Studying the Effects of the Aquatic Exercise Rehabilitation Training on the Patients with Knee Ligament Injury

Jian Ge, Wei Dong*

Ministry of Sport,
Tangshan Polytechnic University
Tangshan, Hebei 063000, China
E-mails: tsgjedu@126.com
wei6913@163.com

**Corresponding author*

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Abstract: *As one of the most complex and flexible joints in the human body, the knee joint is highly susceptible to injury during exercise. Therefore, it is crucial to adopt a scientific approach to deal with sports knee injuries in a timely and effective manner. This study selected 20 individuals with similar physical parameters, like height and weight, from Tangshan Polytechnic College, China, all of whom had knee joint injuries caused by training. They were randomly divided into an experimental group and a control group. The experimental group underwent aquatic rehabilitation training, while the control group received conventional land-based rehabilitation training. Their knee joints were assessed for pain levels, range of motion, functions, and weight-bearing capacity before and after the experiment. It was found that the flexion range of the knee joint of people receiving aquatic exercise rehabilitation training was 10°greater than those receiving conventional training, the basic function score of the knee joint was approximately three points higher, and the bearing strength of the knee joint was about 10 kg larger. The experimental results show that both aquatic exercise rehabilitation training and conventional rehabilitation training can improve knee injuries caused by exercise; however, the rehabilitation effect of aquatic exercise rehabilitation training is better than that of conventional training.*

Keywords: *Knee joint injury, Aquatic exercise, Rehabilitation training.*

Introduction

The knee joint is one of the most important joints in the human body [15] and is particularly susceptible to injury [5]. Injuries to the knee joint can lead to significant functional limitations [13]. Therefore, it is of great practical importance to assist athletes in overcoming knee joint injuries and implement scientific and effective rehabilitation programs. A review of both Chinese and international literature reveals that the aquatic environment has unique properties, such as buoyancy, hydrostatic pressure, and resistance, which can be beneficial to the human body [3]. There are also studies on aquatic exercise rehabilitation therapy. This form of therapy has been applied in the treatment of cerebral palsy [14], Parkinson's disease [9], spinal cord injuries [4], and other areas of neurorehabilitation. The positive effects of aquatic exercise rehabilitation have been consistently affirmed by scholars from both China and abroad. Seco-Calvo et al. [12] found that cold water immersion therapy was more effective for recovering from muscle injuries through a prospective experimental design. Buckthorpe et al. [2] suggested that the primary characteristics of aquatic exercise methods (density, hydrostatic pressure, buoyancy, and viscosity) could help reduce pain and swelling, thereby accelerating rehabilitation. In a meta-analysis, Ma et al. [10] found that aquatic physical therapy positively affected pain, physical function, knee joint extension muscle strength, and walking ability in patients with knee osteoarthritis. Laedermann et al. [6] found through a random double-blind trial that aquatic exercise rehabilitation training presented better efficacy than physical therapy.

Therefore, the aim of this paper is to explore the benefits of aquatic exercise rehabilitation on the functional recovery of knee joints over an eight-week period, utilizing the unique properties of water. This study provides a stronger foundation for selecting various rehabilitation methods for patients with knee joint injuries in the future and provides a theoretical basis for subsequent research on rehabilitation training for these patients. The study selected 20 individuals with similar physical parameters like height and weight and knee joint injuries (specifically ligament injuries at the sprain level) that were rehabilitated through exercise at Tangshan Polytechnic College, China. These injuries were incurred during training. The participants were randomly divided into an experimental group and a control group. The experimental group underwent water-based rehabilitation training, while the control group received conventional land-based rehabilitation training. Before and after the rehabilitation training, the participants' knee joint pain levels, range of motion, functions, and weight-bearing capacity were assessed. The results showed that patients who underwent water-based rehabilitation training experienced superior recovery of knee joint function.

The novelty of this article lies in utilizing the physical properties of water to support individuals with knee joint injuries in their rehabilitation training and designing corresponding aquatic rehabilitation training programs based on the injury characteristics of the subjects. The contribution of this article is to use water's physical properties to aid in the rehabilitation training for sports injuries and provide an effective reference for the treatment of sports injuries and accelerating recovery speed.

