical code: KY2022098), The trial is registered in Chinese Clinical Trial Registration: ChiCTR2200058037. The flow of this study is shown in Figure 1.

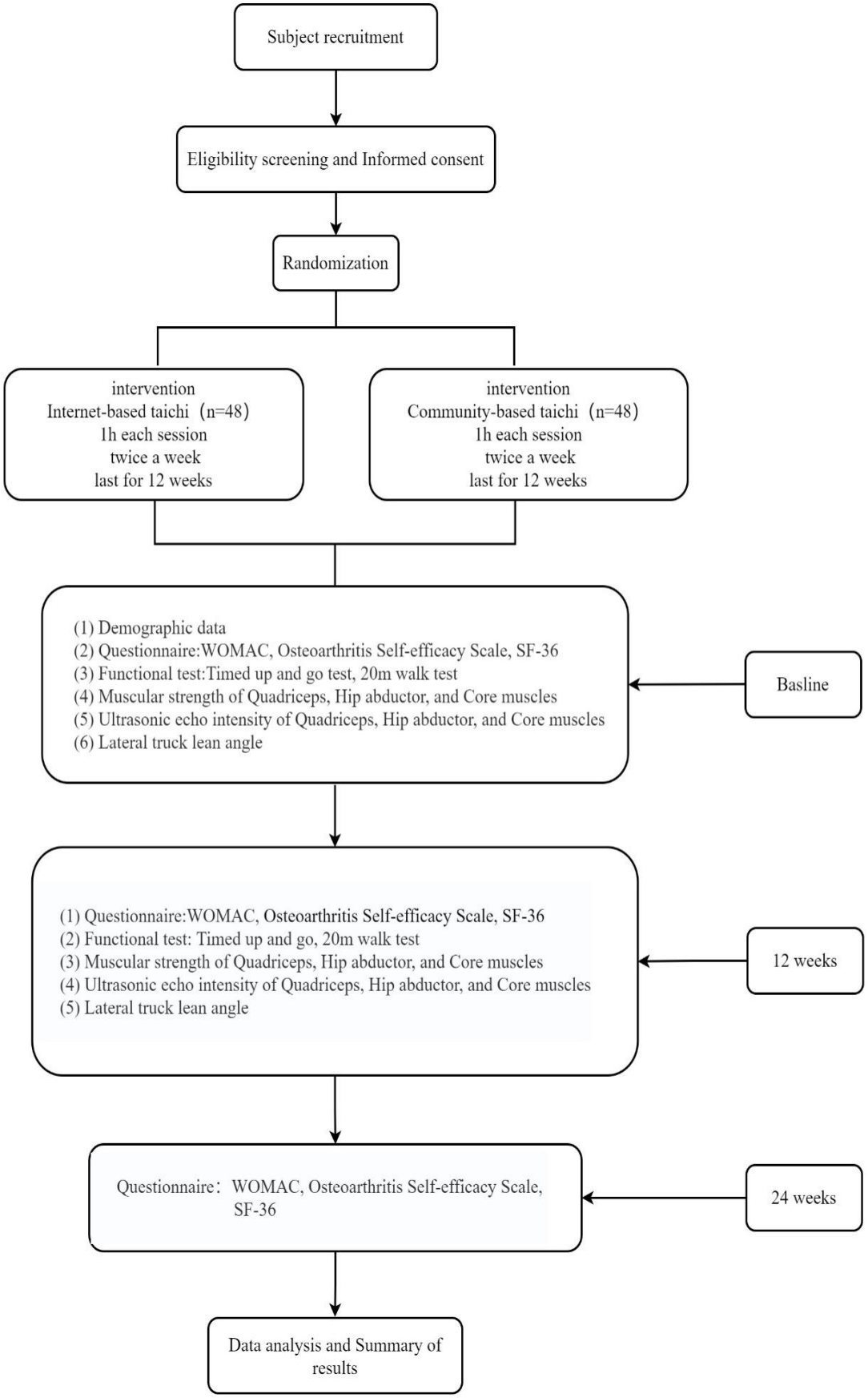

Figure 1: Study flow chart. WOMAC= Western Ontario and McMaster University Osteoarthritis Index

2.2 Sample size calculation

The sample size was calculated by a statistician using PASS 11 software, the noninferiority criterion was used to calculate the sample size, according to the previous study the SD was approximately 4.5(Ge, Keyes, Callas, Ren, & Bookchin, 2010), Considering α=0.05, 1−β=0.8, and the noninferiority margin δ =4 was established according to the suggestions of experts, then put these data into the PASS 11 software, the required sample size was calculated as 76, considering an attrition rate of 20%, a total of 96 individuals with KOA will be needed.

