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Original Article

Feasibility study of core training in knee injury recovery

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ABSTRACT

Objectives: This study aims to investigate the effects of core and routine training on joint function, anterior tibia translation and balance in patients with knee joint injury.

Patients and methods: Between March 2021 and March 2022, a total of 70 patients (49 males, 21 females; mean age: 31.2±5.3 years; range, 17 to 44 years) with knee ligament injury or meniscus injury were included. The patients were divided into core training group (n=35) and conventional training group (n=35) by matching method. During the recovery process, the regular training group performed routine training, whereas the core training group engaged in core training. Both groups were trained for a total of eight weeks. After training, the Visual Analog Scale (VAS), knee Lysholm score, KT-2000 tibial anterior translation, and the star excursion balance test (SEBT) results were collected.

Results: The mean VAS scores in both groups were decreased from baseline values. The mean Lysholm score increased from baseline data; the degree of tibial anterior translation decreased compared with baseline data ($p<0.05$). The mean SEBT scores showed significant improvement over baseline data. In contrast with the routine training group, the mean VAS score of core training was lower and the total score of Lysholm was higher ($p<0.05$). When bending the knee at 90°, the mean tibial anterior translation was 3.87±1.23 mm in the core training group, significantly lower than in the regular training group ($p<0.05$). The SEBT results showed that, after eight weeks of training, healthy and injured legs in core training group exceeded those of the regular training group in the farthest distance ($p<0.05$).

Conclusion: Our study results indicate that core training is more successful than regular training in reducing pain, and it can ameliorate the dynamic balance stability of patients with knee injury.

Keywords: Core training, injury, knee joint, regular training, rehabilitation.

With the improvement of economic level and the upsurge of national sports, there are more and more sports-related knee injury. Scientific exercise can improve the health level, while unscientific exercise will do harm to the body. Exercise-induced knee joint damage is the most usual sports injuries, among which meniscus injury and anterior cruciate ligament (ACL) injury are the most common.[1,2] After ACL injury, there would be problems such as joint pain, poor stability, and difficulty in natural repair.[3] If reconstruction is not carried out as soon as possible, it would lead to premature degeneration of the knee joint. In addition to pain, the symptoms of meniscus injury can lead to foot locking.[4] The physiological structure of the knee joint is complicated, and besides ligament injury and meniscus injury, cartilage injury and even fracture are easy to occur.[5] Therefore, comprehensive, and accurate diagnosis and timely and reasonable treatment are of great value to the recovery of joint function after knee joint injury.

Currently, conservative treatment is usually selected for mild ACL injury or meniscus injury in clinic. For severe injuries, active surgery is necessary. Research displays that training plays an crucial part in the prevention and rehabilitation of knee joint damage, particularly in the later rehabilitation of knee joint injury.[6-8] The core usually refers to the trunk of the human body, including the spine, pelvis, and its surrounding muscle groups. The core is a whole consisting of waist, pelvis, and hip joint.[9] It includes

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the muscles of the back and abdomen, and all the muscles that make up the pelvis.[10] The function of the muscles is to balance and stabilize the human body. Core strength training improves muscle efficiency and body balance in the distal extremities of the shoulders, arms, and legs.[11] The completion of many sports needs core stability, such as running and tennis. Core strength and stability are conductive to improve muscle coordination, on the one hand, it can improve the strength level during exercise, on the other hand, it can reduce joint load and achieve the purpose of preventing injury.[12] During rehabilitation period, core exercises has been proved to effectively reduce the incidence of low back pain and improve the efficiency of the soft tissue sensation involved in joint stability.[13] In recent years, most studies have focused on the influence of core training on the stability of the spine and other aspects. Hlaing et al.[14] reported that core training could increase the accuracy of sensory integration processes and maintain spinal stability in patients with low back pain. Another effect of core training on basketball players is that core training can improve the stability of an athlete's core areas such as the spine and pelvis.[15] However, there are relatively few studies on the efficacy of core training on lower limbs.

In the present study, we aimed to evaluate the clinical value of two rehabilitation programs (conventional rehabilitation training and core training) for lower limb functional rehabilitation in patients with knee injury and to compare the differences between the two group before and after training.

