RESEARCH ARTICLE

Effect of rehabilitation training on golf athletes after knee injury

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With the popularity of golf, the problem of athletes' knee injuries has become increasingly prominent, which seriously affects their sports career and competitive performance. It is urgent to explore efficient rehabilitation training methods. This study focused on the effect of rehabilitation training after knee injury in golf players. A total of 52 active golfers from an university in Beijing, China was recruited and randomly divided into multi-angle isometric exercise (MIE) group and proprioceptive neuromuscular facilitation (PNF) training group with 26 people in each group and consecutive treatments of 6 weeks, 3 times per week. Isometric muscle strength, knee function, balance, and treatment effect were measured before and after treatment, respectively. The results showed that there was no significant difference between the two groups before the treatments. Both groups were improved after treatments with no significant difference in the relative peak torque of quadriceps femoris. However, the relative peak torque of hamstring muscle, Lysholm score, "instability" score, international knee documentation committee (IKDC) score, orthopedic stability index (OSI), ankle performance index (API), medial-lateral index (MLI), and Y balance in PFN group were significantly better than those in MIE group (*P* < 0.05). The results demonstrated that both treatment methods were effective, but the treatment effect of PFN group was better than MIE group.

Keywords: golf players; knee joint injury; rehabilitation training; multi-angle isometric exercise; proprioceptive neuromuscular facilitation.

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Introduction

Golf attracts global participants with its unique charm. Although the number of participants in China is not as high as in Europe, America, Japan, and South Korea, it is showing an upward trend year by year. In traditional perception, golf is considered to have extremely low risk of injury due to the lack of direct physical contact. However, in an 18-hole race, players need to hike several kilometers, frequently start and stop, twist their bodies, and bear different directions of impact force on their knees throughout the entire process [1]. When swinging, the knee joint is a key hub for power transmission from storing and releasing explosive force to stable braking. Long term high-intensity repetitive movements can lead to the accumulation of minor injuries and erosion of the knee joint structure [2, 3]. The knee joint, as the most complex structure, the largest joint, and the strongest lever in the human body, is highly susceptible to injury during golf [4]. Irregular swing movements are the main cause of injury. Improper movements such as lifting the club backwards and hitting the ball can easily damage the knee cartilage and meniscus and even lead to serious injuries such as ligament tears [5, 6]. According to data from the United

States Golf Association (https://www.usga.org/), a significant proportion of golfers have suffered sports injuries with knee joint injuries being more common [7]. In addition, limited ankle and arch function can affect knee joint stability, further increasing the risk of injury [8].

Sports injuries have many negative impacts on sports players, ranging from minor impacts on training and performance to major impacts on physical functioning and even sports careers. It is difficult to rely on clinical medicine alone to completely rehabilitate the dysfunction of the body, and the timely intervention of rehabilitation training will accelerate the process of functional rehabilitation. Therefore, rehabilitation training should be carried out as soon as possible after the sports injury. According to the traditional rehabilitation program, the research on the rehabilitation program for athletes with knee injuries is mainly based on conventional exercise therapy such as isometric muscle training and isotonic muscle training [9, 10]. Golf as a sport requires extremely high joint coordination and dynamic stability. A single training mode often cannot meet comprehensive rehabilitation needs, and exploring more efficient comprehensive rehabilitation plans has become an urgent problem that needs to be solved. Previous studies have shown that the stability of the knee joint depends on the neural feedback mechanism of the joint and muscle ligaments [11]. Research on anterior cruciate ligament reconstruction has also confirmed a close relationship between patient proprioceptive recovery and joint stability recovery, and proprioceptive recovery is an important factor in knee joint function repairing [12]. Therefore, proprioceptive and neuromuscular control training after knee joint ligament injury gradually receives attention.

This study focused on the rehabilitation training effects of knee joint injuries in golfers by comparing the efficacy of different rehabilitation training methods, screening for better rehabilitation plans, and providing scientific basis for the rehabilitation of knee joint injuries in golfers. 52 active golfers from a university in Beijing, China were recruited and randomly divided into two groups being treated with either multi-angle isometric training (MIE) or proprioceptive neuromuscular facilitation training (PNF) method for rehabilitation training effects comparison. The results of this study would provide ideas and directions for future research in this field and promote the development of golf injury rehabilitation.