2.3 Inclusion criteria

Participants accompanying all of the following 4 conditions will be included: 1. Conformance with the diagnostic criteria of the Guidelines for the Diagnosis and Treatment of osteoarthritis (2018 Chinese version):

① Recurrent knee pain within the last month; ② X-rays of both knees(standing position or weight bearing position) show narrowing of the joint space, subchondral bone sclerosis and/or cystic changes, and osteophyte formation at the joint edge; ③ Age ≥ 50 years; ④ duration of morning stiffness≤ 30 minutes; ⑤bony crepitus. Meeting Criteria ① + (any 2 of ②, ③, ④, ⑤) can be diagnosed as knee osteoarthritis.

2. 40 years ≤ age ≤ 75 years; 3. 0＜visual analogue pain score of knee ＜7; 4. Ⅰ≤ Kellgren-Lawrence grades of knee x-ray ≤ Ⅲ; The participates in this trial is similar to previous research that established the efficacy of Tai Chi on KOA(C. Wang et al., 2009).

2.4 Exclusion criteria

Participants accompanying any of the following conditions will be excluded: 1. Inability or unwillingness to cooperate with the intervention procedure and the follow-up scheme; 2. Cognitive decline or impairment (Montreal Cognitive Assessment Scale score< 18); 3. Mental and psychological abnormalities; 4. With organic diseases of the cardiovascular system and respiratory system, such as coronary heart disease, chronic obstructive pulmonary disease, emphysema, pulmonary heart disease, etc; 5. Along with neurological diseases, such as cerebral infarction, cerebral hemorrhage, Parkinson's disease, and balance dysfunction (standing balance ≤ 2 grade); 6. With joint replacement or surgery of the hip, knee, and ankle; 7. With abnormal posture or deformity of the ankle joint, such as foot pronation, foot pronation, high arch foot, flat foot, heel valgus, etc; 8. In the acute phase of knee osteoarthritis; 9.Those who have regularly practiced taijiquan, Qigong, Baduanjin, and other traditional sports; 10.Those who have received injections of sodium hyaluronate or steroidal anti-inflammatory drugs in the knee in the

last 3 months.

2.5 Recruitment strategy

Participants with KOA will be recruited from the communities of Luzhou city and the Affiliated Hospital of Southwest Medical University, the recruitment period is from April 2022 to August 2022, we disseminate the recruitment information by sharing the tweets on WeChat APP online or handing out the brochure in the community or hospital.

Volunteers who meet the inclusion criteria will be enrolled by a designated researcher. Before recruitment, they will be informed about the possible benefits and risks of Tai Chi exercise in this trial and will be required to sign an informed consent; however, they can withdraw from this study at any time without reason.

2.6 Randomization and Blinding

The allocation sequence was designated by the statistician using PASS software. An opaque sealed envelope was used to conceal the sequence before the intervention. In this research, it was impossible to blind subjects and instructors; outcome assessors, data collector, and statistician were blind to group allocation.

Participants will be randomly assigned (in 1:1 ratio) to the Internet-based Tai Chi exercise group (n=48) or the community-based Tai Chi exercise group (n=48) by a special assigned person who does not participate in the test procedure. If participants strongly request to change the grouping after randomization, the allocation can be adjusted according to the actual condition. The blind will be uncovered at the end of the trial when statistical analysis was performed.

2.7 Intervention

The participants are managed using an online chat software named WeChat, and we build group A and group B on Wechat for this trial, the participants randomly assigned to the Internet-based exercise group will be invited to join group A in WeChat, Otherwise, the participants randomly assigned to the community-based exercise group will be invited to join group B in WeChat, after they have achieved the 12-week intervention, they will be moved out of the WeChat group, and then they will be invited to the corresponding follow-up WeChat group A or B.

