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Article

Effect of rehabilitation training on golf athletes after knee injury

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Abstract: Objective: With the popularity of golf, the problem of athletes' knee injuries has become more and more prominent, which seriously affects their sports career and competitive performance, and it is urgent to explore efficient rehabilitation training methods. This study focuses on the effect of rehabilitation training after knee injury in golf players. **Methods:** A total of 52 active golfers from Beijing Sport University and Beijing University Of Agriculture were selected and randomly divided into MIE group and PNF group, with 26 people in each group. Multi-angle isometric training was implemented in the MIE group, and proprioceptive neuromuscular facilitation technique training was implemented in the PNF group, with consecutive treatments of 6 weeks, 3 times per week. Isometric muscle strength, knee function, balance and treatment effect were detected before and after treatment respectively. **Results:** There was no significant difference between the two groups before treatment ($P > 0.05$). After treatment, the two groups were improved, but there was no significant difference in the relative peak torque of quadriceps femoris between the two groups ($P > 0.05$), but the relative peak torque of hamstring muscle, Lysholm score, "instability" score, IKDC score, OSI, API, MLI and Y balance in PFN group were significantly better than those in MIE group ($P < 0.05$). This shows that both treatment methods are effective, but the treatment effect of PFN group is better. **Conclusion:** the application of multi angle isometric training and proprioceptive neuromuscular stimulation technology in the treatment of snow sports athletes with knee joint injury can improve the knee joint function, which has more advantages and better effect than proprioceptive neuromuscular stimulation technology.

Keywords: golf players; knee joint injury; rehabilitation training

1. Introduction

Because of its unique characteristics, golf has attracted participants from all over the world. Although the development of golf in China is relatively late, and the population base is far less than that of Europe, the United States, Japan and South Korea, the number is on the rise year by year. Traditionally, high intensity sports are prone to injuries, while golf, with no direct physical contact, is often considered to have a very low risk of injury. However, golf is not a simple golf swing, but an 18-hole game in which players have to walk for several kilometers, during which they frequently start, stop, and twist their bodies, and their knees are subjected to impact forces in different directions throughout the game [1]. Each accurate swing, but also the feet rooted, the knee dominant force, from the start of the force, to hit the release of the explosive force of the moment, and then to the closing of the stable brake, the knee joint is the key pivot of the power transmission [2]. Repeating these actions over a long period of time and with high intensity, small traumas continue to accumulate and gradually erode the original tough structure of the knee joint. In professional golf, knee injuries are common [3]. As the most complex structure, the largest joint and the strongest leverage part of the human body, the knee joint is extremely vulnerable to injury in golf [4]. Unstandardized swing action is one of the important causes of knee joint injury. It is specifically manifested in the following two aspects: when backward back to the club, the pelvis rotates to the right, the left knee tibia bears the external rotation force, and the left knee joint increases the external rotation stress when the left foot is subjected to the force on the inside of the left foot. At this time, the knee joint is in an unstable state, and the repeated force changes are likely to damage the knee cartilage and meniscus. When swinging the club, the torso and pelvis rotate to drive the left knee femur external rotation, tibia relative internal rotation, the left foot force is transferred to the outer side, repeated twisting is easy to damage the knee cartilage and meniscus [5]. This repeated twisting action puts great pressure on the knee joint, especially during prolonged golfing, and excessive strain may trigger serious injuries such as ligament tears [6]. Statistics from the United States Golf Association also show that a significant percentage of golfers have suffered sports injuries, with knee injuries being more common [7]. In golf, limited ankle and arch function can have a significant impact on knee stability, which in turn increases the risk of knee injuries [8]. When ankle and arch function are problematic, the athlete’s power delivery during the golf swing becomes incorrect.

Sports injuries have many negative impacts on sports, 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, isotonic muscle training, isometric muscle training [9,10]. It has been shown that the stability of the knee joint is maintained by the neurofeedback mechanism of joint and muscle ligaments [11]. In a study on reconstruction of the anterior cruciate ligament, some scholars concluded that there is a better correlation between the recovery of patients’ proprioception and the recovery of their joint stability, and that the recovery of proprioception is an important factor that cannot be ignored in knee function, and that the training of proprioception and neuromuscular control after knee ligament injury has received more and more attention [12]. Therefore, this study investigates the training effect of PFN rehabilitation training on golfers’ knee injuries, so as to provide scientific basis for golfers’ rehabilitation.

