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Comparison between Aquatic and Thera-Band Exercises on Pain Intensity and Endurance among Obese Individuals with Knee Osteoarthritis

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Abstract Knee Osteoarthritis (KOA) causes pain, stiffness, muscular weakness, and walking difficulties, leading to physical inactivity and consequently the rise in obesity as a public health concern. This study aimed to compare the effects of aquatic and Thera-band exercises on pain intensity and endurance among obese people with KOA. In a cross-sectional study, 45 obese participants ($n = 45$; male = 22, female = 23) with KOA (BMI ≥ 27.5 kg.m^{-2}) were recruited and randomly assigned to three groups; aquatic exercise (AqG), Thera-band exercise (TBG) and control (CG) groups. For eight weeks, the AqG and TBG groups performed the exercise program twice weekly at 60 min per session. The Mixed-ANOVA statistical analysis revealed significant differences among the effects of aquatic exercise, Thera-band exercise, and CG after eight weeks in terms of pain intensity (F: 2, 42= 34.18, $p < 0.001$) and endurance (F: 2, 42 = 11.425, $p < 0.001$). Meanwhile, both intervention groups had a significant effect on pain intensity ($p<0.001$) and only AqG revealed a significant difference in endurance ($p < 0.046$) compared with the CG. In addition, there was no significant difference between AqG and TBG in the improvement of pain intensity ($p = 0.896$) and endurance ($p = 0.072$). In conclusion, progressive aquatic and Thera-band exercises are alternative suggestions to improve pain intensity and aquatic exercise can also be more advantageous to recover endurance among people with KOA.

Keywords Aquatic Exercise, Thera-Band Exercise, Pain Intensity, Endurance, Obesity, Knee Osteoarthritis

1. Introduction

Osteoarthritis (OA) is a degenerative joint condition that has become one of the world's major socioeconomic healthcare burdens [1]. People with knee osteoarthritis (KOA) experience frequent pain, greater joint discomfort, stiffness and muscular weakness that contribute to physical impairment [2, 3] and reduced physical activities [4].

Obesity increases the stress on joints and pain intensity in those living with KOA [5], leading to weight gain and weakened muscles. Therefore, the current therapeutic management of KOA emphasizes non-pharmacological treatments like therapeutic exercises, physical therapy and weight loss [6, 7]. However, recent studies suggested that water-based therapeutic exercise can improve muscle strength, balance, joint mobility, weight loss, and endurance among KOA patients, particularly those who are obese and have difficulty doing land-based exercises [8].

Several studies have shown that Thera-band exercises (TBE), a land-based exercise regimen, could improve muscular strength, mobility, knee function and reduce joint pain in chronic musculoskeletal pain [9]. Furthermore, TBE improves chronic non-specific pain associated with various illnesses [10].

Nevertheless, land-based exercises might aggravate joint discomfort and increase the risk of falling among KOA patients [11], reinforcing the advantage of water-based exercise. Since immersion in hot water reduces joint stress and discomfort, aquatic exercise (AE) is recommended as a safe and effective strategy in the management of KOA. The AE not only provides a moderate to low intensity exercise for obese people, but it is a non-weight bearing activity that offers unique qualities such as buoyancy, viscosity as water resistance, hydrostatic forces and favorable temperature [12]. Therefore, it is a promising training method to improve physical function, muscle strength, endurance and weight loss with lesser pain [13].

Even though aquatic exercise has been reported to reduce pain in KOA [14], other studies have revealed that land-based activities are more accessible and resulted in a superior increase in leg muscular strength [15, 16].

Despite contradictory findings between the effects of aquatic and land-based exercise on KOA improvement, few studies have assessed the impact and relevance of these exercises among KOA patients. To date, it is still unclear if AE or TBE (with the resistance effects) is more effective in managing the pain intensity and endurance among obese adults suffering from KOA who have difficulties exercising on land. Thus, this study aimed to investigate the effect of an eight-week AE and TBE (two sessions weekly) on pain intensity and endurance among obese people with KOA.