2.8 The Tai Chi style and the coach

Eight-form Yang Style Tai Chi is chosen as the intervention program, in order to accommodate Tai Chi to the lower limb function of the KOA individuals,

we will modify the Tai Chi program accordingly, these modifications contain: 1. Tell subjects to perform Tai Chi in a high posture 2. with their foot lifted lower than the knee when performing the 'Kick with the left or right heel' and 'Golden cock stands on one leg'. Tai Chi was instructed by a certified Tai Chi coach with more than 10 years of teaching experience, and she has achieved the Tai Chi Champion in Sichuan province, China. The Tai Chi teaching protocol contains a 60-minute Tai Chi session (warm up 10 min, Tai Chi exercise 40 min, cool down 10min), twice a week, lasting 12 weeks, which is similar to previous research that established the efficacy of Tai Chi on KOA23.

2.9 Internet -based Tai Chi exercise

The Internet-based Tai Chi teaching was conducted using Tencent meeting software, the teaching scene is located in the Sports Training Room of the Department of Rehabilitation Medicine, Southwest Medical University, China; the Tai Chi coach performs and instructs the Tai Chi course in front of the computer camera, subjects can learn the Tai Chi lively online using their smartphone or computer, except for live teaching, we have provided the video playback on the Super star learning app, through which the subjects can review the course or practice the Tai Chi following the video after class, in order to ensure the quality of teaching, we require the subjects upload a short Tai Chi video in the WeChat group every weekend, then the Tai Chi coach or rehabilitation physician who has Tai chi practice experience will evaluate the precision of Tai Chi movements, if there are some deviations in their Tai Chi movements, a short video containing the correction of the Tai Chi movement will be sent to the corresponding WeChat group and the subject will be informed at once, then they can modify their Tai Chi movements according to the video direction and feedback their movements again the next weekend after retraining.(Figure 2,3)

Figure 2: The Internet -based Tai Chi instruction: The Teaching Setting

Figure 3: The Internet -based Tai Chi instruction: live instruction

2.10 The community-based Tai Chi exercise

The style, intensity, duration of the Tai Chi prescription is the same as the Internet -based Tai Chi exercise, and the coach is also the same; the difference is that the Internet-based Tai Chi will be conducted online using Tencent Meeting software, while the community-based Tai Chi will be conducted in the Zhongshan park in Luzhou, Sichuan province, China. (Figure 4)

Figure 4: The community-based Tai Chi instruction: The Teaching Station

Except for the instruction session, subjects in both groups will be told to practice Tai Chi for at least 20 min per day, and they can also maintain their usual daily activity, participating in the new exercise program was not permitted. During the follow-up period, patients were instructed to continue practicing Tai

Chi daily.

2.11 Analgesics and NSAID use

During the intervention period, medication is not recommended unless the pain is so severe that the patient cannot endure it, if the subject must take analgesics and non-steroidal anti-inflammatory drugs, he or she should keep a record of the brand name of the drug, as well as the quantity, frequency, and duration of drug intake in detail.

2.12 Outcome measures and follow-up

The baseline demographic and clinical characteristics of each group will be collected at the beginning of the study. These baseline characteristics include age, gender, marital status, education, race/ethnicity, health status, medication use, resting blood pressure, weight (kg) and height (cm), outcome assessments will be performed at the beginning of the study, 3 months and 6 months.

2.13 Primary outcome measures

1. WOMAC pain: the pain dimension of the WOMAC scale contains 5 items, The score of each item ranges from 0 to 100 points; the higher the score, the greater the severity of the symptom or dysfunction(Holtz, Hamilton, Giesinger, Jost, & Giesinger, 2020). 2. Stiffness of WOMAC: the stiffness dimension of the WOMAC scale contains 2 items, the score of each item ranges from 0 to 100 points, the higher the score, the greater the severity of the symptom or dysfunction(Holtz et al., 2020).

2.14 Secondary outcome measures

1. 20 m walk test: It is used for measuring the gait velocity, measurement procedure: prepare a gallery at least 25 meters long, marking a 20 meters' distance with color tape, instruct the subjects to walk 20m at their ordinary pace three times with an interval of 2 min, the researchers will record the time simultaneously.