2. Research objects and methods

2.1. Research object

A total of 52 active golfers from Beijing Sport University and Beijing University Of Agriculture, aged 18–26 years old, including 35 male and 17 female athletes, were selected according to the inclusion and exclusion criteria. All subjects were aware of and signed an informed consent form.

2.2. Inclusion and exclusion criteria

Inclusion criteria: (1) golfers; (2) those who have knee injuries due to training or competition and still have residual knee dysfunction; (3) the presence of injuries that lead to a decrease in knee mobility, the presence of a weak leg or joint misalignment sensation, or a change in the range of motion of the knee joint.

Exclusion criteria: (1) those with knee injuries combined with serious complications in other systems or organs; (2) those with a history of lower limb surgery within 6 months prior to participation in the intervention; (3) those with combined cardiovascular, cerebrovascular, hepatic, renal, or serious life-threatening primary diseases; and (4) those who were unwilling to accept the methodology of this study.

2.3. Subjects and grouping

Fifty-two golfers who met the inclusion criteria were randomly and double-blind 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. There was no significant difference between the subjects in terms of gender, age, and years of training, and $P > 0.05$ (**Table 1**).

Table 1. basic information of patients.

Group	***n***	**Male/Female**	**Age**	**BMI**	**Affected side (left/right)**	**Training year**
MIE	26	17/9	22.27 ± 2.25	20.38 ± 1.87	14/12	6.35 ± 1.76
PFN	26	18/8	22.15 ± 2.43	20.53 ± 1.82	13/13	6.40 ± 1.73
X^2	-	0.087	-	-	0.077	-
t	-	-	0.178	-0.284	-	−0.119
p	-	0.768	0.86	0.777	0.781	0.906

2.4. Treatment plan

During the experiment, the subjects followed the routine training plan for daily training. The participants in both groups received rehabilitation treatment for 18 times, 3 times a week for 6 weeks.

The Mie group received multi angle isometric exercise (MIE):

1) Warm up (5 min): perform a 3-minute brisk walk or standing on tiptoe, and then perform simple flexion and extension activities on the knee joint. Repeat the left and right legs for 10 times, so that the knee joint can get preliminary activities and get ready for training.
2) Multi angle isometric training (30 min)

30° knee flexion isometric training: sit on a chair, put your feet flat on the ground, and slowly bend your knees to 30° to maintain this position. Contract the quadriceps femoris at the front of the thigh and the hamstrings at the back, as if to straighten and bend the knee joint but keep the angle unchanged, and feel the muscle tension. Each contraction lasted for 6 s, and then relaxed for 2 s. One group performed 12 contractions, a total of 3 groups, and the rest between groups was 45 s.

60° knee flexion isometric training: adjust the sitting posture, bend the knee joint to 60°, and repeat the above contraction action. Each contraction lasted for 6 s and relaxation lasted for 2 s. Each group had 10 contractions. Three groups were given a rest of 60 s. The training intensity of this angle is slightly higher. Pay attention to maintaining correct posture and avoid using force.

90° knee flexion isometric training: adjust the sitting posture again, so that the knee joint is bent to 90°, contract the quadriceps and hamstring muscles, maintain for 5S and then relax for 2 s. There were 8 contractions in each group, a total of 3 groups, and the rest time was 60 s. Due to the high degree of muscle contraction at this angle, if there is pain or discomfort, stop training and check the posture.

3) Relaxation (5 min): after the training, walk slowly for 2 min, and then stretch the legs. In the supine position, lift one leg straight, hug the back of the thigh with both hands, pull the leg closer to the body, feel the stretching of the front of the thigh, and change the other side after 20 s to help relax the muscles and reduce the risk of muscle pain and injury.