Materials and methods

Subjects

Twenty participants from Tangshan Polytechnic College, China were selected to participate in this experiment. The age, height, weight, and severity of knee joint injuries of the subjects were surveyed before the experiment to ensure that the degree of knee joint injury and the time to be injured were approximately the same across all subjects in the groups. The specific groups and details of the experimental subjects are displayed in Table 1.

Table 1. Specific grouping and information data of the experimental subjects

	Age, (year)	**Height, (cm)**	**Weight, (kg)**	**Severity of knee joint injury**	**Time to be injured, (day)**
Group A (10 subjects)	21 ± 0.69	175 ± 2.58	78 ± 1.08	Knee ligament injury (at the level of sprain)	3 ± 1.24 before
Group B (10 subjects)	21 ± 0.47	176 ± 3.12	78 ± 0.89	Knee ligament injury (at the level of sprain)	3 ± 2.06 before

Research methodology

A randomized double-blind crossover experiment was designed for all 20 selected subjects. The subjects were randomly divided into 2 groups, 10 participants each, as shown in Table 1. Group A was the aquatic exercise rehabilitation training group, and group B was the conventional rehabilitation training group. Both groups engaged in their respective rehabilitation for eight weeks. Throughout this period, the subjects in the two groups adhered to the same dietary regimen, differing only in their exercise rehabilitation methods. The subjects were assessed before and after the rehabilitation training period, and the data were recorded. A comparative analysis of the data from both groups is performed to evaluate the effectiveness of aquatic exercise rehabilitation training.

The trial lasted for eight weeks. The experimental group engaged in aquatic exercise rehabilitation training from Monday to Friday, participating once daily for approximately one and a half hours each session. Table 2 shows the specific training content. At the same time, in order to meet the actual needs of the experimental subjects, the coach made appropriate adjustments to the exercise program and duration. The control group underwent conventional recovery training. The training content is presented in Table 3.

Table 2. Content of aquatic rehabilitation training

	Exercise name	**Exercise duration and times**
Warm-up exercises	Rotate the shoulder joints and ankle joints	5-10 minutes
Aquatic rehabilitation training (2 minutes rest between every group of exercises)	Walking in water while holding arms across the chest	Three sets, 50 meters each
	Hip extension under traction	Two sets, 20 times each, repeat once upward and backward
	Side leg swing under traction	Two sets, 20 times each, repeat once upward and backward
	Writing Chinese character “八” in water with legs	Three sets, two minutes each
	Bunny hopping	Three sets, 25 meters each
	Deep water jogging	5-10 minutes
	Squatting	Three sets, 25 meters each
Finish and relaxation	Muscle relaxation with a massage gun	5-15 minutes

Research plan
Knee joint-related tests were performed before and after the eight-week rehabilitation training for both groups. The data collected from these tests were compared and analysed to evaluate whether the knee joint injury had improved after the intervention.

Pain level assessment
The pain levels of the subjects were scored for the subjects before and after the experiment using the visual analogue scale (VAS) [8], respectively. The scoring ranged from 0 to 10, with 0 indicating no pain and 10 representing severe pain. A higher score indicated greater pain intensity.

Table 3. Content of conventional rehabilitation training

	Exercise name	Exercise duration and times
Warm-up exercises	Shoulder joints, ankle joints, and other rotational movements	5-10 minutes
Conventional rehabilitation training (2 minutes rest between every group of exercises)	Forward walking on land	Three sets, 50 meters each
	Swing one leg back and forth	Two sets, 20 times each, repeat once forward and backward
	Swing one leg from side to side	Two sets, 20 times each, repeat once outward and inward
	Knee lifting	Switch sides after 15 times
	Open and close both legs with a resistance band in a state of flexing the knees	15 times
	Squat on one leg with a balance ball	Switch sides after 20 times
	Knee range of motion improvement training	10 seconds exertion + 5 seconds relaxation
Finish and relaxation	Muscle relaxation with a massage gun	5-15 minutes

Test of knee joint motion range
The motion range of the leg towards the hip was assessed using a joint angle gauge. The optimal flexion angle was 180°. A larger flexion angle indicated better rehabilitation outcomes. The optimal extension angle was between 0°-10°. A smaller extension angle indicated better rehabilitation outcomes.