2. Timed up and go test: it is a dynamic balance ability assessment method to test functional flexibility. the subjects should stand from a chair, walk 3 m forward, turn, and sit down on the chair again, the usual speed should be stressed, repeat this measurement for 3 times with an interval of 2 min. Researchers should record the duration time immediately, a slower performance on the test was thought to be associated with a higher risk of fall(Dubois, Bihl, & Bresciani, 2017).

3.Osteoarthritis Self-Efficacy Scale: The scale containing eight items was used to assess perceived self-efficacy. self-efficacy is defined as a

person's belief in their ability to organize and execute the actions required to conquer the anticipative situation or task, and high levels of self-efficacy can predict a better psychological state (Ezzat, Whittaker, Brussoni, Mâsse, & Emery, 2021).

4. 36-item short form health survey (SF-36): SF-36 is a brief self-administered questionnaire that consisting of 36 questions and constitutes eight dimensions of health, that is, physical functioning (PF), role physical (RP), bodily pain (BP), general health

(GH), vitality (VT), social functioning (SF), role emotional (RE), and mental health (MH). The social dimension of SF-36 will be extracted to evaluate the social engagement of the subjects in this research(Brazier, 1995).

5. Muscle composition measurement: ultrasound image was used to measure the composition of the quadriceps femoris, hip abductor, transverses abdominis and multifidus muscle. ultrasound echo intensity (EI) quantified by gray value using Image J software will be used to quantify the composition of these muscles (Karapınar, Atilla Ayyıldız, Ünal, & Fırat, 2021), the higher echo intensity represents the adipose tissue and fiber connective tissue, while the lower echo intensity represents the muscle tissue (Chopp-Hurley, Wiebenga, Bulbrook, Keir, & Maly, 2020).

The test procedures were as follows：①Quadriceps Femoris: it contains four muscles, that is, Rectus femoris, Vastus internus, Vastus medialis, Vastus lateralis. The subject was in the supine position with the knee straightening. Rectus femoris: the ultrasound probe was located at 50% on the line from the anterior spina iliaca superior to the superior part of the patella, and was oriented perpendicular to the long axis of the muscle; Rectus femoris is in the superior layer of the thigh. Vastus internus: the location and orientation of the probe were same as Rectus femoris measurement, Vastus internus is in the deep layer of the thigh. Vastus medialis: the ultrasound probe was located at 80% on the line between the anterior spina iliaca superior and the joint space in front of the anterior border of the medial ligament, and was oriented perpendicular to the long axis of the muscle; Vastus medialis is in the superior layer of the thigh. Vastus lateralis: the ultrasound probe was located at 2/3 on the line from the anterior spina iiliaca superior to the lateral side of the patella, and was oriented perpendicular to the long axis of the muscle; Vastus lateralis is in the superior layer of the thigh.

②Gluteus medius: the ultrasound probe was located at 50% on the line from the crista iliaca to the trochanter; Gluteus medius is under the Gluteus maximus.

③Transversus abdominis: Test procedure: The subject was in the supine position with hip flexion and knee flexion of 90° to fully relax the abdomen. the

ultrasound probe was located at the midpoint of the line between the edge of thoracic and the iliac crest on the lateral abdominal wall, perpendicular to the anterior abdominal wall muscle fibers and the abdominal wall. During the test, participants were recieved standardized instructions to “breathe in and out relaxed, hold the breath, and then draw in the abdomen without moving the spine”. When acquiring the ultrasound images, participants were asked to hold their breath for 5 seconds at the end expiration of natural breathing and abdominal respiration, respectively; three pictures should be acquired for each breathing pattern, and the bilateral transversus abdominis muscle will be measured; the average value of the three measurements was taken as the final measurement value for each side in two breathing patterns.

④Multifidus muscle: The Multifidus muscle is bilaterally adjacent to the spinous process, located deeply in the groove between the spine and the transverse process of the vertebral and is very strong in the lumbar region, so the multifidus muscle of L3, L4, L5 was selected for measurement. Test procedure: the subject was lying prone on the examination bed with a pillow placed under the abdomen to eliminate lumbar lordosis to keep the multifidus muscles relaxed, then the spinous process of L3, L4, L5 was marked, the probe was successively placed on the multifidus muscle of L3, L4, L5 on one side along the long axis of the trunk in turn, then participants were asked to breathe naturally, the image acquisition was collected once for each segment of L3-5, the average of 3 measurements was taken as the lumbar multifidus muscle on one side, two sides of the lumbar multifidus muscle will be measured.