Materials and methods

Research subjects

A total of 52 active golfers (35 males and 17 females) from Beijing Sport University (Beijing, China), aged 18 - 26 years old, were recruited for this research with the inclusion criteria as having knee injuries due to training or competition and still having residual knee dysfunction with the presence of injuries leading to a decrease in knee mobility, a weak leg or joint misalignment sensation, or a change in the range of motion of the knee joint. The exclusion criteria were the knee injuries combined with serious complications in other systems or organs and having a history of lower limb surgery within 6 months prior to participation in this study. The participants were divided into the MIE group and the PNF group using a randomized numerical table in accordance with the numbering of the cases in the order in which they were collected with 26 in each group. The MIE group included 17 males and 9 females with an average age of 22.27 ± 2.25 years old, BMI of 20.38 ± 1.87, and training duration of 6.35 ± 1.76 years, while the PNF group comprised 18 males and 8 females with an average age of 22.15 ± 2.43 years old, BMI of 20.53 ± 1.82, and training duration of 6.40 ± 1.73 years of training with no statistically difference between two groups. All procedures were approved by the Ethics Committee of North China Electric Power University (Beijing, China).

Rehabilitation training plan for each group

Both groups went through 18 rehabilitation treatments for 6 consecutive weeks with 3 times a week. The MIE group conducted the isometric training within the range of joint activity according to the individual situation with a group of exercises being performed at five different knee flexion angles of 30°, 50°, 70°, 90°, 110° and the quadriceps and hamstring muscles being trained in the "tens" mode as 10 s contraction, 10 s rest, 10 reps, and 1 min rest between groups. The total training time was 40 min. The PNF group applied basic and special manipulation combinations including upward to contralateral curved movements (D1F), downward outward pedaling motion (D1E), upward and outward opening action (D2F), downward backward push action towards the opposite side (D2E) for dysfunction like weak muscle strength and/or poor balance ability. Each treatment lasted 40 min with 8 - 10 s resting time between the treatments.

Evaluation scheme and indicators

1. Isokinetic muscle strength test

Biodex System 4 PRO Multi-Joint Isometric Muscle Strength Evaluation Training System (Biodex Medical Systems, Inc, Shirley, New York, USA) was employed in this study to test the indexes of isokinetic centripetal muscle strength of the knee joint and the relative peak torque (PT) of the quadriceps and hamstrings at an angular velocity of 60°/s. After calibration of the instrument, the subject sat on the seat of the system, adjusted the body position, and fixed the trunk. The instrument was used to remove the influence of the weight of the limb. The test was performed on the healthy side and then on the affected side. The subject was asked to maintain a knee angular velocity of 60°/s and to perform 5 repetitions of knee extension and knee flexion.

2. Knee joint function test

Subjects performed a 3-minute *in situ* leg raising activity to improve the accuracy of the joint positional perception assessment. After setting the initial knee angle, the subject was required to wear a blindfold and earplugs to exclude visual and auditory factors and immobilize pelvis. The operator drove the lower limb to a certain position and returned to the initial position. The subject was then allowed to move to the designated position on his/her own and the difference in angle was recorded. The measurements were repeated three times and averaged. Knee function was assessed using the Lysholm score out of 100 with higher scores indicating better knee function. The improvement of knee joint stability was judged by the change of Lysholm score before and after intervention. The international knee documentation committee (IKDC) score reflects the status of knee joint motor function, and the higher the score, the better the knee joint function. The IKDC score was calculated as follows.

IKDC = total score/87 × 100.

3. Balance capacity test

(1) Postural stability test

The indexes of overall stability index (OSI), anterior-posterior index (API), and medial-lateral index (MLI) were tested at the stand position by using a balanced function testing system (Biodex Medical Systems, Inc, Shirley, New York, USA) with an 8-level increasing difficulty level, which reflected the overall degree of offset of the body's center of gravity and the average amplitude of swing in the sagittal and frontal planes, respectively. The lower values represented the better balance [12]. Prior to the start of the test, the subject stood on the test stand with arms crossed. The non-supporting leg bent at the knee and closed together with the calf being raised 90 degrees. During the test, the subject was asked to look at the cursor on the screen and adjust the center of gravity of the body to keep the cursor on the center cross as much as possible. Each test lasted 20 seconds and was repeated 3 times with a 10-second rest interval each time. If balance was lost during the test, the fall was recorded, and the test was repeated. The average of the 3 test records was taken as the result.

(2) Y-balance test

Lower limb length (LL) was measured using soft tape with the subject in a supine position and

Table 1. Comparison of muscle strength before and after treatment.