Knee joint function test
Knee function tests were performed according to the Lysholm knee function rating scale [11] before and after the experiment. The scoring points were knee joint swelling, walking ability, and difficulty in ascending and descending stairs. The total score was 100 points; the scoring criteria are shown in Table 4. A higher score indicated better rehabilitation outcomes.

Knee joint weight bearing test
The maximum weight that the knee joint can support was measured both before and after the experiment. The weight began at 5 kg and gradually increased until the subject felt strained. The more weight that the knee joint could bear, the better tolerance and rehabilitation outcomes were.

Mathematical and statistical analysis

The data were processed and analysed using SPSS software. The results were presented as mean ± standard deviation. Differences in the indicators within the groups before and after the experiment were analysed by a paired sample t-test. Comparisons between different groups were analysed by an independent sample t-test [7]. The level of $p < 0.05$ indicated statistically significant difference, and $p < 0.01$ suggested that the difference was very significant.

Table 4. Knee function score scale

	Scoring criteria	Score
Knee swelling (max 20 points)	Frequent swelling of the knee joint	0 point
	Swelling of the knee joint during force generation	10 points
	No swelling	20 points
Walking ability (max 40 points)	Frequent limp	0 point
	Slight limp	20 points
	No limp	40 points
Difficulty in ascending and descending stairs (max 40 points)	Unable to go up and down stairs because of a knee joint injury	0 point
	Slightly difficult to climb stairs because of knee joint injury	20 points
	Climbing stairs without difficulty	40 points

Results

Pain degree assessment

It was observed that there was no significant difference in pain scores between groups A and B before the experiment ($p < 0.05$), and the subjects' pain perception at the injury site was nearly the same (Fig. 1). There was a very significant difference ($p < 0.01$) in pain perception at the injury site in groups A and B before and after training, indicating that both conventional rehabilitation training and aquatic exercise rehabilitation training were positive in relieving knee joint pain.

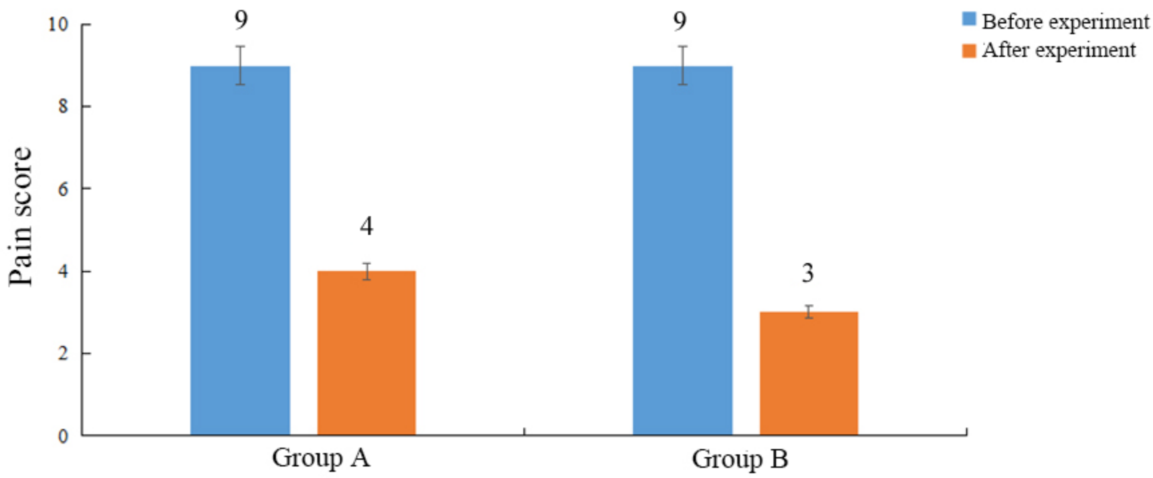

Fig. 1 Pain scores of the groups A and B before and after the experiment

Knee joint motion range

It could be seen in Table 5 that no significant differences ($p < 0.05$) existed in either flexion scores or extension scores between groups A and B before the experiment. After the experiment, group A exhibited highly significant differences ($p < 0.01$) in both flexion and extension range of motion. The flexion range of group B was increased by approximately 10°, suggesting a significant difference ($p < 0.05$), while the difference in extension range was not significant ($p < 0.05$). These results showed that individuals who participated in the aquatic exercise rehabilitation training experienced considerably better recovery in knee joint motion range compared to those who underwent conventional rehabilitation training.