6. Muscle strength measurement: The isometric strength of both sides will be measured using a handheld dynamometer (brand: NscingEs), previous studies have shown that the hand-held dynamometer had a high reliability of test-retest [intraclass correlation coefficient (ICC) = 0.98], moderate to good validity with the isokinetic dynamometer compared to the quadriceps strength (r = 0.62) (Almeida, Albano, & Melo, 2019).

Hip abductor strength: Subjects are instructed to lie laterally on the bed, the limb to be measured is located above and with hip slightly extended, the limb below is in a hip and knee flexion position; the dynamometer is placed on the lateral femoral condyle of the limb to be measured by the researcher, the subjects will be told to abduct the hip joint from the neutral position in their maximum effort for 5 seconds, the researcher should keep the dynamometer fixed, the test will be conducted 3 times with a 30-second interval, the hip abductor strength of both sides will be measured.

The resistance arm is defined as the distance between the greater trochanter and the lateral condyle of the femur. Multiplying the maximum force (N) by the resistance arm (m), the torque can be calculated (N·m) (Kean, Bennell, Wrigley, & Hinman, 2015). (Figure 5)

Figure 5: Measurement of Hip Abductor Isometric Strength

Quadriceps strength: Subjects are guided to sit upright with their knees in 90° flexion. The dynamometer is placed on the proximal tibia 10 cm away from the lateral malleolus, and subjects are instructed to make a maximum isometric contraction lasting 5 seconds, the test is conducted 3 times with an interval of 30 seconds. The quadriceps strength of both sides will be measured. (Figure 6). The distance between the lateral condyle of the femur and the lateral malleolus will be measured by tape and is considered the resistance arm of the quadriceps femoris. Multiplying the maximum force (N) by the resistance arm (m), the torque can be calculated (N·m).

Figure 6: Measurement of Quadriceps Femoris Isometric Strength

7. Core muscle strength measurement: Core muscle strength is measured using the Chattanooga Group (USA) pressure biofeedback gauge, a previous study showed that the inter-rater reproducibility of TrA/IO and Multifidi

was 0.876, 0.508 respectively; the intra-rater reproducibility of TrA/IO and Multifidi was 0.747, 0.293 respectively(D Faustino et al., 2021). Subjects are instructed to lie down in a supine position, with their hips and knees flexed, then the pressure bag will be placed back between the last rib and the posterior superior iliac spine, and the researcher will inflate the bag until the pressure is 40 mmHg. Transverse abdominal muscle strength: Instructing the subject to breathe naturally, then tell the subject to contract the abdominal muscle, draw the navel to the spine, and try to compress the bag without shifting the pelvis. the maximum pressure above 40 mmHg lasting for 10 seconds is considered the final result, the increase in the pressure value was used as the evaluation indicator, and the pressure was measured three times with intervals of 5 minutes as described above(Faustino, Vieira, Candotti, Schmit, & Loss, 2021). Multifidus muscle strength assessment: Instructing the participants to maintain normal breathing, contract the lower back muscles, try to lift the trunk slightly to reduce the pressure of the bag without moving the pelvis, considering the result of pressure below the baseline (40 mmHg) lasting 10 seconds as the final result, and the pressure was measured three times with an interval of 5 minutes as described above33.