PNF group was treated with proprioceptive neuromuscular facilitation (PNF):

1) Warm up (5 min): walk slowly or jump open and close for 3 min to make the body slightly warm. Carry out simple encircling, flexion and extension activities on the knee joint. Repeat each action for 10 times to move the joint and prevent injury.
2) PNF training subject (30 min)

PNF training of quadriceps femoris: contraction relaxation (CR): the patient lies on his back, and the therapist holds the leg and thigh in one hand, straightening the knee joint to the maximum range and keeping it stretching for 30 s. Then the patient forced the quadriceps femoris to resist the resistance of the therapist for 6 s, then relaxed, repeated 5 times, and rested for 30 s each time. Contraction relaxation contraction (CRAC): on the basis of Cr, the patient immediately contracts the quadriceps femoris again after relaxation. The therapist gives resistance for 6 s, then stretches the knee joint, repeats for 5 times, and rests for 45 s.

Hamstring PNF training: contraction relaxation (CR): the patient lies on his back, the therapist holds the back of his thigh with one hand, and holds his ankle with the other hand, flexing the knee joint to the maximum range and keeping it stretched for 30 s. After that, the patient forced the hamstring muscle to resist resistance for 6 s and then relaxed, repeating for 5 times, resting for 30 s each time. Contraction relaxation contraction (CRAC): exercise the quadriceps of the same thigh for 5 times and rest for 45 s.

PNF spiral diagonal mode training (taking the right knee as an example): D1 flexion mode: the patient is supine, the therapist holds the right ankle with the right hand and the outside of the right knee with the left hand. First passively guide the flexion, adduction and external rotation of the right lower limb for 5 times, and then let the patient actively complete the movement. The therapist gives appropriate resistance, repeats for 8 times, and rests for 60 s.

D1 extension mode: the therapist holds the right ankle with the right hand and the inside of the right knee with the left hand. First passively guide the extension, abduction and internal rotation of the right lower limb for 5 times, and then the patient takes the initiative to do it. The therapist gives resistance and repeats it for 8 times.

3) Relaxation session (5 min): lie down for 2 min and breathe deeply. Perform static stretching on the quadriceps and hamstrings for 20 s to help relieve muscle tension and pain.

2.5. Evaluation scheme and indicators

2.5.1. Isokinetic muscle strength test

In this study, the Biodex System 4 PRO Multi-Joint Isometric Muscle Strength Evaluation Training System manufactured in the United States was used for experimental testing. The test indexes were 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. The test procedure was as follows: firstly, the instrument was calibrated, the subject sat on the seat of the Multi-Joint Isokinetic Strength Evaluation Training System, adjusted the body position and fixed the trunk, and 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.

2.5.2. Knee joint function test

The assessment method was as follows: first, 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. After the subject's pelvis was immobilized, the operator drove the lower limb to a certain position and returned to the initial position, and then the subject was 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 can be judged by the change of Lysholm score before and after intervention.

The IKDC score reflects the status of knee joint motor function, and the higher the score, the better the knee joint function. It is calculated as IKDC = total score/87 × 100.

2.5.3. Balance capacity test

1) Postural Stability Test: The study indexes include Overall Stability Index (OSI), Anterior-Posterior Index (API), and Medial-Lateral Index (MLI), which reflect 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, when the subjects are standing. Lower values represent better balance [12]. The test was conducted using 8 levels of increasing difficulty. 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 close together, and the calf raised 90°. 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 s 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 tests was taken as the final result.

2) Y-balance test [13]: lower limb length (LL) measurement is a part of the Y-balance test. First, the subject was placed in a supine position, lying flat on the test bench, ensuring that the lower limbs were fully extended. Using a soft tape measure, the surveyor measured the subject's lower limb length from the anterior superior iliac spine to the medial ankle to the nearest 0.5 cm. Subsequently, the test was performed with the subject standing barefoot on an intermediate pedal. For each of the three directions: anterolateral, posteromedial and posterolateral, the subject pushed the healthy foot to the farthest position of the vernier caliper while maintaining body balance. Each direction was repeated three times and the maximum value was recorded. Finally, the test results in the three directions were standardized. The standardization formula is: (anterior lateral A ± posterior medial PM ± posterior lateral PL)/Limb Length LL × 100, and the composite score is the average of this standardization formula.

2.5.4. Efficacy comparison

After treatment, the recovery of patients was counted. The patient's knee discomfort disappeared completely, which was defined as recovery; The swelling and pain of the patient's knee joint were basically improved and had no effect on daily life, which was defined as significant effect; 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, which was defined as effective; The swelling and pain of the patient's knee joint did not improve or worsen compared with before treatment, which had a serious impact on daily life and work, and was defined as invalid.

