The Effect of TRX vs. Aquatic Exercises on Self-Reported Knee Instability and Affected Factors in Women with Knee Osteoarthritis: A Randomized Controlled Trial

Shirin Asar
Kermanshah university of medical science`
Farzaneh Gandomi (gandomi777@gmail.com)
Razi University https://orcid.org/0000-0002-8607-3803
Mahsa Mozafari
Bu Ali Sina University
Freshteh Sohaili
Razi University

Research article

Keywords: self-reported knee instability, Osteoarthritis, TRX, Aquatic Exercises.

Posted Date: October 22nd, 2019

DOI: https://doi.org/10.21203/rs.2.13552/v2

Version of Record: A version of this preprint was published at BMC Sports Science, Medicine and Rehabilitation on April 29th, 2020. See the published version at https://doi.org/10.1186/s13102-020-00175-y.

Abstract

Background Knee Instability (KI) is described as a sense of the knee buckling, shifting, or giving way during the weight bearing activities. High prevalence (65%) has been reported for KI amongst the patients with knee osteoarthritis (KOA). So, we studied the effect of two interventions on self-reported KI and affected factors.Methods In this single blind, randomized, and controlled trial, 36 patients with radiographic grading (Kellgren–Lawrence 1–4) of knee osteoarthritis were selected for participating. patients were allocated in three groups aquatic exercises (n=12), Total Resistance eXercises (TRX) exercises (n=12) and control (n=12) by random. 8-week TRX and aquatic exercises were carried out by experimental groups. Pain severity was assessed by visual analog scale (VAS), Balance was also evaluated by Berg Balance Scale (BBS), quadriceps strength by dynamometer, and knee range of motion (ROM) by inclinometer, Western Ontario and McMaster Universities Osteoarthritis (WOMAC), self-reported KI were also measured before and after interventions.Results The results of One-way ANOVA showed that there was no significant difference between aquatic exercises and TRX (P>0.05) for KI, BBS, WOMAC, and pain. But there was significant difference between the aquatic exercises and the control for KI (P=0.0001), BBS (P=0.0001), WOMAC Stiffness (P=0.0001), and pain (P=0.006). Also, there was significant difference between the TRX and the control for KI (P=0.0001), BBS (P=0.0001), and pain (P=0.003) except WOMAC Stiffness (P=0.07).Conclusions TRX and aquatic interventions had a similar effect on the patients' KI, pain, function, and also balance variables, but TRX exercises had more effect on the knee stiffness improvement.

Background

Knee instability (KI) is the most common problem amongst patients with knee osteoarthritis (KOA) which can problems in weight bearing or walking activities. Knee instability is described as a sense of the knee buckling, shifting, or giving way during the weight bearing activities. High prevalence rate (60-80%) has been reported for KI amongst the patients with KOA[1]. In prior studies, knee instability has been associated with the pain increasing, activity daily living disrupting, gait pattern altering, and also fall number increasing[2, 3]. Additionally, investigations have reported that the factors involved in muscle neuromuscular deficiency such as joint laxity, proprioception deficiency, and inappropriate muscle stiffness strategies can expose patients to this instability [3,4-6]. Accordingly, Schmitt and Rudolph (2007) have reported that knee instability can be considered as an important factor in motion predicting strategies for KOA patients during their walking [5]. Consequently, it is possible that KOA patients with KI have a kind of compensatory strategy in their walking pattern, which will affect the disease progression [7]. In fact, the knee instability may result in increasing the knee movements in sagittal and frontal planes while walking and weight bearing, and altering the loading on the knee joint [1, 9]. This problem can affect the patients' life quality by reducing trust in the joint, and avoiding daily activities [10, 11]. As a result, adding the joint instability to the knee osteoarthritis outcomes can put patients at fall risk, secondary problems, and also may change their walking pattern [12]. Evidence indicates improvement in pain and even joint deformation in patients with early osteoarthritis subsequent to the improvement of

instability in their knee [13]. Therefore, paying attention to KI as an accelerator in the arthritis symptoms recovery has attracted the attention of specialists and researchers recently.

TRX is the new sling training for an intense full-body workout by which body coordination and stability can improve effectively. The results of earlier researches have indicated that TRX exercises activated the stabilizing muscles of the various joints of the body, especially the core muscles that would improve the lower extremity function [14]. Other benefits of this exercise include variety of exercises and attractiveness, simplicity, ease to use, and little space occupation [15]. Bryan et al. (2014) carried out TRX exercises, and reported that they could result in increase in activation of abdominal muscles [16]. Another intervention that can be effective in improving proprioception and neuromuscular control has been recognized to be therapeutic exercises in water environment. As the previous studies report, one of the best treatment protocols for people with knee osteoarthritis is water-based therapeutic exercises. Water qualities such as hydrostatic pressure and water temperature can facilitate blood circulation. Also, water resistance that acts in the opposite direction to body motion may enhance muscular strengthening. Additionally, weight loss due to Buoyancy force and pain receptors inhibition was regarded by specialists [17]. There have been some studies on the effect of aquatic exercises on pain and function in patients with knee osteoarthritis. As an example, Alcalde et al. (2017) reported such advantages as reduced pain intensity, increased flexibility, improved functional capacity and quality of life following a 12-week aquatic physical therapy. Lu et al. (2015) also reviewed the effect of aquatic exercise on KOA patients. They concluded that aquatic exercise was effective and safe enough to be considered as an adjuvant treatment for patients with knee OA[18,19]. Knee proprioception improvement has been reported in patients with knee osteoarthritis following aquatic exercises. So, it is possible for the proprioception improvement which is important in neuromuscular control to affect joint dynamic stabilization and joint stability.

Prior to the present study, one study was conducted comparing some variables such as (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), pain, gait pattern, Berg balance scale (BBS), function, and quality of life (SF_{36}) between subjects with (n=31) and without (n=37) self-reported knee instability. The results manifested that KI could affect BBS (p=0.016), function (p=0.016), WOMAC stiffness subscale (p=0.004) significantly [20].

However, despite plethora of studies conducted on the risk factors of the knee joint instability in patients with osteoarthritis, to the best of researchers' knowledge, no investigation has been conducted on its control strategies. Most of the therapists have just concentrated on the patients’ pain and function improvement, while neglecting knee joint instability in the patients. The present study, however, subsequent to the results of the authors' previous study was deemed to look for appropriate interventions to reduce knee instability in patients. The main purpose of the present study was to compare the aquatic and TRX exercises effects on the self-reported KI and its affected factors like balance, pain, WOMAC stiffness subscale, and also knee flexion ROM, quadriceps strength. Therefore, it was hypothesized that 1). TRX and aquatic exercises caused improvement in pain, balance, stiffness, knee flexion ROM,

quadriceps strength, and self-reported KI statistically, 2). the TRX would have more effectively reduced the self-reported KI than aquatic exercises intervention.

Methods

Trial design

This single blind, randomized, and controlled trial, which was conducted at Razi University rehabilitation center in Kermanshah, Iran, lasted for eight weeks starting with February and ending in May, 2019. The assessors who measured variables for patients were blinded about the group allocation. This study included three steps: 1. Pre-tests 2. 8-week aquatic and TRX exercises for case groups, and the control group which just received drug regimens by the rheumatologist, and 3. Post-tests (Fig 1).