8. Lateral trunk lean angle: Human posture control is evaluated by the Azure Kinect DK marker-less motion capture system. Azure Kinect DK has a better bone joint tracking function, which can capture 26 joints and accurately track human motion and posture. Research shows that Microsoft Kinect and 3D motion analysis systems had comparable inter-trial reliability (ICC difference=0.06±0.05; range, 0.00-0.16) and excellent concurrent validity, with Pearson's γ -values > 0.90 for most measurements (r=0.96±0.04; range, 0.84-0.99) (Clark et al., 2012). The timed up and go test (TUG) is chosen as the functional activity to assess the gesture control of the KOA individual, because the TUG includes five parts: sit-stand transfer, forward gait, middle turning, returning gait, turning-standing-sitting; these tasks require a higher challenge of gesture control; it not only needs a coordinated body and strong muscle strength of the lower limb, but also needs good balance ability and control ability. The TUG was recorded 3 times using the Kinect, with an interval of 5 minutes, the lateral trunk lean angle will be analyzed during the middle turning phase of the TUG. The trunk is defined as a line connecting from the midpoint of hip joints to the midpoint of shoulder joints, the lateral trunk lean angle is calculated as the angle between the line and the plumb line in the coronal plane. The scale and functional assessment will be performed by a single trained researcher, muscle strength measurement and lateral trunk lean angle will be performed by another trained researcher, ultrasound measurement will be performed by 3 doctors with more than 5 years of clinical experience in musculoskeletal ultrasound diagnosis.

Adherence: In order to ensure the compliance of the subjects, we have made the commitment that the assessments or intervention in the trial are free

of charge. Furthermore, if the subjects have completed the trial with good compliance, we will provide free physical therapy on their KOA for 3 months. Throughout the 12-week intervention period, the attendance of the subjects will be recorded and if the participants missed the session, we will track the reasons. The questionnaire survey will be conducted every 2 weeks to record the amount of Tai Chi and other exercises.

Safety: Adverse events will be monitored during the research by inquiring the subjects and conducting an online questionnaire survey every two weeks. If adverse events occur, they will be recorded immediately in detail, and after the causes are identified, proper instructions will be given to resolve these problems. Among adverse events, joint pain is the most common case, which indicates that Tai Chi motion may not be proper for subjects, in this case, the practice of Tai Chi should be suspended immediately and we will tell subjects to rest for 3 days, and then the Tai Chi movement of the individual should be reevaluated clearly by the coach, and the error that exists in the Tai Chi movements should be corrected, ensuring that the Tai Chi movements are precise. If knee pain was not relived by those adjustments, we will provide physical therapy free of charge to modify the disease. In addition, there may be some unexpected events during the trial, such as the onset or exacerbation of the underlying disease, if such a case occurs, the trial will be suspended immediately and the subject will be sent to hospital at the same time.

2.15 Data Management

The data will be recorded in the case report form (CRF), the initial letter of the first name and given name will be used to record the name of subjects in the CRF, the data recorded in CRF will be entered in the Excel database and checked by two persons. This research is not pharmaceutical clinical trial, due to the small risks and short duration, the data monitoring committee (DMC) is not needed in this trial.

2.16 Statistical analysis

The severe knee will be chosen for analysis. If the pain intensity of both knees was the same, we chose one knee as the affected side through randomization. Multiple imputation was used for missing data. The research data will be analyzed using SPSS V.25.0 statistical software; a statistician blinded to the grouping will perform the statistical analysis. Data analysis will be based on the intention-to-treat (ITT) and per protocol (PP) principles. The results of the ITT and PP analysis will be compared for consistency. The two-sided confidence interval approach was used, a p value <0.05 will be considered statistically significant. Participants who have an absence rate $\geqslant$ 40%（non adherence to protocol）or fail to complete the study will be treated as having no change from baseline at all times. Multiple interpolation method is

used to process missing data. For quantitative data, if the data distribution was normal, the data will be presented as the mean ± SD. Otherwise, the data will be present as median ± quartile, categorical variables will be described with percentages (%). The two-sample t test will be used to compare clinical data between the Internet -based Tai Chi group and the community-based group, the paired sample t test will be used to compare the data between the baseline and the end of the intervention period in both groups. Subgroup analysis will be conducted based on age or Kellgren-Lawrence grades of knee x-ray.