2. Methodology

2.1. Participants

This study was a randomized control trial with two intervention programs utilizing random number generator sampling. A total of 45 obese KOA participants (n = 45, male = 22, female = 23) were recruited for this study. The inclusion criteria were obese participants (based on Southeast Asia obesity class; BMI ≥ 27.5 $kg.m^{-2}$), clinically diagnosed with KOA (Grade 2) without any intervention treatment procedures. Meanwhile, the exclusion criteria included low BMI, history of surgery, cardiorespiratory health problem, water phobia, or any other contra-indication for AE, and inability to safely enter and exit the pool. Following ethical approval (NMRR); NMRR-20-2287-56652 (IIR), all participants were informed about the study procedures and signed a consent form prior to their participation. They were also notified that they could withdraw from the study at any time without any consequences. Then, the participants were randomly placed into three groups: AqG (n = 15), TBG (n = 15), and CG (n = 15). Both intervention groups participated in AE for eight weeks (16 sessions) at the hydrotherapy section of the Physiotherapy Department, Taiping Hospital, Malaysia. The hydrotherapy pool was an adjustable, warm (36°C) platform pool (4 m × 8 m). These intervention programs were conducted from April to May 2021. All participants followed the standard operating procedure during the COVID-19 pandemic, and the participation was limited to three individuals per session.

2.2. Outcome Measurements

The pain intensity was measured using the Visual Analogue Scale (VAS). The VAS consists of a straight line (0-10 lines) with the endpoints defining extreme limits such as 'no pain at all' and 'pain as worst'. The participants were asked to mark their pain level on the line between the two endpoints [17]. A six-minute walking test (6MWT) [18] was conducted to measure the endurance also. The number of laps and any additional distance was recorded for each participant. Then the total distance walked to the nearest metre was calculated. The test was conducted at the gymnasium of Physiotherapy Department. In addition, weight, height, and body mass index (BMI) were recorded using a weighing scale (SECA, Hamburg, Germany) and height scale (Leicester, UK).

2.3. Sample Size

The power of analysis was calculated using G*Power 3.0.10, which indicated that a sample size of 15 would give 80% power. Therefore, 15 participants were recruited for each group.

2.4. The Intervention Programs

2.4.1. Aquatic Exercise (AE)

The AE intervention program was conducted for eight weeks with two sessions weekly at 60 minutes per session. The depth of the aquatic therapy pool was adjusted to ensure that the participants' entire legs were immersed during the activities. Typically, the water level reached their medium sternum level (1.2 m) [19, 20], and the water temperature was maintained at 36°C [19], with the supervision of an AE therapist. Each session consisted of 10 minutes warm-up, 40 minutes AE, 10 minutes of cooling down, relaxation exercises, and self-care, free water activity. The AE routine included walking (forward and backward), knee flexion and extension (in standing position), side lunges, jogging, side stepping, standing knee lift, hip kicker, leg balance (right & left), deep water cycling (using woggle), pool plank and wall push up [19-21]. The intensity and frequency of the exercise gradually increased every week, with an intensity of 13 –

17 Borg-Scale (60-70%) of the participant's maximum heart rate [22]. An overview of the AE program is detailed in Table 1.

2.4.2. Thera-band exercise (TBE)

The resistance, low-cost, portable and versatile TBE was also conducted at two sessions weekly for 60 minutes. To calculate the self-selected of repetition maximum, a yellow, red, green or blue band was performed, starting from a minimum of 10 repetitions for every participant. Furthermore, the Borg Rating of Perceived Exertion was used during training sessions.