2.6. Statistical methods

SPSS 25.0 software was used to statistically analyze and process the obtained data. Measurement data were described by mean ± standard deviation, and differences between groups before and after treatment were analyzed by t-test; count data were described by n, and differences were analyzed by X^2 test. The difference was statistically significant at $P < 0.05$.

3. Research results

3.1. Muscle strength comparison

The aim of this study was to evaluate the effects of two treatments on the relative peak torque of quadriceps femoris and hamstring muscles. 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. See **Table 2** and **Figure 1** for specific data. 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 significantly better than that in MIE group. This shows that both treatment methods are effective, but the treatment effect of PFN group is better.

Table 2. Comparison of muscle strength before and after treatment.

Group	*n*	Quadriceps		Hamstring	
		Before	After	Before	After
MIE	26	76.47 ± 10.62	99.48 ± 11.25	51.76 ± 5.84	63.77 ± 6.90
PFN	26	77.51 ± 9.81	103.61 ± 11.51	51.53 ± 6.61	68.31 ± 7.02
t	-	−0.367	−1.370	0.133	−2.351
p	-	0.715	0.197	0.894	0.023

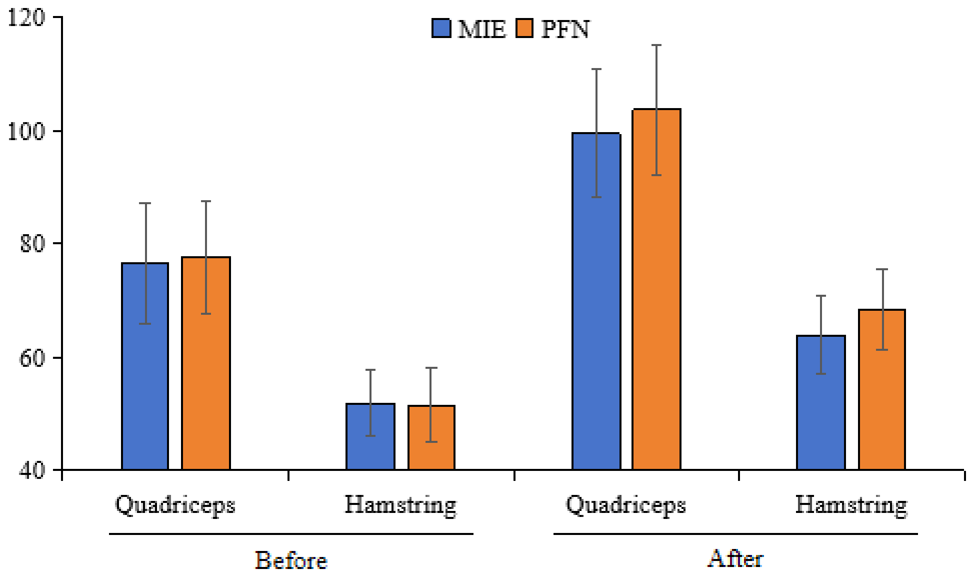

Figure 1. Comparison of muscle strength before and after treatment.

3.2. 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 ($P > 0.05$), and the knee function of the two groups was basically the same before intervention (**Table 3**, **Figure 2**). After the intervention, the Lysholm score, “instability” score and IKDC score improved in both groups, and the PFN group had a better effect, and the difference between the two groups was statistically significant ($P < 0.05$).

Table 3. Comparison of humeral and knee joint function scores before and after treatment.