Muscle group	Intervention	MIE (n = 26)	PFN (n = 26)	*P*
Quadriceps	Before	76.47 ± 10.62	77.51 ± 9.81	0.715
	After	99.48 ± 11.25	103.61 ± 11.51	0.197
Hamstring	Before	51.76 ± 5.84	51.53 ± 6.61	0.894
	After	63.77 ± 6.90	68.31 ± 7.02	0.023

fully extended lower limbs. The measurement was from the anterior superior iliac spine to the medial ankle to the nearest 0.5 cm. Subject was then in standing position with barefoot on an intermediate pedal and pushed the healthy foot to each of the farthest positions of the vernier caliper in anterolateral (A), posteromedial (PM), and posterolateral (PL) directions while maintaining body balance. Each direction was repeated three times, and the maximum value was recorded. The test results in the three directions were standardized as (A ± PM ± PL) / LL × 100. The composite score was the average of this standardization formula [13].

4. Efficacy comparison

The patient's knee discomfort disappeared completely after treatment being defined as recovery, while the swelling and pain of the patient's knee joint were basically improved and had no effect on daily life being defined as significant effect, and the swelling and pain of the patient's knee joint were improved compared with those before treatment, and they were able to take care of themselves or had a slight impact on daily life being defined as effective. The swelling and pain of the patient's knee joint did not improve or worsen compared with before treatment and had a serious impact on daily life and work being defined as invalid.

Statistical analysis

SPSS 25.0 (IBM, Armonk, New York, USA) software was used to statistically analyze and process the obtained data. Measurement data were described as mean ± standard deviation, and differences between groups before and after treatment were analyzed by t-test with *P* value less than 0.05 as statistically significant difference.

Results and discussion

Muscle strength comparison

The results showed that there was no significant difference in the relative peak torque of quadriceps femoris and hamstring muscles between the two groups before treatment. After treatment, the relative peak torque of quadriceps femoris and hamstring muscles in MIE group was 99.48 ± 11.25 N·m and 63.77 ± 6.90 N·m, respectively. The relative peak torque of quadriceps femoris and hamstring muscle in PFN group was 103.61 ± 11.51 N·m and 68.31 ± 7.02 N·m, respectively. There was no significant difference in the relative peak torque of quadriceps femoris between the two groups after treatment, but the relative peak torque of hamstring muscle in PFN group was better than that in MIE group (Table 1). The quadriceps muscle as the main driving force for knee joint extension could effectively enhance its strength in both training groups, indicating that the two training modes had the same strengthening effect on the main driving force muscle of the knee joint. The hamstring muscle played a key role in knee flexion and stability, and the PNF group had significant advantages, which might be due to the fact that PNF technology used a combination of "contraction relaxation" and "contraction relaxation contraction" movements to more fully activate the hamstring muscle fibers, recruit more exercise units, and more efficiently activate the neuromuscular reflex pathway compared to simple multi angle isometric contractions, thereby enhancing

Table 2. Comparison of humeral and knee joint function scores before and after treatment.

Scores	Intervention	MIE (n = 26)	PFN (n = 26)	*P*
Lysholm score	Before	68.82 ± 6.71	69.24 ± 26	0.817
	After	72.51 ± 10.56	78.19 ± 9.32	0.045
"Unstable" score	Before	15.93 ± 4.91	15.59 ± 4.36	0.792
	After	17.31 ± 5.29	20.42 ± 3.95	0.008
IKDC score	Before	73.42 ± 9.45	74.07 ± 9.28	0.805
	After	76.12 ± 10.11	82.75 ± 6.64	0.007

Table 3. Comparison of postural stability scores before and after treatment.

Group	Intervention	MIE (n = 26)	PFN (n = 26)	*P*
OSI	Before	0.48 ± 0.09	0.47 ± 0.80	0.768
	After	0.34 ± 0.04	0.29 ± 0.06	0.002
API	Before	0.36 ± 0.09	0.38 ± 0.09	0.364
	After	0.22 ± 0.03	0.18 ± 0.04	0.006
MLI	Before	0.36 ± 0.90	0.35 ± 0.10	0.599
	After	0.24 ± 0.07	0.18 ± 0.07	0.004

muscle strength [14]. For golfers, enhanced hamstring strength could better coordinate with the quadriceps to stabilize the knee joint, reduce abnormal joint displacement during swing, and lower the risk of injury recurrence.