Participants

A total of 200 knee osteoarthritis' patients were studied for eligibility among which 36 individuals met the eligibility criteria. 12 patients were allocated to the aquatic exercise, 12 to TRX exercises, and the rest to the control group. However, 111 patients didn't meet the eligibility criteria and 53 declined to participate. Participants of the present research (200 female) were recruited from two groups: individuals who had regular referral from rheumatologist physicians, and those patients who waited for common physiotherapy in rehabilitation centers.

Participants were included if they had (1) the age of more than 40 years ,(2) American College of Rheumatology clinical criteria for knee OA(Altman et al., 1986), (3) Kellgren and Lawrence radiographic disease severity scale ≥ II, and (4) self-reported knee instability. Additionally, participants were excluded if they (1) had strokes, (2) had uncontrolled hypertension, (3) were unable to walk without assistant instruments, (4) had received other treatment interventions in the past three months, (5) had obesity (BMI>40kg/m^2), (6) suffered from neuromuscular diseases like multiple sclerosis and Parkinson, (7) had lower extremity fracture, (8) concurrent hip osteoarthritis, (9) waited for arthroplasty,(10) or had cardiovascular diseases [7, 21].All the patients who had received injection in the 6-month-period prior to the study, or had had surgical procedures were excluded from the study. All the patients included in this study had bilateral arthritis, however, the knee in which they reported symptom of instability was assessed. All the patients in this study received the similar drug regimens including Meloxicam 7.5 milligram, Glucosamine Sulfate 750 milligram, and Calcium-D in daily manner.

The G.Power (Ver. 3.1, Heinrich Heine University) software was used to estimate the minimum sample size. According to the results of previous researches and based on the test power of 0.90, the effect size of 0.63 and the significance level of 0.05, the minimum sample size was determined to be 36 [22]. Finally, they were divided randomly into three groups including TRX (n=12), aquatic exercises (n=12), and control (n=12) groups (Table 2).

Study interventions

TRX exercises

The TRX ® Rip Trainer ™ (model)was used for performing the exercises. TRX training was completed by a TRX specialist, while an assistant coach also helped to prevent the patients from doing wrong exercises. The safety points were checked by trainer every session to avoid injuries before the exercises started. The TRX straps hanging down from anchor point, and Suspension Anchor^{TM} were adjustable to execute various exercises. Exercises were designed based on the patients' motion limitations like knee flexion and extension. Furthermore, TRX exercises were started at their easiest forms, and gradually but progressively turned to be more and more difficult. The difficulty level of exercises increased step by step by 1) Narrowing the base of support which increased the difficulty due to reducing stability2) Changing the angle of pull, in other words, the farther the person was from the vertical, the greater the resistance3) and the pendulum was used in ground exercises in which the feet were placed in the Suspension Trainer and the hands were off the ground (head or back was on the ground). The gravity center in relationship with the perpendicular gravitational pull determined the difficulty. 4)Using a one handle can increase the exercises difficulty.5-10 min introducing the sessions' exercises and their correct techniques, 5-10 min warm-up, which was stretching exercises, and also 40-50 min TRX exercises were performed per session. Participants who had wrist pain through the planks' tests, could put their forearm on the ground in order to prevent the wrist pain increasing. The TRX exercises protocol were followed for eight weeks, three times a week, and with the duration of 60 minutes for each session. Most of the exercises were focused on the core muscles, hip abductors, and leg muscles strengthening (Table 1) [23].

Table 1. TRX exercises protocol

First Month	Exercises
Days 1	1)TRX row, 2) TRX biceps curl, 3) TRX scapular retraction, 4)TRX standing roll out, 5) toe touches, 6) TRX hip press, 7) TRX hamstring curl, 8) walking high kick, 9) TRX Sit Up Plank exercises 3 set 10 second
Days 2	1)TRX mid row, 2) TRX calf raise, 3) TRX kick back, 4) TRX standing push up plus, 5) clamshell, 6) lying side leg lift/ lateral raise, 7) Hamstring runner TRX, 8) TRX bent raise (single leg), 9) TRX side plank. Plank exercises 3 set 15 second
Days 3	1) TRX high row, 2) TRX single leg reaching Roman deadlift, 3) TRX split fly, 4) TRX chest press, 5) lying leg raise, 6) TRX Routain, 7) supine plank TRX, 8) TRX bent leg raise, 9) TRX hip abduction. Plank exercises 3 set 20 second
	At the week1 and 2, All exercises 3 set 10 repetition. At the week 3 and 4, All exercises 3 set 15 repetition.
Second Month	**Exercises**
Days 1	1) TRX T deltoid fly, 2) TRX standing hip drop, 3) TRX triceps press, 4) TRX standing calf raises 5) Flutter kicks 6) Side crunch leg raises 7) TRX supine plan/with pull through 8) TRX hip abduction, 9) TRX assisted sit up Plank exercises 3 set 20 second
Days 2	1) TRX Y deltoid fly TRX hip press, 2) TRX torso rotation, 3) TRX overhead back extension, 4) TRX prone iron cross, 5) Side oblique crunch, 6) Swimmers, 7) supine TRX on elbow, 8) TRX saw 9) TRX oblique leg raises Plank exercises 3 set 25 second
Days 3	1) TRX L deltoid fly, 2) TRX power pull 3) TRX bicep revers curl 4) TRX chest fly 5) Russian twist with medicine ball 6) Alternate heel touchers 7) TRX side plank/ top arm assisted pike 8) TRX pendulum, 9) TRX Pike Plank exercises 3 set 30 second
	At the week1 and 2, All exercises 3 set 10 repetition. At the week 2 and 4, All exercises 3 set 15 repetition.

Days1: all exercises which were carried out in Sundays; **Days2:** all exercises which were carried out in Mondays; **Days3:** all exercises which were carried out in Wednesdays.

Aquatic exercises

Aquatic exercise intervention was accomplished for eight weeks, three times a week, 24 sessions in total, with each session lasting for exactly 90 minutes. So, each participant was obliged to experience 24 sessions of rehabilitation with 90 minutes of duration for each session during the conducting phase of the study. The water temperature was approximately 32 ° C (89° F), and the minimum water depth was considered1.3 meter. The water based exercises protocol included: 10 minutes' warm-up along with walking (forward, backward, and sidewalk), and also stretching exercises for lower extremity muscles (quadriceps, hamstrings, tricepssurae, abductors and adductors of hip, and gluteal muscles), 20-minute strength exercises with elastic band and sandbag (gluteus, adductors and abductors of hip, quadriceps, hamstrings, and triceps surae muscles); 20 minutes of aerobic exercises (stationary running or deep water-running); 20 minutes of step training and proprioceptive exercises; 10 minutes of core exercises, and then 10 minutes of cool down. Resorting to previous study findings, we selected exercises of the present study with the purpose of improving function, pain, and balance [24, 25]. The aquatic exercises protocol was supervised by a certified physiotherapist in the pool (table 2).