Group	*n*	Lysholm		“Unstable” score		IKDC	
		Before	After	Before	After	Before	After
MIE	26	68.82 ± 6.71	72.51 ± 10.56	15.93 ± 4.91	17.31 ± 5.29	73.42 ± 9.45	76.12 ± 10.11
PFN	26	69.24 ± 6.26	78.19 ± 9.32	15.59 ± 4.36	20.42 ± 3.95	74.07 ± 9.28	82.75 ± 6.64
t	-	−0.233	−2.058	0.266	−2.777	−0.249	−2.792
p	-	0.817	0.045	0.792	0.008	0.805	0.007

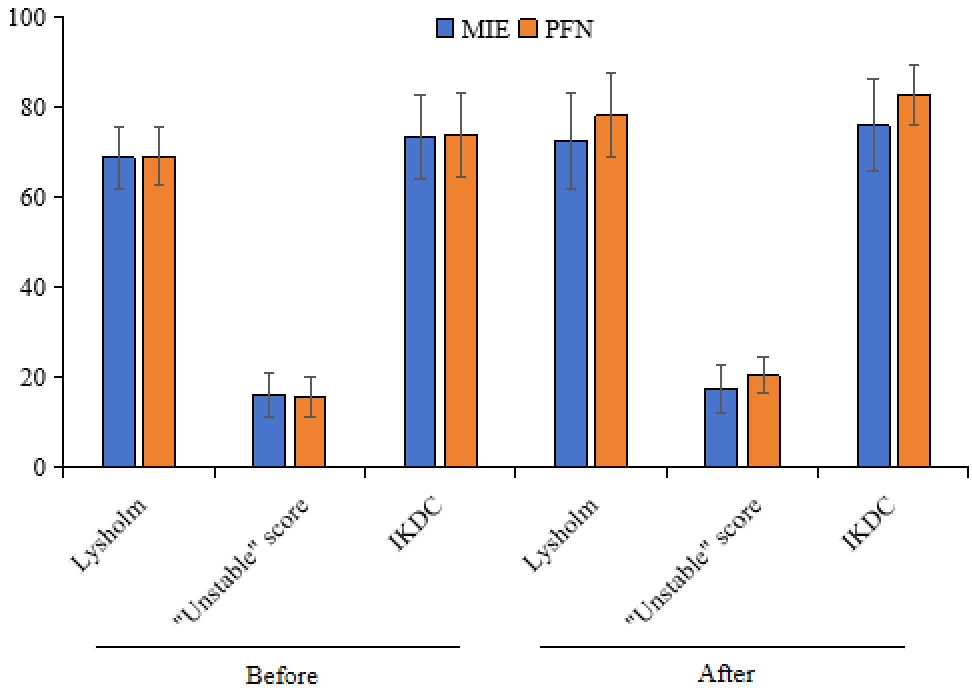

Figure 2. Comparison of humeral and knee joint function scores before and after treatment.

3.3. Balance force comparison

As shown in **Table 4** and **Figure 3**, before treatment, the differences in OSI, API and MLI between the two groups were not statistically significant ($P > 0.05$). After treatment, all the indexes of the two groups improved, and the PFN group had a better effect on the change of overall stability index, and there was no statistical significance between the two groups ($P < 0.05$).

Table 4. Comparison of postural stability scores before and after treatment.

Group	***n***	**OSI**		**API**		**MLI**	
		Before	**After**	**Before**	**After**	**Before**	**After**
MIE	26	0.48 ± 0.09	0.34 ± 0.04	0.36 ± 0.09	0.22 ± 0.03	0.36 ± 0.09	0.24 ± 0.07
PFN	26	0.47 ± 0.08	0.29 ± 0.06	0.38 ± 0.09	0.18 ± 0.04	0.35 ± 0.10	0.18 ± 0.07
t	-	0.296	3.337	-0.916	2.897	0.529	3.060
p	-	0.768	0.002	0.364	0.006	0.599	0.004