Table 5. Knee joint motion range score of groups A and B

	Flexion angle, [°]	**Extension angle, [°]**
The flexion angle of normal people for reference	94.65 ± 11.21	-1.45 ± 1.23
Group A before the experiment	77.50 ± 16.28	-4.29 ± 4.06
Group A after the experiment	93.26 ± 17.83$^{**,\#}$	-1.94 ± 2.49$^{**,\#\#}$
Group B before the experiment	75.30 ± 15.67	-4.58 ± 3.36
Group B after the experiment	85.35 ± 14.05*	-3.79 ± 2.67

Significant differences between before and after the experiment: * – $p < 0.05$; ** – $p < 0.01$; significant differences between group A and group B: $^{\#}$ – $p < 0.05$; $^{\#\#}$ – $p < 0.01$.

Basic function of the knee joint

It has been seen from the data in Table 6 that there was no significant difference in the scores for swelling, walking ability, and ascending and descending stairs between groups A and B before the experiment ($p < 0.05$). Three basic functions in both groups A and B were greatly improved after rehabilitation training, showing a very significant difference ($p < 0.01$). It was also found that the scores for swelling and ascending and descending stairs in group A were 4 points higher than those in group B, which was a very significant difference ($p < 0.01$). The walking ability in group A reached score of 26.6, nearly 2 points higher than that in group B ($p < 0.05$). This suggested that the walking ability in group A recovered better than in group B. These results indicated that both training modalities significantly impacted the recovery of basic knee joint function. However, the effect of aquatic exercise rehabilitation training was markedly superior to that of conventional rehabilitation training.

Table 6. Basic knee function scores of groups A and B before and after the experiment

	Swelling score	**Walking ability score**	**Score of ascending/ descending stairs**
Group B before the experiment	10.83 ± 3.29	22.10 ± 6.22	19.24 ± 7.15
Group B after the experiment	12.18 ± 5.42**	24.63 ± 5.92**	23.96 ± 8.09**
Group A before the experiment	9.87 ± 6.92	23.64 ± 7.52	21.03 ± 8.39
Group A after the experiment	16.01 ± 3.52$^{**,\#\#}$	26.60 ± 5.76$^{**,\#}$	28.41 ± 7.53$^{**,\#\#}$

Significant difference before and after the experiment: ** – $p < 0.01$; significant difference compared to the control group # – $p < 0.05$; ## – $p < 0.01$.

Knee joint weight bearing

It was seen from Table 7 that the maximum tolerable weight supported by the knee joint did not differ significantly between groups A and B prior to the experiment ($p < 0.05$). However, there was a very significant difference ($p < 0.01$) in the maximum tolerable weight before and after the experiment for both groups, suggesting that both groups had a very significant improvement in knee joint weight-bearing capacity. The comparison of maximum tolerable weight after the experiment suggested that the maximum tolerable weight of group A was approximately 10 kg greater than that of group B, showing a very significant difference ($p < 0.01$). These results showed that athletes who underwent rehabilitation had a significant improvement in the tolerable weight of the knee joint, but the recovery outcomes of the athletes who underwent aquatic rehabilitation was significantly better than that of the athletes who underwent conventional rehabilitation.

Table 7. Maximum bearing weight of the knee joint of groups A and B

	When bending legs in a prone posture, [kg]	**When lifting legs in a sit-standing posture, [kg]**
Group B before the experiment	11.56 ± 3.98	13.27 ± 5.07
Group B after the experiment	24.68 ± 4.25**	32.87 ± 8.71**
Group A before the experiment	12.27 ± 3.80	13.19 ± 6.08
Group A after the experiment	34.91 ± 5.67$^{**,\#\#}$	43.50 ± 9.76$^{**,\#\#}$

Significant difference before and after the experiment: ** – $p < 0.01$; significant difference compared to the control group: $^{\#\#}$ – $p < 0.01$.