Table 2. Water-Based Exercise Program [a]

e of cise	Exercises	Set
n up	walking (forward, backward, sidewalk, with kickboard) stretching exercise for lower extremity muscles :quadriceps, hamstrings, triceps surae, abductors and adductors of hip and gluteal muscles	3.10 (first 4 weeks) and 10 seconds rest 3.12 (second 4 weeks) and 10 seconds rest
ngth	Hip flexion, extension, and hyperextension, Hip abduction and adduction Knee flexion and extension, Double-Leg Calf Raise, Single-Leg Calf Raise, resisted hip extension, resisted hip abduction (resistance was considered water, noodle, and sand bag	3.10 (first 4 weeks) and 10 seconds rest 3.12 (second 4 weeks) and 10 seconds rest
bic	Bounce: Knee lift/knee-high jog, Inner thigh lift/ankle reach Front, Leg curl/hamstring curl/heel-high jog, Kick front /straight leg Kick front/karate, Kick corner, Kick across, Kick side, Kick back, Cross-country ski, Bike on the noodle Jumping jack, Cross-country ski, Leap, Jazz kick/front, Jazz kick/corner, Pendulum	3.12 (first 4 weeks) and 10 seconds rest 3.15 (second 4 weeks) and 10 seconds rest
and rioceptive	Gait training in anteroposterior, lateral-lateral, and diagonal. Then they will go up and down step alternating legs. Hand on hip as leg perform a rocking horse. Knee chest (supine, prone, and standing) Cross-country ski. Also, step up and step down: forward and side ward.	3.10 (first 4 weeks) and 10 seconds rest 3.12 (second

		4 weeks) and 10 seconds rest
e	Stand and abduct and adduct the shoulder, Spinal rotation, standing with diagonal movement of hands with sand ball, Spinal rotation with sand ball , Bike on the noodle	3.10 (first 4 weeks) and 10 seconds rest 3.12 (second 4 weeks) and 10 seconds rest
down	Deep breathing-forward and back ward tandem walking-static stretching interspersed with water walking- - figure 8 arm sweep with spinal rotation and shoulder abduction and adduction.	10 seconds for each stretch
ndom selection of exercises from the following list was performed during each session.		

Randomization and Blinding

Participants were randomized by the use of Random Number Generator Software (Research Randomizer, version 3.0), and also were allocated to three groups using Sequentially Numbered Opaque Sealed Envelopes (SNOSE) concealed allocation method. A physiotherapist who did not involve in the data collection and evaluation of the outcomes did the random allocation sequence, enrolled participants and assigned participants to interventions. Participants were distributedto TRX (n=12), aquatic exercises(n=12), and also control groups (n=12) by random (allocation ratio 1:1:1).

The assessors of this research were blinded about the exercises and interventions assigned to the groups, but there was no possible way for blinding the subjects to training as well as statistician towards the groups and their assigned exercises.

Study outcomes

We designed this research based on authors' previous study and literatures results [2,6,7]. So, we assessed the effect of 8-week aquatic and TRX exercises on factors that may be affected by KI such as WOMAC stiffness subscale, balance, pain, KI, quadriceps strength and knee flexion ROM.

Knee pain

Knee pain intensity was measured by using 10-cm visual analog scale (VAS) with the scoring range between 0-10cm. “0” indicated the pain absence, “1” minimal pain, and “10” is extreme or intolerable pain. The participants were asked “how much pain do you have during your daily activities?” the VAS was used to measure the intensity of participants’ subjective pain before and after the interventions. A good reliability and validity was reported for the VAS (intraclass correlation 0.92) [26].

WOMAC stiffness

WOMAC is a reliable and valid instrument (ICC:0.80).Stiffness subscale had two items that were rated by the Likert scale of 0 (no symptoms)- 4 (extreme symptoms), with a total range of 0-8, and higher scores displaying worse symptoms [27].

Berg Balance Scale (BBS)

BBS, which was used to assess the balance consists of 14 different tasks, was assessing balance in sitting and standing position and in transfer. Each motor task was rated by the use of 5-point scale ranged from 0 to 4. The total score ranges from 0 to 56, where 56 represents normal balance. The test-retest reliability for the BBS was reported to be excellent (ICC= .71 to .99) [28].

Knee instability

Self-reported knee instability was evaluated according to giving way, and also shifting evidence, during the last month by Felson’s questionnaire [29]. Knee instability severity was graded based on the numerical scale (0 to 5) in response to the following question. The question was “What degree of giving way, buckling, or shifting of the knee would affect your daily routine activity?” The ratings were as follows: 5 = “I have no symptom”, 4 = “I have symptom, but it does not affect my ADL”, 3 = “Symptoms affect my ADL slightly”, 2 = “symptoms affect my ADL moderately”, 1 = “symptoms affect my ADL strongly”, 0 = “symptoms prevent me to perform all my everyday activities” [25]. The test-retest reliability of this self-report rating of KI was estimated by the use of an intra-class correlation coefficient (ICC =0.72) [30].

Knee Flexion ROM

The Bubble inclinometer device was used to measure Knee flexion ROM. The subjects were placed in prone position. Then the inclinometer was placed on the behind of the tibia. The test was conducted on the limb which had more involvement. Knee flexion was stopped in end-range of passive motion and further movement was restricted by pain. Three trials were recorded and the average value was used for analysis [31].

Knee extensors strength

Maximal isometric strength of the knee extensors (quadriceps muscle) was measured using the Baseline Pull-Push Dynamometer. This digital dynamometer measures the force up to a maximum of 199.9 kg. Measurements were used at 80˚- 90˚ of knee flexion. the instrument was calibrated according to the

instructions, before any measurement. The patients were seated in a comfortable position with the backrest angled at 100˚. The shin pad was placed 2 cm between the above the medial and lateral malleoli. The instrument shaft remained horizontal to the anterior aspect of the mid shaft of tibia and horizontal to the posterior aspect over the musculotendinous junction of calf muscles. Subjects were then asked to hold that position while pushing against the dynamometer. Subjects were asked to push against the gauge pad as hard as possible when given the appropriate command. All measurements were performed with the limb segment in a position that was with gravity eliminated. Resting times between trials were approximately 60 seconds. Each contraction was held for six seconds. The peak force was recorded and average of records was considered as the quadriceps strength [32].

Ethical Considerations

This study's protocols were reviewed and approved by the research ethics committee of the Medical Sciences University of Kermanshah in Iran (Registration no.: IR.UMMS.REC.1397.718). The study’s protocol was also registered in the Iranian Registry of Clinical Trials (Registration no.: IRCT20181222042070N1). The subjects provided informed consent forms, and all the tests and measurements were carried out at the Sport Rehabilitation Laboratory of Razi University, Iran. As well, all the participants both completed and signed the consent form in person.

Statistical analysis

We analyzed BBS, Pain, WOMAC (stiffness), knee flexion ROM, quadriceps strength, and self-reported knee instability variables before and after the 8-week aquatic and TRX exercises.