Table 1. A summary of the eight-week AE program for obese KOA patients

	Exercise (Self-selected speed) Intensity	Distance/ Repetitions/ Hold × Sets							
		W1	W2	W3	W4	W5	W6	W7	W8
Main exercise (40 minutes); 36°C	Walking; forward & backward; Self-selected speed (meters)	16 × 2	20 × 2	16 × 3	20 × 3	16 × 4	20 × 4	16 × 5	20 × 5
	Knee flexion & extension (standing)	8 × 2	8 × 2	6 × 3	10 × 2	8 × 3	8 × 3	10 × 3	10 × 3
	Side lunges	8 × 2	8 × 2	6 × 3	10 × 2	8 × 3	8 × 3	10 × 3	10 × 3
	Jogging; Self-selected speed (m)	8 × 2	8 × 2	8 × 3	8 × 3	8 × 4	16 × 2	16 × 2	16 × 3
	Side stepping; right & left	8 × 2	8 × 2	10 × 2	12 × 2	15 × 2	18 × 2	20 × 2	25 × 2
	Standing knee lift; right& left (steps)	8 × 1	8 × 1	10 × 1	12 × 1	12 × 1	12 × 1	13 × 1	13 × 1
	Hip kickers; right & left (steps)	8 × 1	8 × 1	10 × 1	12 × 1	12 × 1	12 × 1	13 × 1	13× 1
	Leg balance; right and left front and sides (hold; seconds)	4 × 2	4 × 2	5 × 2	5 × 2	4 × 3	4 × 3	5 × 3	5 × 3
	Deep water cycling; using woggle (min)	1:20 × 1	1:20 × 1	1:30 × 1	1 × 2	1:20 × 2	1:30 × 2	1 × 3	1 × 3
	Pool plank (s)	-	-	-	-	20”	30”	30”	30”
	Wall push-up	-	-	-	-	8	10	10	10

Table 2. A summary of the eight-week TBE program for obese KOA patients

	Exercise	Repetitions × Sets (Hold -10 sec)							
		W1	W2	W3	W4	W5	W6	W7	W8
Main exercise (40 minutes)	Hip flexion & extension (standing)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Hip abduction & adduction (standing)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Quick kicks	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Terminal knee extension	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Knee flexion & extension (sitting)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Knee flexion & extension (prone)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Mini squat	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Leg Press	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Upper body mobilization (lateral and front raise, overhead press)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Shoulder diagonal (flexion & extension)	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6	10 × 7	10 × 7
	Squat	-	-	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6
	Lunge	-	-	10 × 3	10 × 4	10 × 5	10 × 5	10 × 6	10 × 6

The TBE included hip flexion and extension (standing position), hip abduction and adduction (standing position), quick kicks, terminal knee extension, knee flexion and extension (sitting position), knee flexion and extension (prone position), mini squat, leg press, squat, lunge, upper body mobilization (lateral raise, front raise, overhead press) and shoulder diagonal (flexion and extension) [9]. An overview of the TBE program is shown in Table 2.

It should be noted that the CG was also given a physiotherapy appointment after eight weeks. Nevertheless, the researchers could not control the participants' self-treatments in this group.

2.5. Data Analysis

The baseline (before the intervention program) and post-test (a day after intervention programs) data were collected in this study. The demographic data, pain intensity (VAS) and endurance (6MWT) were analyzed using SPSS software (version 23) and expressed as mean and standard deviation. Meanwhile, a mixed ANOVA with Sphericity Assumed was conducted to assess the differences between AqG, TBG and CG in the pain intensity improvement and endurance after eight weeks. Since the sample size of this study was less than 50, the data normality was verified using the Shapiro-Wilk normality test. Additionally, the variances for VAS and 6MWT between groups were assessed by using Levene's test. The significance level was considered at $p \leq 0.05$.

3. Results

The descriptive statistics were tabulated in Table 3. Meanwhile, Kolmogorov-Smirnov test results showed that the distribution of outcome variables was normal and parametric tests could be used.

A Mix ANOVA was conducted to compare the main effects of exercise programs (AqE, TBE and control) and time on pain intensity. The intervention programs consisted of AqG, TBG and control with two time points (baseline and after eight weeks).

It was found that the effects of intervention groups were statistically significant $F(2, 42) = 34.18$, $p = 0.001$, partial $eta^2 = 0.619$, except for the control group. Table 4 demonstrates the main effects of AqG and TBG, where the effect of time and exercise program were not significant between AqG and TBG (Mean difference = 0.03, p =

0.896). However, even though the comparison of the mean difference of AqG and TBG was not significant, the results illustrated a higher reduction with a larger effect size in AqG pain intensity than TBG.

For effects between groups on endurance were statistically significant F (2, 42) = 11.43, p < 0. 000, partial eta^2 = 0.352, except for the control group. Meanwhile, Table 4 shows that the effect of time and exercise program was insignificant between AqG and TBG (Mean difference = 21.85, p = 0.072). However, the results not only illustrated an increase in endurance with a larger effect size in AqG endurance than TBG, but it revealed that there is no significant difference between TBG and the control group also (Mean difference = 0.516, p = 0.965).