Discussion

In the 1960s, aquatic rehabilitation become an important method in modern rehabilitation training and has been widely adopted in the field of sports training. Aquatic exercise rehabilitation refers to the targeted exercise performed in water to achieve the specific recovery of muscles, nerves, and sensory functions based on the unique properties of water, such as temperature, buoyancy, and hydrostatic pressure [1]. On one hand, aquatic rehabilitation therapy aids athletes in eliminating fatigue after long-time exercise, restoring the body's balance, and preventing fatigue accumulation. On the other hand, it effectively enhances patients' neurological recovery and assists injured athletes in their rehabilitation, thus restoring athletes' health or speeding up the recovery process.

This study is focused on 20 students with knee joint injuries (specifically ligament injuries at the sprain level) that were rehabilitated through exercise at Tangshan Polytechnic College, China. The participants were randomly divided into two groups: a control group receiving conventional rehabilitation training and an experimental group undergoing aquatic rehabilitation training. Before and after the training, the subjects were assessed for knee joint pain levels, range of motion, functions, and weight-bearing capacity. As mentioned before, the experimental group showed significantly better recovery from knee joint injuries following the rehabilitation training. The reasons for the above results were analysed. Aquatic exercise rehabilitation training has the following unique benefits compared to conventional rehabilitation training methods. First, buoyancy effectively reduces the bearing weight. The buoyancy of water can offset up to 90% of the body's gravity, thereby alleviating stress on the joints and muscles and the athletes' pain to prevent excessive strain that could exacerbate injuries. Secondly, the incidence of exercise-related injuries in water is low. Water provides support during exercise. The human body in an aquatic environment can benefit from upward buoyancy, facilitating lateral movement and minimizing the influence of exercise-related injuries. Thirdly, people feel a larger resistance in water than on land. When movements are performed too quickly, water resistance can slow them down, helping to prevent further injuries. Fourthly, the flow of water can massage and soothe the body to reduce muscle cramps, and the appropriate water temperature can promote muscle relaxation.

Conclusion

This paper primarily discusses knee joint injuries and aquatic rehabilitation training based on the properties of water. Twenty people with knee injuries were selected from Tangshan Polytechnic College, China as subjects for the analysis. They were randomly divided into two groups: group A who underwent aquatic exercise rehabilitation training, and group B who received conventional rehabilitation training. The data from both groups before and after the training were statistically compared. It was found that the basic knee joint function score for group A was about three points higher than that of group B; the maximum tolerable weight for the knee joint in group A was about 10 kg greater than that in group B; the difference in the flexion motion range of the knee joint between groups A and B was 11.69°. Therefore, the following conclusions are drawn. Both aquatic rehabilitation and conventional rehabilitation effectively alleviate pain caused by knee joint injuries and significantly improve the range of motion, basic function score, and tolerable weight of the knee joint for people with such injuries. However, the rehabilitative effects of aquatic rehabilitation are more significant than those of conventional rehabilitation training. In other words, aquatic rehabilitation training based on the properties of the water is more effective the than conventional rehabilitation training methods.

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Assoc. Prof. Jian Ge, B.Sc.
E-mail: tsgjedu@126.com

Jian Ge is an Associate Professor of Physical Education with a Bachelor's Degree in Sports Training, specializing in teaching physical education courses and training track and field teams. In the teaching process, he uses unique educational methods to stimulate students' enthusiasm for sports. The classroom is lively, and his educational methods are like bright lights, illuminating the path of students' physical education and setting a benchmark for physical education. He stood out in the micro course competition of Tangshan Polytechnic University, China. The micro course meticulously crafted by him won the first prize with innovative teaching methods, vivid explanations, and wonderful presentations. On the sports field, the team he leads has achieved remarkable results. The team members have shone brightly on the stage of the Universiade multiple times and won numerous awards.

Assoc. Prof. Wei Dong, M.Sc.
E-mail: wei6913@163.com

Wei Dong is an Associate Professor of Physical Education. He graduated with a Master's Degree in Physical Education from Hebei Sport University, China and B.Sc. in Tangshan Polytechnic University, China. Specializing in physical education teaching and training. He won first prize in provincial teaching competitions and titles such as excellent coach. He leads the school sports team in various competitions and won awards multiple times. He has made outstanding contributions in the reform of physical education teaching and sports research.