First, we used Shapiro-wilks and Leven’s test for assessing the normal distribution of data, and also the variances homogeneity. When variances normality and homogeneity tests were confirmed, the data were considered to be parametric. Consequently, demographic and baseline parameters were analyzed by the one-way analysis of variance (ANOVA). Additionally, Tukey’s post hoc test was used for the pairwise comparisons. In order to compare the changes of each dependent variable over the time (t0=pretest, and t1=posttest) and between groups, the variables were analyzed by employing mixed-model repeated measures ANOVA using time and group as factors time × group (2×3). In the presence of significance, Tukey’s post hoc test pairwise comparisons were used. Also, we used Paired samples t-test for pretest to posttest assessing in each group. Statistical analysis was performed using statistical software, SPSS version 20.0 (IBM SPSS, Armonk, NY, USA). Statistical significance was determined at p-values less than 0.05. All results were reported as the mean ± standard deviation.

Results

The results of Shapiro Wilks and Levene's test indicated that both assumptions for data distribution normality and homogeneity of the variances were accepted(P>0.05). Furthermore, the obtained comparative results about demographic characteristics and dependent variables in the baseline for interventions and control groups are displayed in Table 3. The results of one-way ANOVA and Tukey's test indicated that no significant differences were found amongst the treatments and control groups in the baseline characteristics (all P> 0.05).

Table 3. demographic characteristics of study participants

Variables	TRX (n=12) M(SD)	Aquatic exercises (n=12) M(SD)	Control (n=12) M(SD)	P-value*
Age (year)	55.9(8.6)	57.5(6.9)	63.8(7.5)	0.08
Weight (kg)	80.9(3.4)	78.2(10.9)	73.6(8.9)	0.3
Height (cm)	161.9(5.7)	165.6(6.8)	162.5(4.7)	0.058
BMI (kg/m2)	29.8(7.2)	28.5(3.7)	23.1(11.6)	0.07
VAS(cm)	6.8(2.4)	7.2(2.2)	8.3(2.2)	0.3
Kellgren & Lawrence	2.7(0.8)	3.0(0.6)	2.7(0.6)	0.6
(nee Instability (pretest)	2.1(1.6)	1.6(1.4)	2.9(1.4)	0.1
OMAC stiffness (pretest)	4.4(2.3)	4.9(2.1)	4.7(1.2)	0.8
VAS (pretest)	7.6(2.4)	7.7(2.1)	7.5(2.0)	0.8
BBS (pretest)	37.6(8.9)	41.3(8.3)	37.9(8.3)	0.4
adriceps strength (pretest)	13.4(1.6)	14.9(1.6)	12.7(1.7)	0.6
Knee flexion (pretest)	104.7(6.5)	110.4(6.4)	115.7(6.9)	0.5

* No significant differences among groups for pretests. BMI: Body Mass Index; BBS: Berg Balance Scale; VAS: Visual Analog Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis.

Self-reported KI

Instability scores were significantly reduced over time in both aquatic and TRX exercises (p<0.0001). In both intervention groups, a significant improvement in instability scores was detected from 8 weeks compared to the baseline (t0 vs. t1, p=0.0001 in TRX; t0 vs. t1, p=0.0001 in aquatic exercises), but this was not significant in control (t0 vs. t1, p=0.45). Additionally, the differences amongst groups regarding the time were significant (p=0.02). Moreover, Tukey's post hoc test indicated that there was no significant difference between aquatic exercises and TRX (P=0.84), but there was a significant difference between the aquatic exercises and the control (P=0.035) as well, there was significant difference between TRX and control groups (P=0.043) (Fig 2, table 4).

Pain

VAS scores for pain were significantly reduced over time in both TRX and aquatic groups ($p<0.0001$). In both intervention groups, a significant improvement in VAS scores were detected from 8 weeks compared to the baseline (t0 vs. t1, p=0.0001 in TRX; t0 vs. t1, p=0.0001 in aquatic exercises), but this was not significant in control group (t0 vs. t1, p=0.13). Additionally, the differences amongst groups regarding the time factor were significant (p=0.03). Tukey's post hoc test indicated that there was no significant difference between the aquatic exercises and TRX (P=0.63), but on the contrary, there was significant difference between the aquatic exercises and control groups (P=0.04). Also, there was significant difference between the TRX and control (P=0.03) (Fig 2, table 4).

WOMAC (Stiffness)

Stiffness subscale scores of WOMAC significantly improved over time (p=0.04). A significant improvement in stiffness scores was detected from 8 weeks compared to the baseline (t0 vs. t1, p=0.04 in TRX), but this was not significant in aquatic and control groups (t0 vs. t1, p=0.058, t0 vs. t1, p=0.14). Additionally, the differences amongst groups concerning the time factor weren't significant (p=0.12 in control). Tukey's post hoc test, also, showed that there wasn't significant difference between aquatic exercises and control groups (P=0.25). However, there was significant difference between TRX and the control (P=0.05), and there was still no significant difference between the aquatic exercises and TRX (P=0.9) (Fig 2, table 4).

Berg Balance Scores

Balance scores were significantly increased over time ($p<0.0001$). A significant improvement in balance scores were detected from 8 weeks compared to the baseline (t0 vs. t1, p=0.0001 in TRX; t0 vs. t1, p=0.0001 in aquatic group), but this was not significant in control group (t0 vs. t1, p=0.45). Likewise, the differences between groups regarding the time factor were significant (p=0.001). As Tukey's post hoc test indicated, there was a significant difference between the aquatic exercises and control groups (P=0.001). There was, also, significant difference between the TRX and control (P=0.016), but there was no significant difference between the aquatic and TRX groups (P=0.13) (Fig 2, table 4).

Knee flexion ROM

Regarding the interaction effect of time group (p=0.031), a significant improvement in knee flexion scores were detected from 8 weeks compared to the baseline (t0 vs. t1, p=0.03 in TRX), but this was not significant in aquatic and control groups (t0 vs. t1, p=0.1 in aquatic, and p=0.12 in control). Further, the differences between groups with regard to the time factor weren't significant (p=0.052) (Fig 2, table 4).

Quadriceps strength

Quadriceps strength scores also significantly increased over time (p=0.01). A significant improvement for quadriceps strength scores were detected from 8 weeks compared to the baseline in TRX (t0 vs. t1,

p=0.001), but there was no significant improvement for aquatic and control groups (t0 vs. t1, p=0.21, t0 vs. t1, p=0.88). Additionally, the differences between groups concerning the time factor were not significant (p=0.42) (Fig 2, table 4).