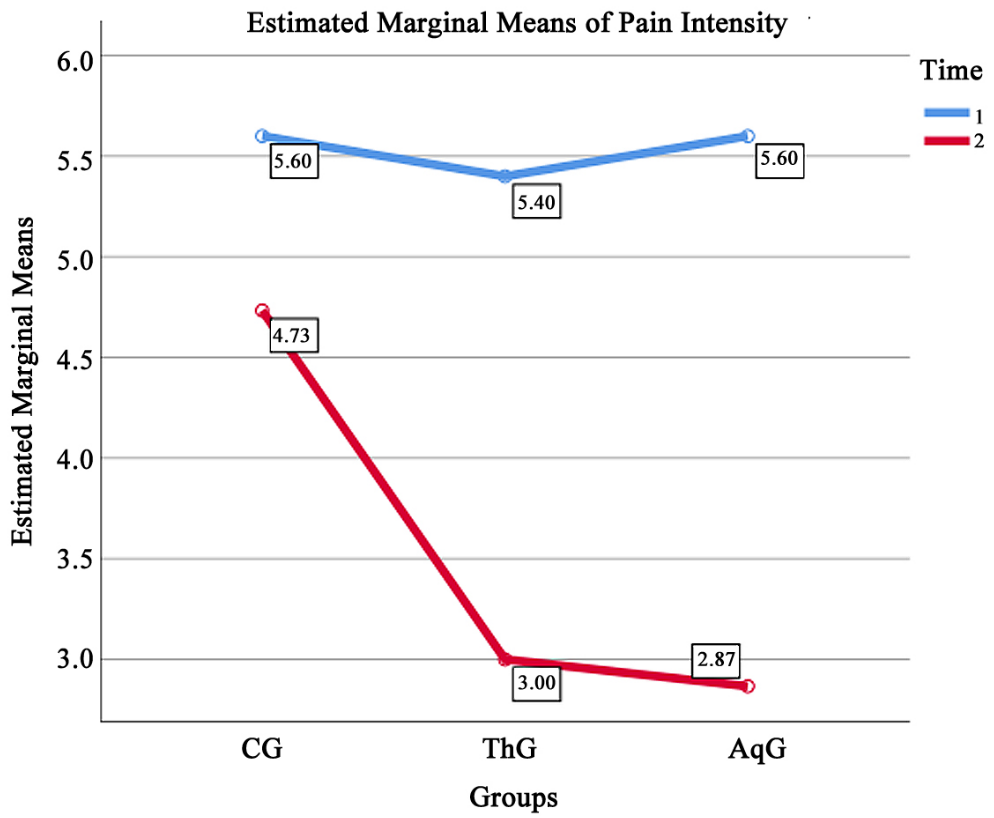
Figure 1 shows the estimated mean of pain intensity (VAS scale) and 6MWT (meters) in the baseline (time 1) measurement and also after eight weeks of intervention programs (time 2) among the groups.

Table 3. Physical characteristics of the participants (Mean ± SD)

Variables/ Group	AqG (n = 15)	TBG (n = 15)	CG (n = 15)
Gender	M: 6 (40.0) F: 9 (60.0)	M: 9 (60.0) F: 6 (40.0)	M: 7 (46.7) F: 8 (53.3)
Age (years) n (%)	51.33 ± 4.72	49.47 ± 5.11	50.27 ± 6.34
Height (cm)	156.98 ± 5.07	160.37 ± 4.16	157.5 ± 3.63
Pre-weight Post-weight (kg)	83.38 ± 7.05 82.71 ± 7.18	88.00 ± 4.92 87.67 ± 5.13	85.74 ± 5.36 86.40 ± 4.86
Pre-BMI Post-BMI ($kg.m^{-2}$)	33.89 ± 2.97 33.62 ± 3.02	34.41 ± 2.18 34.28 ± 2.22	34.10 ± 52.97 34.41 ± 2.83
Pain duration (months)	7.87 ± 2.33	8.27 ± 2.28	8.47 ± 2.17
Pre-VAS Post-VAS (score)	5.60 ± 0.91 2.87 ± 0.52	5.40 ± 0.63 3.00 ± 0.76	5.60 ± 0.83 4.73 ± 0.88
Pre-6MWT Post-6MWT (meters)	305.87 ± 32.66 354.80 ± 32.68	295.57 ± 28.48 321.40 ± 32.25	305.80 ± 40.67 310.13 ± 40.69