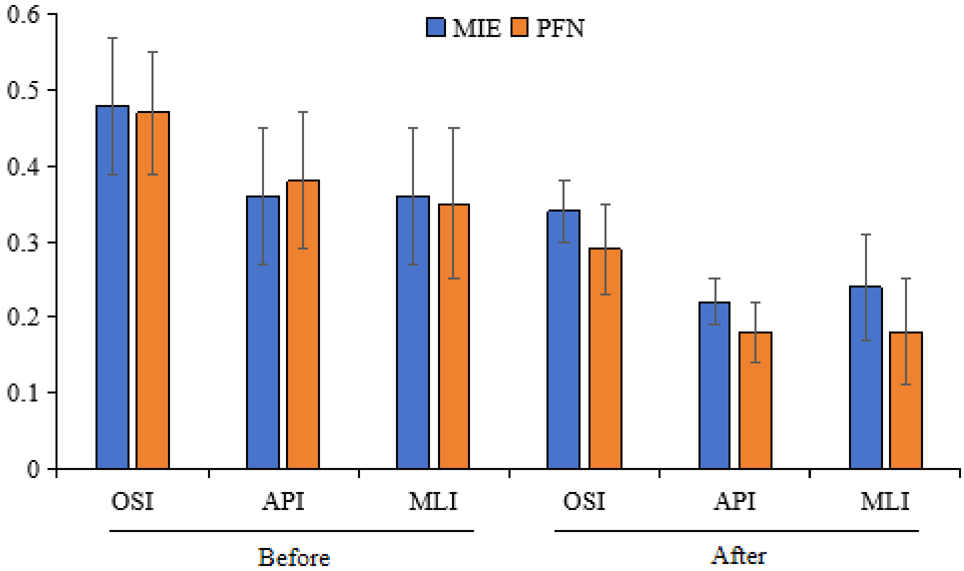

Figure 3. Comparison of postural stability scores before and after treatment.

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: sagittal, frontal, and horizontal planes [14]. As shown in **Table 5** and **Figure 4**, before treatment, the Y-balance scores of the subjects in the MIE group were 96.46 ± 5.61, and the Y-balance scores of the subjects in the PFN group were 96.53 ± 6.61, and the differences between the two groups were not statistically significant ($P > 0.05$). After treatment, the composite Y-balance score of the subjects in the MIE group was 99.61 ± 5.52, and the composite Y-balance score of the subjects in the PFN group was 104.85 ± 5.92, and the scores of the two groups were improved and the difference was significant ($P < 0.05$).

Table 5. Comparison of Y-balance scores before and after treatment.

Group	***n***	**Y-balance**	
		Before	**After**
MIE	26	96.46 ± 5.61	99.61 ± 5.52
PFN	26	96.53 ± 6.61	104.85 ± 5.92
t	-	−0.041	−3.296
p	-	0.968	0.002

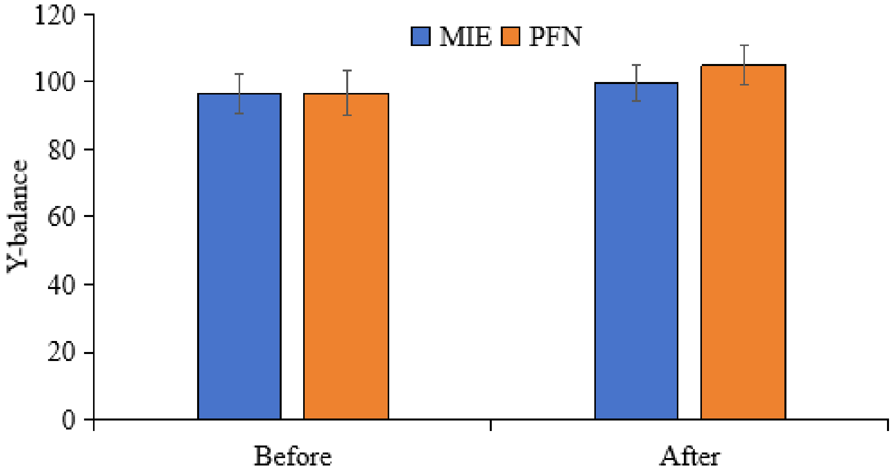

Figure 4. Comparison of Y-balance scores before and after treatment.

3.4. Comparison of therapeutic effects

In the MIE group, 8 people were cured after treatment, 12 people showed effect and 6 people were effective; in the PFN group, 16 people were cured after treatment, 8 people showed effect and 2 people were effective, and the difference between the two groups was significant ($P < 0.05$) (**Table 6**).

Table 6. Comparison of curative effect after treatment.