3. Discussion

With the development of the Internet technology, Tai Chi exercise aimed at KOA rehabilitation can be taught and supervised online, and KOA individuals can participate in training at home, which may provide great convenience to KOA individuals and prevent the Tai Chi program from being hampered by extreme weather and traffic problems. To our knowledge, this is the first research to compare the therapeutic effects of Internet-based Tai Chi exercise and community-based Tai Chi exercise on KOA. If these hypotheses were confirmed, there was a potential that the Internet-based Tai Chi mode can be become a long-term, supervised, home rehabilitation program for the management of KOA (Coughlan, Kiernan, & Arnous, 2019). Referring to the therapeutic mechanism, previous research considered that the therapeutic effects of Tai Chi on KOA can be attributed to strengthening the muscle strength of the lower limbs, but the mechanism of the muscle strengthening effects of Tai Chi were not discussed in further detail, this research hypothesis that Tai Chi exercise can improve muscle strength by reducing muscle infiltration. If this hypothesis is proved, it may deepen our understanding of the therapeutic mechanism of Tai Chi on KOA. Not only that, different from the previous research, this research explores the therapeutic mechanism of Tai Chi exercise on KOA from a holistic perspective that integrates muscle composition, muscular strength, and posture control in the coronal plane, which may provide a systematic therapeutic strategy for KOA. There are inevitably some deficiencies in this research.

First, because the intervention style in this trial is exercise, we can only blind the data collectors and data analysts to the grouping, thus there are unavoidable some biases in the results. Second, the research was conducted in the region of South Sichuan, the conclusion cannot be generalized to other regions, so a large sample and multicenter clinical trial are needed in the future. Third, in this research, the lateral trunk lean angle is measured by the Azure Kinect DK, which is marker less, portable, and inexpensive. Research on the validity of the Microsoft Kinect for assessing postural control has shown that the intertrial reliability of the Microsoft Kinect and 3D motion analysis systems are comparable, and the Microsoft Kinect can validly assess kinematic strategies of postural control (Clark et al., 2012). Another study also found that the angle

of inclination of the trunk and pelvic segment calculated by Kinect was generally similar to those using the gold standard VICON system (Asaeda, Kuwahara, Fujita, Yamasaki, & Adachi, 2018). However, the Kinect is not the optimal evaluating tool for gesture recognition, there is inevitable deviation in the results, and future studies should be conducted using the three-dimensional motion analysis system, which is thought to be the golden standard for motion analysis.

4. Conclusion:

This randomized controlled trial meticulously explores the therapeutic potential of Internet-based Tai Chi for managing knee osteoarthritis (KOA) in Chinese athletes, a group particularly susceptible to this condition due to their rigorous physical activities. The study's design, which compares the efficacy of Internet-based Tai Chi with that of traditional community-based Tai Chi, is pivotal in understanding the adaptability and effectiveness of digital health interventions in sports medicine. The primary outcome, measured by the Western Ontario and McMaster University Osteoarthritis Index, along with secondary outcomes including various physical performance tests and quality of life assessments, provide a comprehensive understanding of the impact of Tai Chi on KOA. These measurements are crucial in determining not just the symptomatic relief but also the functional improvements and overall well-being enhancements that Tai Chi can offer to athletes suffering from KOA. Furthermore, this study delves into the feasibility and accessibility of Internet-based Tai Chi, an aspect that is increasingly relevant in our digitally evolving world. For athletes, whose schedules and frequent travels might limit access to traditional community-based programs, the flexibility and convenience of an online platform could be a game-changer. This trial has the potential to establish a new paradigm in the rehabilitation of athletic injuries and chronic conditions. By analyzing muscle strength, ultrasound echo intensity, and other physical parameters, the study also contributes to the scientific understanding of the mechanisms behind Tai Chi's therapeutic effects. This is particularly valuable for tailoring specific Tai Chi routines to athlete's needs, optimizing rehabilitation strategies, and enhancing performance recovery.

In conclusion, the findings from this trial could significantly impact how KOA is managed in athletes, offering a novel, convenient, and effective approach. Internet-based Tai Chi could potentially be recognized as a viable, accessible alternative to traditional rehabilitation methods, aligning with modern healthcare trends and the unique requirements of athletes. This could lead to broader adoption of digital health practices in sports medicine, ultimately benefiting the athletic community at large.

Conflicts of interest

The authors declare that they have no competing interests, report that

the sponsor did not participate in the investigation that could have influenced the outcome of this work.

Ethics and dissemination

Research has been approved by Clinical Trials Ethics Committee of the Southwest medical university (Ethical number: KY2022098) and was in accordance with the Declaration of Helsinki. Important protocol modifications can be carried out after the agreement of the REC/IRBs. The results will be published on medical journal.

Data availability statement

Data are available from the corresponding author on reasonable request.

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