Table 4. Mixed ANOVA analysis between time and study groups for pain intensity (VAS) and endurance (6MWT)

Variable	**Group (I-J) respondent**	**Mean Difference (I-J)**	**Std. Error**	***p***	***F***	η^2
VAS (scores)	CG- TBG	0.967*	0.253	0.000	34.18	0.619
	CG- AqG	0.933*	0.253	0.001		
	AqG- TBG	0.033	0.253	0.896		
6MWT (m)	CG- THG	0.517	11.847	0.965	11.43	0.352
	AqG- CG	22.367*	11.847	0.046		
	AqG- TBG	21.850	11.847	0.072		



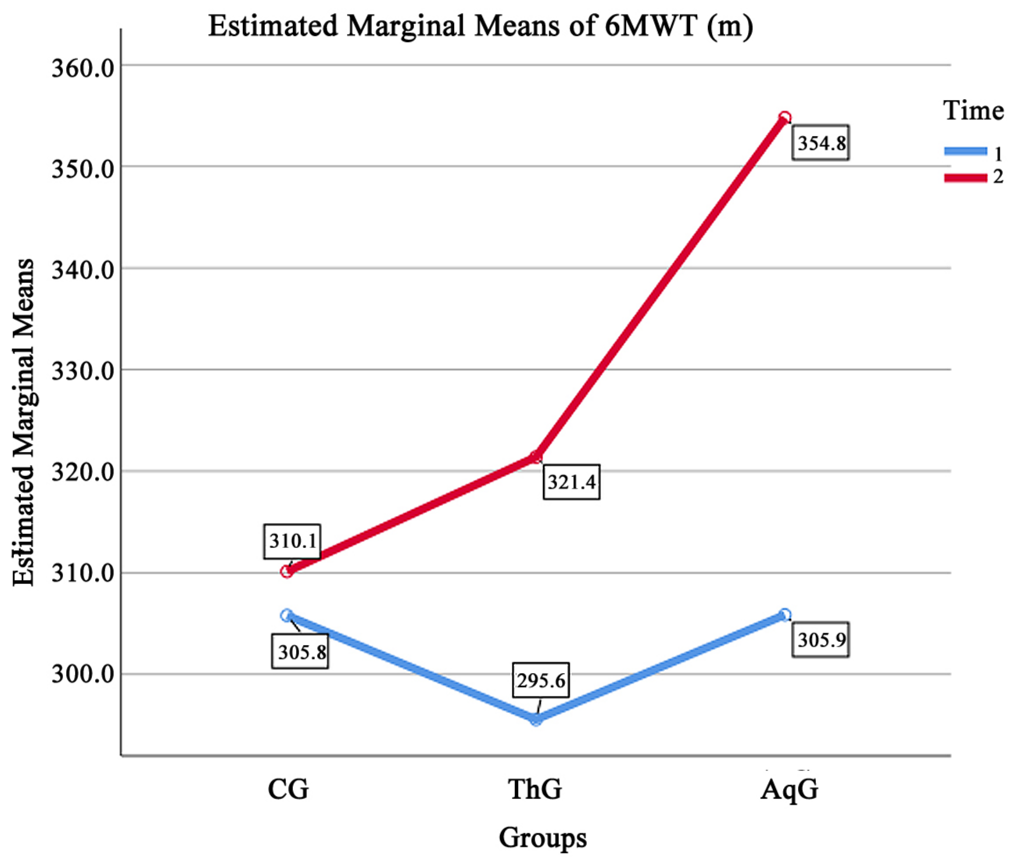


Figure 1. Estimated mean of pain intensity and 6MWT in baseline test and post-test

4. Discussion

The impact of KOA and its epidemiology varies in different communities. In this study, the effect of AE and TBE on pain intensity and endurance among obese adults with KOA were evaluated within eight weeks. The findings revealed that even though AqG performed better than CG in endurance, there was no significant difference between AqG and TBG in pain intensity and endurance improvement.