Table 4. Changes in clinical outcomes after 8-week TRX and aquatic interventions

ome ure	groups	t0 M(SD)	t1 M(SD)	Change by the time	Between group difference	AQ vs. TRX	AQ vs. CON.	TRX vs. CON.
				0.0001*	0.02€	0.8	0.03#	0.04#
				0.0001*				
				0.45				
IAC ıess	TRX	4.4(2.3)	2.8(2.1)	0.04*	0.12	0.9	0.25	0.05#
	Aqua therapy	4.9(2.1)	2.9(0.02)	0.058				
	Control	4.7(1.2)	5.5(2.0)	0.14				
S	TRX	7.6(2.4)	3.4(2.2)	0.0001*	0.03€	0.6	0.03#	0.04#
	Aqua therapy	7.1(2.7)	3.1(1.6)	0.0001*				
	Control	7.5(2.0)	6.7(2.5)	0.13				
S	TRX	37.6(8.9)	47.91(7.88)	0.0001*	0.0001€	0.9	0.001#	0.1
	Aqua therapy	41.3(8.3)	52.5(4.88)	0.0001*				
	Control	37.9(2.2)	33.83(1.88)	0.45				
iceps ıgth	TRX	13.4(1.6)	16.9(2.6)	0.001*	0.4	0.8	0.2	0.3
	Aqua therapy	14.9(3.5)	16.4(4.3)	0.21				
	Control	12.7(4.7)	12.2(5.7)	0.88				
ɔe ion	TRX	109.7(5.5)	129.4(4.9)	0.03*	0.052	0.5	0.6	0.9
	Aqua therapy	110.4(6.7)	121.9(8.5)	0. 10				
	Control	115.7(8.9)	110.2(5.2)	0. 12				

SD: Standard Deviation; VAS: Visual Analogue Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; cm: centimeter; t0: baseline measures; t1: 8-week measures.

(□)means p<0.05 for posttest compare to the baseline.(#) means p<0.05 for post hoc pairwise comparison between groups. (€) meansp<0.05 between groups differences.

Discussion

The results of the present study are in agreement with the first hypothesis of the study which states that there is no significant statistical difference in all the research outcomes between intervention groups except for the WOMAC(stiffness), which indicates a significant difference between TRX and control groups but no significant difference between aquatic and control groups. In fact, the improvement of the measures of dependent variables subsequent to the aquatic intervention can be related to 1. the water's viscosity or resistance which can be very effective for muscle retraining as well as for increasing the rehabilitation progressions, 2. hydrostatic pressure, which supports and stabilizes the patients, allowing people with balance deficits to perform exercises without the fear of falling, 3. water warmth, which can lead to reduction in pain and muscle spasm,4. buoyancy, which decreases loading of joints, and finally the unique characteristics of in-water- exercising which may allow people to perform exercises which otherwise they would be unable to perform on land. The findings of some of the studies in the field including Alcalde et al. (2017), Taglietti et al. (2018), and Lu et al. (2015) are in line with our findings [18,19, 25]. Consistent with the results of the present study, they reported that aquatic exercises could improve pain, function, and balance in patients with KOA. However, WOMAC(stiffness) outcome wasn't significant between aquatic and control groups. It may be the result of non-significant improvement (pretest to posttest) in quadriceps strength for aquatic group. This is in corroboration with the findings of studies reported recently, indicating that presence of self-reported KI may be a sign of inadequate dynamic knee joint stability and diminished knee joint control in the patients' population [1, 7]. Quadriceps muscle is one of the important dynamic knee joint stabilizers, so the inadequate quadriceps strength can cause the higher rate of knee joint instability in knee osteoarthritis patients with KI [7]. Moraiti et al. (2009) have also reported that deficits in muscular strength and proprioceptive sensory input, which are thought to alter the neural control of the muscles around the knee joint, have also been previously associated with greater knee flexion/extension motion variability after ACL reconstruction [33, 34].

Moreover, the findings of the present study indicated the effectiveness of the TXR intervention in the significant improvement of the dependent variables. Body weight and TRX sling provide an appropriate resistance to strengthen the core and extremities muscles in KOA patients. Both intervention protocols had strengthening exercises in order to strengthen the core muscle, the thigh and the leg muscles. The outcomes, however, indicated that quadriceps muscle strength increased significantly from pretest to the posttest just for TRX group. This different strength progression between groups maybe due to muscle relaxation caused by water warmth characteristics. Significant improvements in pain, balance, WOMAC(stiffness), quadriceps muscle strength, knee flexion ROM, and self-reported KI in these patients after 8-week TRX intervention may have been due to the core and leg muscles strengthening. This is in harmony with Foroughi et al. (2019) who have stated that adding isolated core postural control training to physiotherapy exercises was associated with significantly greater improvements in pain, function, and center of pressure trajectories than physiotherapy exercises alone [35]. Likewise, Arazi et al. (2018), and

Leónet al. (2019) have published the matching results. They stated that extremities function was influenced by lumbo-pelvic-hip muscular strengthening in TRX exercises [36,37]. In line with the findings in the literature and consistent with our findings, it seems that TRX exercises could strengthen the hip and core muscles, so the patients can put the foot within the base of support area, resulting in confidence improvement in patients. This is consistent with Shakoor et al. (2017), which found that quadriceps muscle strength can be an important predictor for worsening the knee instability [38]. Reduction in the dynamic KI could decrease pain and knee stiffness. Subsequently, reduced knee stiffness could improve knee ROM and balance in KOA patients.

With regard to the second hypothesis of the study, it was found that that there were significant statistical differences in all study outcomes from pretest to posttest in intervention groups except WOMAC (stiffness subscale), quadriceps muscle strength, and knee flexion ROM. Additionally, between group differences was significant between TRX and control groups. Nevertheless, no significant difference as for aquatic and control groups for WOMAC stiffness was reported. It seems that TRX exercises could reduce compensatory knee joint-stiffening strategy by significantly strengthening the dynamic knee stabilizer muscles including quadriceps. Besides, it can improve dynamic stability and neuromuscular control, ultimately improving the painless knee flexion ROM. The above results are consistent with Dixonet et al. (2010) who reported that greater self-reported stiffness was associated with lower peak knee adduction moment for the OA patients. Esch et al. (2006) also reported that patients with OA, high knee joint laxity, and low muscle strength are most at risk of being disabled [40]. Zwart et al. (2015), reported also the same results. They assessed the associations between knee muscle strength and falls, controlling for knee joint proprioception, varus-valgus knee joint laxity, and knee instability among patients with knee osteoarthritis, who reported knee instability. They concluded that high knee extension and flexion muscle strength decreased the risk of falls in patients with knee OA and self-reported knee instability [41].

Some researchers have conducted comparable studies on aquatic-based and land-based exercise effects on function, mobility and other health outcomes in people with knee and hip osteoarthritis. They reported the same results for aquatic exercise for adults with arthritis as those of land-based exercises [42, 43]. Likewise, Wyattet al. (2001) conducted a study to detect differences between an aquatic exercise program and a land-based exercise program on KOA patients' pain and function. They reported that both aquatic and land-based exercise programs are beneficial to patients with osteoarthritis [44], the findings which are in corroboration with the results of our study. On the other hand, Lund et al. (2008), compare the efficacy of aquatic and land-based exercise program in patients with knee osteoarthritis. They concluded that land-based exercise showed some improvement in pain and muscle strength compared to the control group, while no clinical benefits were detectable after aquatic exercise [45].

Due to the study setting and extraneous variables, the present study could not escape some limitations including: the analyses were based on the self-reports of instability symptoms instead of instability objective measurements. the sex of subjects (as only women participated in the study), a small sample size and inability to use more groups, failure to control the diet, the subjects' life style, insufficient time to

measure the electromyography (EMG) activity associated to the involved muscles. And subjects' motivation for doing exercises, whose control could provide better results. In future studies, it may be worthwhile to examine the mixed model of TRX-aquatic exercises, and compare it with the TRX and aquatic exercises. Additionally, it may be worthy to examine the Pilates and TRX intervention effect on other variables like quadriceps strength and muscle EMG.