PATIENTS AND METHODS

Study design and study population

This study was conducted at Peking University Third Hospital Qinhuangdao Hospital, Department of Orthopedics, between March 2021 and March 2022. A total of 70 patients (49 males, 21 females; mean age: 31.2±5.3 years; range, 17 to 44 years) with knee ligament injury or meniscus injury meeting the inclusion criteria were recruited. The history of knee joint varied between one and five years. In order to ensure the consistency of injury type and degree, all patients were divided into core training group (n=35) and conventional training group (n=35) by pairing method. Inclusion criteria were as follows: *(i)* having knee ligament injury or unilateral meniscus injury with clear clinical symptoms and pathological changes. At the same time, the patients met the diagnostic criteria of knee ligament injury or meniscus I-II injury; *(ii)* not having acute stage of injury; *(iii)* having no other joint injuries, and stable condition and being willing to undergo rehabilitation treatment. Exclusion criteria were as follows: *(i)* acute stage injury; *(ii)* accompanied by other joint injuries; *(iii)* suffering from malignant tumor, infectious disease, mental illness; *(iv)* referred or radiative pain in the knee due to lumbar or hip lesions; *(v)* previous knee surgery history, lumbar surgery history. A written informed consent was obtained from each patient. The study protocol was approved by the Peking University Third Hospital Qinhuangdao Hospital Ethics Committee (date: 10.05.2020, no: 2020006). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Rehabilitation program

All patients underwent rehabilitation training for two months after receiving routine treatment in the hospital. Routine treatment is non-surgical, including physical therapy and drug therapy as follows: *(i)* local hot compresses promote blood circulation to the knee area, which can gradually subside inflammation and reduce joint swelling; *(ii)* non-steroidal anti-inflammatory drugs (NSAIDs) taken orally can reduce inflammation and pain and help with recovery; *(iii)* Knee joint fixation support, if necessary. The movements of rehabilitation training are guided by rehabilitation trainers, and after the patients has mastered the essentials of the movement, it is independently carried out under the supervision of rehabilitation specialists.

Conventional training group: The protocol includes quadriceps and hamstring muscle isometric contraction, ankle joint extension and flexion training (Week 1 after treatment). Under the protection of the knee brace (Week 2), static semi-squats are performed within 45° combined with quadriceps strengthening exercises, including going up and down stairs, and strength cycling. Then, passive or active knee flexion to 30°, 90°, 120° (Week 4) is initated with low-intensity exercise, mainly striding and jogging (Week 6), followed by high-intensity exercises, such as kicking a ball or skipping rope (Week 8).

Core training group: Patients in this group need to increase core muscle training on the basis of conventional training. The details are as follows: *(i)* The patient is in prone position, with his/her arms straight forward and his/her legs straight back. While inhaling, lift your arms and legs off the ground at the same time, keep them for 5 sec, then exhale slowly and return to the original position; *(ii)* the patient is in supine position, with his/her body close to the ground and his/her arms flat on his/her sides. Bend the knees 30°, lift the hip joint forcibly, keep it for 5 sec, and slowly relax and put down the hip joint; *(iii)* the patient is in the lateral position, with arms naturally placed on the chest and lower limbs extended. The patient slowly lifts the upper and lower limbs with the knee joint extended and, then, slowly recover to the original position after holding for 5 sec. Repeat each of the above movements six times, once a day.

Observation and evaluation

1. Joint pain degree: the intensity of joint pain was appraised using the Visual Analog Scale (VAS) score, which is a subjective evaluation index to measure the pain intensity. The higher the score, the greater the pain intensity.

2. Knee joint function: knee joint function was evaluated by Lysholm scale. Lysholm score, proposed by Lysholm and Gillqui[16,17] in 1985, is a condition specific score for evaluating knee ligament injury and has been widely used in a variety of other diseases, such as meniscus injury, cartilage degeneration or degeneration. In this study, the Chinese version of the Lysholm scale was performed to score the knee function of the patients. Several studies have shown that the Chinese version of Lysholm score has a good reliability and validity in assessing knee function.[18,19] Lysholm scale score is 100 points in total. A total score of less than 70 indicates that knee function has been impaired. The higher the score, the better the recovery of knee joint function.

3. Anterior tibia translation of knee joint: KT-2000 joint measuring instrument is used to evaluate the degree of tibia anterior translation of knee joint and quantify the degree of joint relaxation. With the help of a measuring instrument, the forward movement of the tibia was measured by applying 20 lb of tension when knee flexion was 30°.