Group	*n*	Cure	Markedly effective	Effective	Invalid
MIE	26	8	12	6	0
PFN	26	16	8	2	0
t	-	6.489			
p	-	0.039			

4. Discussion

In golf, the knee joint, as the key joint connecting the preceding and the following, frequently flexes, stretches and rotates. Incorrect swinging technique is the first cause of knee injury, and many novice players have uneven stress on the knee joint due to chaotic sequence of force generation and improper transfer of the center of gravity [15,16]. Furthermore, long-term high-frequency swing, knee joint repeated flexion and extension friction, synovial membrane damage, joint cavity effusion, swelling ensues, and develops into synovitis [17,18]. Traditional rehabilitation methods focus on strengthening muscles in isolation, such as multi-angle isometric training [19]. However, golf requires a high degree of joint coordination and dynamic stability, and a single training mode is often difficult to meet the rehabilitation needs [20]. At present, we should explore a comprehensive rehabilitation program that integrates strength, proprioception, balance and coordination to help athletes' knee joint function repair in an all-round way and return to the arena quickly. The results of this study show that there was no significant difference in the detection indexes between the two groups before treatment ($P > 0.05$). After treatment, the detection indexes of the two groups were improved, but the relative peak torque of quadriceps femoris between the two groups was not significant ($P > 0.05$), but the relative peak torque of hamstring muscle, Lysholm score, "instability" score, IKDC score, OSI, API, MLI and Y balance of PFN group were significantly better than Mie group ($P < 0.05$). This shows that the application of multi angle isometric training and proprioceptive neuromuscular stimulation technology in the treatment of snow sports athletes with knee joint injury can improve the knee joint function, which has more advantages and better effect than proprioceptive neuromuscular stimulation technology. This may be because PNF technology can more effectively activate the neuromuscular reflex pathway by stimulating proprioceptors, such as muscle spindle and Golgi tendon organs, so that the muscle can respond to changes in joint position and motion state quickly and accurately, and enhance neuromuscular control ability. It contains contraction relaxation and contraction relaxation contraction combined actions, which can more fully activate muscle fibers and recruit more motor units than simple isometric contraction, so as to increase muscle strength. Moreover, the diagonal spiral motion mode and extreme stretching of PNF can better stimulate the proprioceptors around the joints and improve the proprioceptive acuity. For golfers, precise neuromuscular control and strong muscle strength can make golfers more stable in controlling the club when swinging, improve the hitting distance and accuracy, and flexibly adjust their movements and increase scoring opportunities in the face of complex and changeable course conditions and hitting requirements. In terms of the prevention of sports injuries, the knee joint is vulnerable to torsion and pressure in golf. The knee joint stability and proprioception improved by PNF training can make it more sensitive to abnormal external forces, adjust posture in time, reduce the risk of injury to the anterior cruciate ligament and meniscus, ensure the durability and health of the golfer's career, reduce the suspension of training due to injury and absence from the game, ensure the continuity of training and competition, and help golfers achieve better results and development in golf.

Based on the results of this study, the following are specific suggestions for transforming it into the actual rehabilitation training of golf players: in the early stage of acute injury (1–3 days), first take rice measures, and at the same time carry out painless multi angle isometric exercises, such as isometric contraction at different angles of knee flexion, to maintain muscle tension and joint range of motion. From the subacute stage to the middle stage of rehabilitation (4–14 days), the primary form of PNF stretching and contraction combined training was introduced, combined with balance training, to improve proprioception and stability. In the later stage of rehabilitation (15 days to 6 weeks), increase the difficulty of PNF, carry out spiral diagonal mode training, and combine it with golf special movements to improve the knee function in the actual sports scene. In the long-term rehabilitation, the two kinds of training should be included in the maintenance training plan, 2–3 times a week, the knee joint function should be evaluated regularly, and the training plan should be adjusted according to the results to prevent injury recurrence.

Although this study has achievements, it also has limitations. First, the sample size is small, and only 52 golfers participate, which may lead to large variability in the results and limited statistical effectiveness. Secondly, the selection of research objects is limited to Beijing Sport University and Beijing University Of Agriculture, and the players involved are similar in physical condition and sports level, while the players in special circumstances are not fully included. Moreover, the observation period of the study was 6 weeks, which was relatively short, and could not fully reflect the long-term training effect and potential delayed adaptive response. It is necessary to carry out large-scale, diversified samples and long-term observation research in the future, so as to overcome the shortcomings, deepen the understanding of golf players' knee rehabilitation training methods, provide more reliable basis for them, and promote the research and development in this field.

Ethical approval: Not applicable.

Conflict of interest: The author declares no conflict of interest.

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