Conclusion

Based on this study results, we concluded that TRX and water-based interventions had a similar effect on the self-reported KI, pain, and balance variables, but TRX exercises had more effect on knee stiffness, quadriceps strength, and knee flexion ROM, in comparison with the water-based exercises. As a result, TRX intervention could be recommended to physical therapist as an appropriate protocol for the KOA patients rehabilitation.

List Of Abbreviations

KOA: Knee osteoarthritis; TRX: Total Resistance eXercises; KI: Knee Instability; SNOSE: Sequentially Numbered Opaque Sealed Envelopes; ADL: activity daily living; ROM: Range of Motion; BBS: Berg Balance Scale; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; VAS: visual Analog Scale; ES: Effect Size; EMG: Electromyography; BMI: Body Mass Index; ANOVA: Analysis of variance.

Declarations

Ethics approval and consent to participate

Patients have a right to privacy that should not be infringed without informed consent. And the patients give written informed consent for publication that approved by the research ethics committee of the Medical Sciences University of Kermanshah in Iran (Registration no.: IR.UMMS.REC.1397.718).This study was registered in the Iranian Clinical Trial Center with the number IRCT20181222042070N1, http://www.irct.ir/trial/36221, registered 02 February 2019.

Consent for publication

Not applicable

Availability of data and materials

Not applicable

Competing interests

The authors declare that they have no competing interests.

Funding

No funding

Authors' contributions

FGwas responsible for the conception and design of the study. FGwas involved in the analysis and/or interpretation of data. ShA,MM and FS were responsible for the first drafts which was revised by all authors.

Acknowledgment

I would like to express my very great appreciation to dr. Abbasi for his valuable and constructive suggestions during the planning and development of this research work. I would also like to thank the patients who participated in this study and performed all of the exercises interventions exactly.

References

1. Gustafson JA, Gorman S, Fitzgerald GK, Farrokhi S. Alterations in walking knee joint stiffness in individuals with knee osteoarthritis and self-reported knee instability. Gait posture. 2016;43:210-5.
2. Knoop J, van der Leeden M, van der Esch M, Thorstensson CA, Gerritsen M,Voorneman RE, Lems WF, Roorda LD, Dekker J, Steultjens MP. Associationof lower muscle strength with self-reported knee instability in osteoarthritis of the knee:results from the Amsterdam Osteoarthritis cohort. Arthritis Care Res. 2012; 64, 38-45.
3. van der Esch M, Knoop J, van der Leeden M, Voorneman R, Gerritsen M, Reiding D, Romviel S, Knol DL, Lems WF, Dekker J, Roorda LD. Self-reported knee instability and activity limitations in patients with knee osteoarthritis: results of the Amsterdam osteoarthritis cohort. Clin Rheumatol.2012; 31, 1505-1510.
4. An YW. Neurophysiological Mechanisms Underlying Functional Knee Instability Following an Anterior Cruciate Ligament Injury. Exerc Sci. 2018; *27*(2), 109-117.
5. Schmitt LC, Rudolph KS. Influences on knee movement strategies during walking in persons with medial knee osteoarthritis. Arthritis Rheum. 2007; 57:1018-1026.
6. Skou ST, Wrigley TV, Metcalf BR, Hinman RS, Bennell KL. Association of knee confidence with pain, knee instability, muscle strength, and dynamic varus–valgus joint motion in knee osteoarthritis. Arthritis Care Res (Hoboken) 2014; 66:695–701.
7. Farrokhi S, O'Connell M, Gil AB, Sparto PJ, Fitzgerald GK. Altered gaitcharacteristics in individuals with knee osteoarthritis and self-reported knee instability. JOrthop Sports Phys Ther.2015; 45, 351-359.
8. Gustafson JA, Robinson ME, Fitzgerald GK, Tashman S, Farrokhi S. Knee motion variability in patients with knee osteoarthritis: the effect of self-reported instability. Clin Biomech. 2015;30(5):475-80.

9. Hobbelen DGE, Wisse M. A disturbance rejection measure for limit cyclewalkers: The Gait Sensitivity Norm. IEEE Trans Robot.2007; 23 (6). 1213-1224.
10. Allen KD, Arbeeva L, Callahan LF, Golightly YM, Goode AP, Heiderscheit BC, Huffman KM, Severson HH, Schwartz TA. Physical therapy vs internet-based exercise training for patients with knee osteoarthritis: results of a randomized controlled trial. Osteoarthr Cartil. 2018;26(3):383-96.
11. Nguyen US, Felson DT, Niu J, White DK, Segal NA, Lewis CE, Rasmussen M, Nevitt MC. The impact of knee instability with and without buckling on balance confidence, fear of falling and physical function: The Multicenter Osteoarthritis Study. Osteoarthr Cartil. 2014 ;22(4):527-34.
12. Sturnieks DL, Tiedemann A, Chapman K, Munro B, Murray SM, Lord SR. Physiological risk factors for falls in older people with lower limb arthritis. J Rheumatol. 2004; 31(11):2272–9.
13. Neogi T, Guermazi A, Roemer F, Nevitt MC, Scholz J, Arendt-Nielsen L, Woolf C, Niu J, Bradley LA, Quinn E, Frey Law L. Association of joint inflammation with pain sensitization in knee osteoarthritis: The Multicenter Osteoarthritis Study. Arthritis Rheum. 2016;68(3):654-61.
14. Kosmata A. Functional Exercise Training with the TRX Suspension Trainer in a Dysfunctional, Elderly Population: Appalachian State University; 2014.
15. Sadek MT. Effect of TRX suspension training as a prevention program to avoid the shoulder pain for swimmers. Sci Mov Health. 2016;16(2):222-7.
16. Byrne JM, Bishop NS, Caines AM, Crane KA, Feaver AM and Pearcey GE. Effect of using a suspension training system on muscle activation during the performance of a front plank exercise. J Strength Cond Res. 2014; 28(11):3049-3055.
17. Prentice WE. Rehabilitation techniques for sports medicine and athletic training. 5th Edition.McGraw-Hill. 2004. 78-220.
18. Alcalde GE, Fonseca AC, Bôscoa TF, Gonçalves MR, Bernardo GC, Pianna B, Carnavale BF, Gimenes C, Barrile SR, Arca EA. Effect of aquatic physical therapy on pain perception, functional capacity and quality of life in older people with knee osteoarthritis: study protocol for a randomized controlled trial. Trials. 2017;18(1):317.
19. Lu M, Su Y, Zhang Y, Zhang Z, Wang W, He Z, Liu F, Li Y, Liu C, Wang Y, Sheng L. Effectiveness of aquatic exercise for treatment of knee osteoarthritis. Z Rheumatol. 2015 ;74(6):543-52.
20. Soheily F, Gandomi F, Asar Sh, Mozafari M.The Effect of Knee Instability on Balance, Physical Performance, Dynamic Walking Index, Gait pattern, and Quality of Life in Women with Knee Osteoarthritis, J Res Sport Rehabil. 2018; 6(11). [in Persian]
21. Altman, R., Asch, E., Bloch, D., Bole, G., Borenstein, D., Brandt, K., Christy, W., Cooke, T.D., Greenwald, R., Hochberg, M. and Howell, D., 1986. Development of criteria for the classification and reporting of osteoarthritis: classification of osteoarthritis of the knee. Arthritis Rheum, 29(8), pp.1039-1049.
22. Rashid SA, Moiz JA, Sharma S, Raza S, Rashid SM, Hussain ME. Comparisons of Neuromuscular Training Versus Quadriceps Training on Gait and WOMAC Index in Patients with Knee Osteoarthritis and Varus Malalignment. J Chiropr Med. 2019;18(1):1-8.