Previous studies have reported positive outcomes of warm pool water (34 °C) treatment between four to eight weeks for pain alleviation, edema reduction, ease of movement, muscle relaxation, joint protection and relaxing stiff muscle [20, 23]. Furthermore, water immersion increases plasma methionine–encephalin levels while suppressing plasma b-endorphin, corticotrophin, and prolactin levels, resulting in muscular relaxation and reduced joint swelling [24], thus, supporting this study outcome in the improvement of pain intensity and endurance.

Moreover, the results of this study aligned with Wang et al. [25], where both aquatic and land-based exercise programs were equally effective in reducing pain, improving knee range of motion and the 6MWT among patients with KOA. Nevertheless, the earlier study was conducted among healthy community-dwelling populations and may not be generalized to clinical OA populations with a greater functional decline and different grade of OA like the present study, which involved an obese population with KOA (grade 2). Despite the slight difference in methodology (TBE as a land-based exercise in the present study), the outcomes were almost similar except for the endurance.

In addition, previous studies have shown that the water hydrostatic during AE can help OA patients through pain alleviation by lowering peripheral edema and suppressing sympathetic nervous system activity. The exercise-induced hypoalgesia (EIH) activates afferent muscle A-delta and C fibers and the descending tract, where patients are distracted from the pain stimuli, thus, lowering pain sensitivity [26]. Furthermore, since the immersion depth is proportional to the percentage of weight bearing, buoyancy may help in pain alleviation during exercise [27, 28]. The hydrostatic pressure compresses the tissues and, when combined with the circulatory changes that occur during immersion (non-weight bearing), lowers edema and allows for more movement, reducing joint and soft-tissue stiffness, thus, improving pain complaints [29].

Multiple studies have shown that water training improves physiological and biomechanical characteristics in the elderly, including walking speed, motor coordination, and balance. A study conducted by Shoepe et al. [30] found that water exercises develop muscle strength and postural stability independently in the elderly and promote huge motions without the danger of falls and subsequent injuries. Apart from that, water viscosity allows for slower motions, giving the elderly more time to create and react to stimuli during the workouts, as opposed to land exercises which are conducted more rapidly. The combination of frequency and motion speed can enhance strength and flexibility in the water [30]. In that, the improvement of endurance via aquatic exercise program can probably be supported through this study's findings.

Performing land exercises like TBE can aggravate joint pain and increase the risk of falls in a population with limitations and difficulty doing exercise [29]. Therefore, AE is considered a safe and effective tool in treating KOA due to water properties, particularly immersion in warm water to avoid joint overload and pain symptoms, besides improving their functional capacity [31]. It is also worth mentioning that all AqG participants were more satisfied to join and continue AE, boasting a 100% attendance compared to the TBG (91%) throughout the study. Nonetheless, the data obtained were insufficient to validate optimal intervention sessions for AE because of the two sessions/week limit during COVID-19 pandemic protocol. In contrast, TBE could be carried out more sessions by the TBG at home, which may have influenced the findings of this study and can be considered as another of the study's limitation. Even though the properties of water assist in pain reduction and increase in endurance, further research is needed to examine the significant impact of AE with resistance aids for obese participants with KOA with a larger sample size to elucidate the effect of AE compared to TBE.

5. Conclusion and Recommendation

The AE and TBE are effective and beneficial alternatives to improve pain intensity, while AE can be more beneficial as a significant intervention program to improve endurance for obese people with KOA. These findings revealed that even though AE is safe and non-weight bearing, exercise could slightly improve pain intensity. Therefore, although TBE is an equally effective option to improve pain intensity, this progressive AE was a non-weight bearing and efficient intervention program to enhance endurance among obese patients suffering from KOA. Moreover, appropriate TBE is likely a simple alternative therapeutic modality to hydrotherapy in pain intensity reduction. Further research should be conducted by combining AE and TBE as an effective intervention and treatment package to improve both pain intensity and endurance among obese patients with KOA.

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