4. Dynamic balance ability: the star excursion balance test (SEBT) was chosen to estimate the dynamic balance ability of the patient based on the published literature.[20] It has eight directions, and each direction is 45° apart. These directions are anterior (ANT), anterolateral (ALAT), lateral,[21] posterolateral (PLAT), posterior (POST), posteromedial (PMED), medial (MED), and anteromedial (AMED).[22] During the test, the patient stands on one leg at the origin, keeps his/her body upright, and places his/her hands on the hip position. For the directions of PMED, MED and AMED, the patient should use his/her left foot for support and right foot to touch the marker line; foe the direction of PLAT, LAT, ALAT, the patient should use his/her right foot for support and left foot to touch the marker line; take the left and right feet for support twice in directions ANT and POST (Figure 1). If the patient is unable to retract the lower limb while maintaining balance, or if his/her standing foot is removed from its original position, it would be marked as a failure. The patient's arrival distance in each direction would be recorded and analyzed by the same researcher. All patients are tested barefoot.

Statistical analysis

Power analysis and sample size calculation were performed using the PASS software version 11.0 (NCSS, LLC. Kaysville, Utah, USA). Accordingly, at least 32 individuals in each group were required on the basis of a 95% confidence interval (α=0.05, two-sided) and 90% test power (β=0.1), and at least 35 individuals should be included in each group assuming a 10% dropout rate.

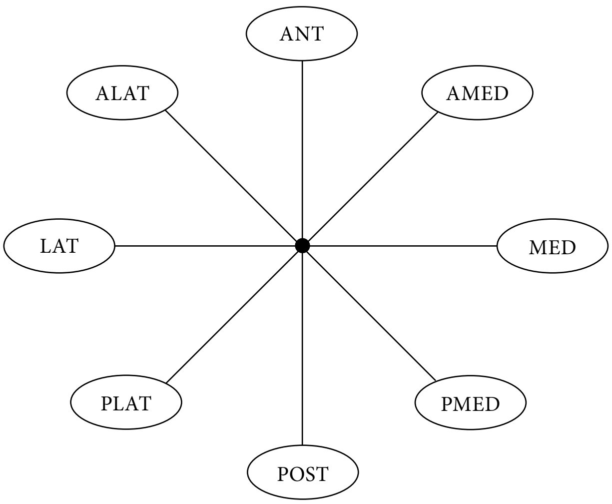

Figure 1. A schematic of the star excursion balance test (SEBT).

ANT: Anterior; ALAT: Anterolateral; LAT: Lateral; PLAT: Posterolateral; POST: Posterior; PMED: Posteromedial; MED: Medial; AMED: Anteromedial.

TABLE 1
Comparison of clinical data of patients

	Regular training group (n=35)		Core training group (n=35)		
Characteristics	n	Mean±SD	n	Mean±SD	*p*
Age (year)		31.6±5.2		30.7±5.4	0.268
Sex					0.454
Male	24		25		
Female	11		10		
Body mass index (kg/m²)		23.67±2.62		24.18±2.55	0.197
Cause of injury					0.533
Ball sports	18		16		
Heavy objects	10		11		
Falling accidents	5		6		
Others	2		2		

SD: Standard deviation.

Statistical analysis was performed using the IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA). Whether the data confirmed to the normal distribution was checked using the Kolmogorov-Smirnov test. Continuous data were expressed in mean ± standard deviation (SD) or median (min-max), while categorical data were expressed in number and frequency. The quantitative data were compared using the independent sample t-test, while the chi-square test was used for qualitative data comparison. The paired t-test was performed for comparison before and after treatment. A *p* value of <0.05 was considered statistically significant.

TABLE 2
Comparison of VAS scores under different training methods

	Baseline	8 weeks	
Groups	Mean±SD	Mean±SD	*p*
Regular training (n=35)	4.53±1.04	3.26±0.85	<0.001
Core training (n=35)	4.61±1.18	2.38±0.41	<0.001
p	0.177	<0.001	

	Difference between after intervention and baseline data
Groups	Mean±SD
Regular training (n=35)	1.11±1.17
Core training (n=35)	2.25±1.14
p	<0.001

VAS: Visual Analog Scale; SD: Standard deviation.

RESULTS

Baseline data of patients

According to the matching method, all patients were grouped into the conventional training group and the core training group. There was no significant difference in age, sex ratio, body mass index (BMI), and cause of injury between the two groups, which was comparable and ensured the feasibility of the experiment (p>0.05) (Table 1).