Comparison of knee function scores

Before intervention, there was no statistically significant difference in Lysholm score, "instability" score, and IKDC score between the two groups, and the knee function of the two groups was basically the same before intervention. After the intervention, the Lysholm score, "instability" score, and IKDC score improved in both groups with the PFN group demonstrating a better effect than MIE group (P <0.05) (Table 2). Lysholm score and IKDC score are core indicators for evaluating knee joint function, directly reflecting joint stability, mobility, and motor function recovery [15]. The PNF group showed a more significant improvement in both scores, indicating a more comprehensive repair of knee joint function, which was because PNF training not only strengthened muscle strength, but also simulated the complex motion trajectory of the knee joint during golf swing through spiral diagonal mode training, enhanced neuromuscular control ability, and enabled athletes to adjust posture more accurately during joint activities, reducing discomfort such as "soft legs" and "joint movements", thereby improving overall function [16, 17]. However, MIE training only focused on isometric contractions at fixed angles, lacking training in joint dynamic control ability, resulting in limited functional improvement.

Balance force comparison

The results showed that, before treatment, the differences in OSI, API, and MLI between the two groups were not statistically significant differences. After treatment, all the indexes of the two groups improved. The PFN group had a better effect on the change of overall stability index than MIE group (P < 0.05) (Table 3). As an effective method to evaluate the dynamic balance of the human body, the Y balance test mainly evaluates the stability of the body posture when the contralateral limb performs tele-extension movements in different directions with unilateral support, and it integrates the body's ability to move in three different planes including sagittal, frontal, and horizontal planes [18]. The Y-balance scores of the subjects in the MIE group were 96.46 ± 5.61, while that in the PFN group were 96.53 ± 6.61 before treatment. There was no significant difference between two groups. However, after treatment, the composite Y-balance score of the subjects in the MIE group was 99.61 ± 5.52 compared to 104.85 ± 5.92 in the PFN group ($P < 0.05$). Balance ability is the key to stable golf swing for golfers, which relies on the coordinated control of proprioception and neuromuscular systems [19]. PNF training used extreme stretching and spiral diagonal movement modes to fully stimulate proprioceptors around joints, improve proprioceptive sensitivity, and enable athletes to quickly perceive body center of gravity shift and adjust muscle contractions in a timely manner to maintain balance [20, 21]. On the other hand, MIE training only focused on muscle strength enhancement and did not specifically train proprioceptive and neuromuscular coordination, so its effectiveness in improving balance ability was not as good as PNF. For golf, good dynamic balance can help athletes stabilize their center of gravity during swing, improve hitting accuracy and distance.

Comparison of therapeutic effects

In the MIE group, 8 people were cured after treatment, while 12 people showed significant effectiveness, and 6 people were effective. In the PFN group, 16 people were cured after treatment, 8 people showed significant effectiveness, and 2 people were effective. There was a significant difference between two groups ($P < 0.05$) (Table 4). The PNF group demonstrated a higher cure rate and overall better therapeutic effect, confirming its comprehensive advantages in improving muscle strength, joint function, and balance ability. Golf requires extremely high dynamic stability and precise neuromuscular control of the knee joint. PNF training integrated strength enhancement, proprioceptive recovery, and coordination training, which met the specific needs of golf and could more comprehensively solve functional impairments after knee joint injuries, helping athletes recover their athletic abilities faster. However, MIE training focused on muscle strength and lacked targeted training for the coordination and balance abilities required for specialized exercises, resulting in relatively limited therapeutic effects.

Table 4. Comparison of curative effects after treatment.

Group	MIE (n = 26)	PFN (n = 26)	*P*
Cure	8	16	0.039
Significant effective	12	8	
Effective	6	2	
Invalid	0	0	

Conclusion

Both MIE and PNF training could improve the joint function of golfers with knee joint injuries, but PNF training has more prominent advantages. By stimulating proprioceptors to activate neuromuscular reflex pathways, strengthening hamstring muscle strength, enhancing knee joint function and balance ability, it was more in line with the need of golf for joint dynamic stability and neuromuscular control and could better help athletes to recover their competitive state. Therefore, golfers could effectively restore knee joint function and improve athletic performance through scientific and reasonable rehabilitation training methods after knee injuries. Meanwhile, these successful rehabilitation cases also provided reference for other athletes. However, the sample size of this study was relatively small, and the research subjects were limited to athletes. The observation period was only 6 weeks, which might not reflect the long-term training effect and delayed adaptive response. Future research should further expand the sample size and explore the optimal rehabilitation training program, providing stronger support for the health and development of golfers.

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