23. Dawes J. Complete Guide to TRX Suspension Training. Hum Kinet; 2017 Mar 30.
24. Bartels EM, Juhl CB, Christensen R, et al. Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database Syst Rev. 2016; 3.
25. Taglietti M, Facci LM, Trelha CS, de Melo FC, da Silva DW, Sawczuk G, Ruivo TM, de Souza TB, Sforza C, Cardoso JR. Effectiveness of aquatic exercises compared to patient-education on health status in individuals with knee osteoarthritis: a randomized controlled trial. Clin rehabil. 2018;32(6):766-76.
26. Bijur PE, Silver W, Gallagher EJ. Reliability of the visual analog scale for measurement of acute pain. Acad Emerg Med. 2001;8(12):1153-7.
27. Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol.1988; 15:1833e40.
28. Berg K, Wood-Dauphinee S, Williams JI, Gayton D 1989 Measuring balance in the elderly: preliminary development of an instrument. Physiother Can; 41: 304–311.
29. Felson DT, Niu J, McClennan C, Sack B, Aliabadi P, Hunter DJ, et al. Knee Buckling: Prevalence, Risk Factors, and Associated Limitations in Function Knee Buckling: Prevalence, Risk Factors, and Associated Limitations in Function. Ann Intern Med. 2007;147(8):534-40.
30. Fitzgerald GK, Piva SR, Gil AB, Wisniewski SR, Oddis CV, Irrgang JJ. Agility and perturbation training techniques in exercise therapy for reducing pain and improving function in people with knee osteoarthritis: a randomized clinical trial. Phys ther. 2011;91(4):452-69.
31. Park KN, Cynn HS, Kwon OY, Lee WH, Ha SM, Kim SJ and Weon JH. Effects of the abdominal drawing-in maneuver on muscle activity, pelvic motions, and knee flexion during active prone knee flexion in patients with lumbar extension rotation syndrome. Arch Phys Med Rehabil.2011; 92(9):1477-1483.
32. Maayah, MF, Al-Jarrah MD, El Zahrani SS, Alzahrani AH, Ahmedv ET, Abdel-Aziem AA, Lakshmanan G, Almawajdeh NA, Alsufiany MB and Asi YOA. Test-retest strength reliability of the Electronic Push/Pull Dynamometer (EPPD) in the measurement of the quadriceps and hamstring muscles on a new chair. Open J Intern Med.2012; *2*(02):123.
33. Moraiti CO, Stergiou N, Ristanis S, Vasiliadis HS, Patras K, Lee C, et al. The effect of anterior cruciate ligament reconstruction on stride-to-stride variability. Arthroscopy.2009;25: 742–749.
34. Andriacchi TP, Mündermann A, Smith RL, Alexander EJ, Dyrby CO, Koo S. A framework for the in vivo pathomechanics of osteoarthritis at the knee. Ann Biomed Eng. 2004; 32: 447–457.
35. Foroughi F, Sobhani S, Yoosefinejad AK, Motealleh A. Added Value of Isolated Core Postural Control Training on Knee Pain and Function in Women with Patellofemoral Pain Syndrome: A Randomized Controlled Trial. Arch Phys Med Rehabil. 2019 ;100(2):220-9.
36. Arazi H, Malakoutinia F, Izadi M. Effects of eight weeks of TRX versus traditional resistance training on physical fitness factors and extremities perimeter of non-athlete underweight females. Phys Act Rev. 2018; 6:73-80.

37. León AF, Soto V, Araneda O, Venegas RG, de la Rosa FJ. Muscle activity of the Lumbo-pelvic-hip complex in three isometric exercises using TRX® rip trainer™. Retos: nuevas tendencias en educación física, deporte y recreación. 2019(35):216-20.
38. Shakoor N, Felson DT, Niu J, Nguyen US, Segal NA, Singh JA, Nevitt MC. The association of vibratory perception and muscle strength with the incidence and worsening of knee instability: The Multicenter Osteoarthritis Study. Arthritis Rheumatol. 2017;69(1):94-102.
39. Dixon SJ, Hinman RS, Creaby MW, Kemp G, Crossley KM. Knee joint stiffness during walking in knee osteoarthritis. Arthritis Care & Research: Arthritis Rheum. 2010;62(1):38-44.
40. Van der Esch M, Steultjens M, Knol DL, Dinant H, Dekker J. Joint laxity and the relationship between muscle strength and functional ability in patients with osteoarthritis of the knee. Arthritis Rheum. 2006;55(6):953-9.
41. de Zwart AH, van der Esch M, Pijnappels MA, Hoozemans MJ, van der Leeden M, Roorda LD, Dekker J, Lems WF, van Dieën JH. Falls associated with muscle strength in patients with knee osteoarthritis and self-reported knee instability. Int J Rheum Dis. 2015;42(7):1218-23.
42. Dong R, Wu Y, Xu S, Zhang L, Ying J, Jin H, Wang P, Xiao L, Tong P. Is aquatic exercise more effective than land-based exercise for knee osteoarthritis? Medicine. 2018;97(52).
43. Rahmann AE. Exercise for people with hip or knee osteoarthritis: a comparison of land-based and aquatic interventions. Open Access J Sports Med. 2010;1:123.
44. Wyatt FB, Milam S, Manske RC, Deere R. The effects of aquatic and traditional exercise programs on persons with knee osteoarthritis. J Strength Cond Res. 2001;15(3):337-40.
45. Lund H, Weile U, Christensen R, Rostock B, Downey A, Bartels EM, Danneskiold-Samsøe B, Bliddal H. A randomized controlled trial of aquatic and land-based exercise in patients with knee osteoarthritis. J Rehabil Med. 2008;40(2):137-44.

Figures

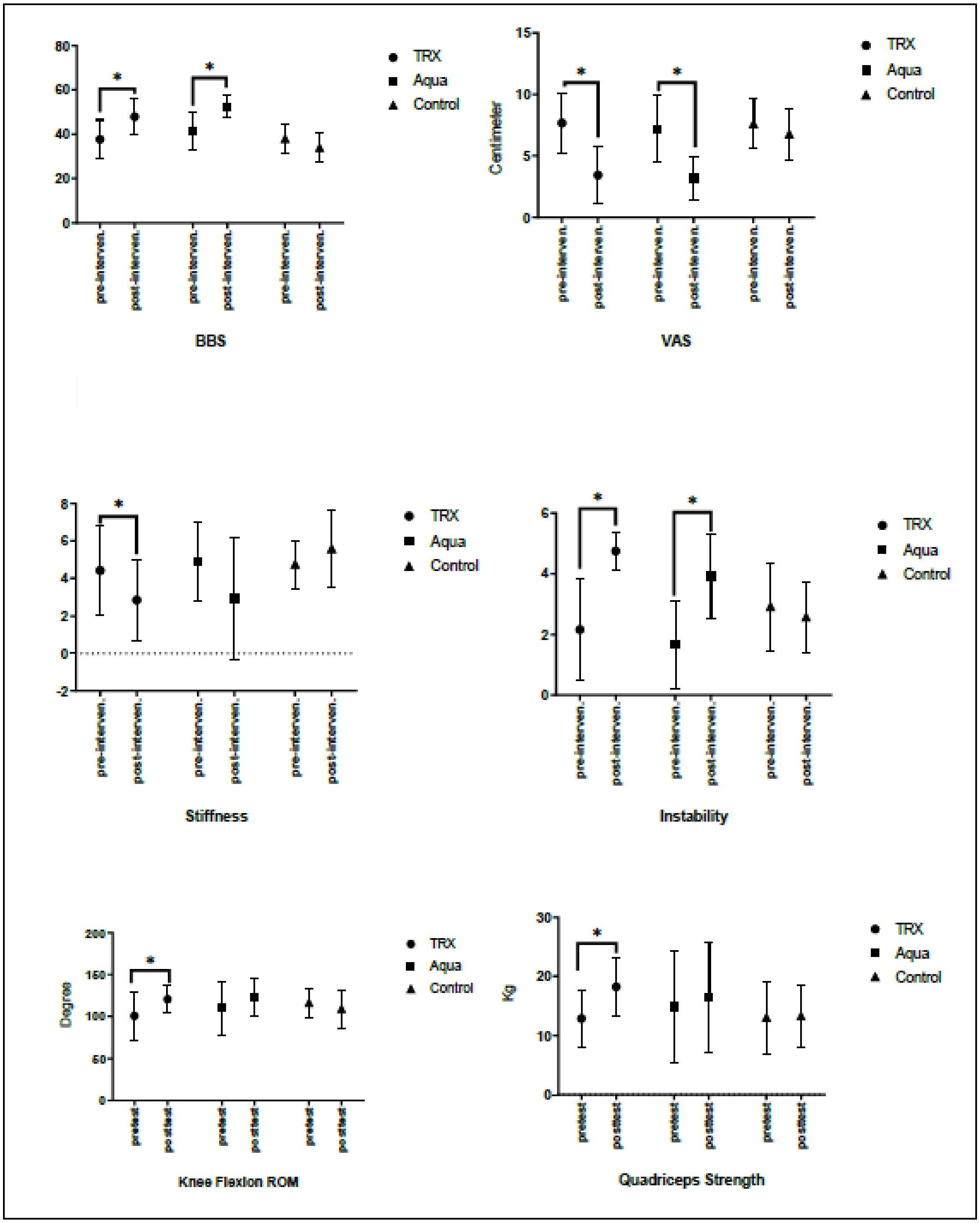

Figure 1

Participants Flow Diagram

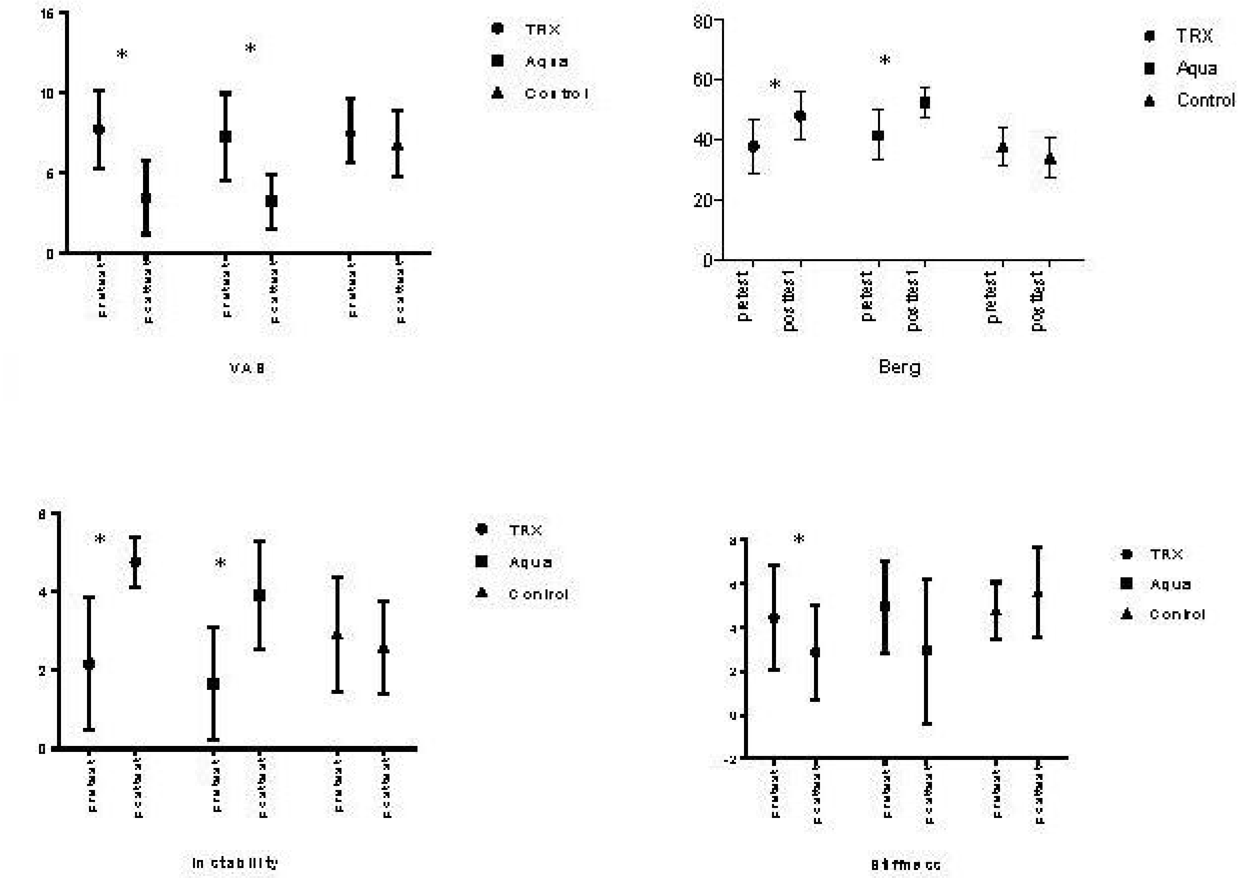

Figure 2

Pretest to posttest mean comparison for TRX training, Aquatic exercises and control groups. (*) means statistical significant differences at the 0.05 level.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- eq1.jpg
- CompleatedCONSORT2010Checklist.doc