Comparison of VAS pain scores between the groups

Table 2 shows that, for both groups, the mean VAS scores after eight weeks of training were lower than baseline, indicating that exercise training could effectively relieve and reduce knee pain (p<0.001). In addition, the VAS score of the core training group after eight weeks of training was significantly lower than that of the conventional training group (p<0.001), indicating that the pain relief effect of core training was greater than that of the conventional training. Table 2 shows the difference between baseline data and post-intervention data of the two groups after receiving exercise intervention, and the results demonstrated that the difference of core training group was markedly higher than that of the regular training group (p<0.001).

Comparison of knee function between two groups of patients

In Table 3, no significant difference was observed in baseline Lysholm scores and total scores between the two groups at the time of enrollment (p>0.05).

TABLE 3
Baseline and Week 8 knee function in both groups

Joint function		Regular training group (n=35) Mean±SD	Core training group (n=35) Mean±SD	*p*
Pain	Baseline	14.14±3.93	14.28±3.67	0.875
	Week 8	20.14±3.09	22.14±2.51	0.004
	p	<0.001	<0.001	
Limp	Baseline	2.71±1.40	2.80±0.93	0.765
	Week 8	4.54±0.76	4.82±0.57	0.103
	p	<0.001	<0.001	
Instability	Baseline	12.71±4.08	12.67±4.23	0.796
	Week 8	19.43±4.16	20.57±3.79	0.234
	p	<0.001	<0.001	
Locking	Baseline	12.14±2.51	12.28±2.53	0.813
	Week 8	14.57±1.42	14.71±1.18	0.648
	p	<0.001	<0.001	
Stairs	Baseline	6.46±1.61	6.45±1.88	0.915
	Week 8	9.11±1.63	9.62±1.60	0.042
	p	<0.001	<0.001	
Squatting	Baseline	3.71±0.83	3.77±0.77	0.765
	Week 8	4.23±0.57	4.51±0.51	0.049
	p	<0.001	<0.001	
Support	Baseline	3.40±1.61	3.34±1.68	0.886
	Week 8	4.31±1.28	4.49±1.15	0.557
	p	<0.001	<0.001	
Swollen	Baseline	6.23±1.93	6.29±1.95	0.902
	Week 8	9.09±1.96	9.54±1.29	0.253
	p	<0.001	<0.001	
Total points	Baseline	61.51±7.27	61.94±7.62	0.810
	Week 8	85.37±5.09	90.46±5.64	0.001
	p	<0.001	<0.001	

SD: Standard deviation.

After eight weeks of rehabilitation training, the scores of the regular training group and the core training group were markedly higher than their baseline scores ($p<0.001$), indicating that the knee joint function of the patients recovered effectively after rehabilitation training. After training for eight weeks, the total score in the core training group was increased compared with the regular training group, and the scores of pain, climbing stairs and squatting were also higher than that of the regular training group ($p<0.05$), suggesting that the core training helped the recovery of knee joint function than the regular training. In addition, the comparison of the score difference between the two groups before and after exercise intervention showed that the difference of total score and pain score in the core training group was higher than that in the regular training group ($p<0.05$) (Table 4).

Comparison of anterior tibia translation of knee joint

As shown in Table 5, no statistically significant difference was found in baseline anterolateral tibia translation between the two groups when knees were flexed by 30° and 90° ($p>0.05$). At 30° of knee flexion, the anterior tibia of the two groups were significantly

TABLE 4
Comparison of differences in scores between the groups before and after intervention

Items	Groups	Difference between after intervention and baseline data Mean±SD	*p*
Pain	Regular training	6.00±3.80	0.042
	Core training	7.86±3.69	
Limp	Regular training	1.83±1.24	0.419
	Core training	2.03±0.75	
Instability	Regular training	6.71±3.62	0.051
	Core training	7.85±3.87	
Locking	Regular training	2.29±2.53	0.638
	Core training	2.57±2.52	
Stairs	Regular training	2.86±1.83	0.805
	Core training	2.97±2.02	
Squatting	Regular training	0.51±0.81	0.322
	Core training	0.72±0.85	
Support	Regular training	0.91±2.09	0.596
	Core training	1.14±1.44	
Swollen	Regular training	2.86±2.07	0.445
	Core training	3.26±2.28	
Total points	Regular training	24.25±6.97	0.032
	Core training	28.14±7.88	

SD: Standard deviation.

TABLE 5
Comparison of tibial anterior translation of injured knee joint under different flexion degrees

Flexion degree		Regular training (n=35) Mean±SD	Core training (n=35) Mean±SD	*p*
30°	Baseline	11.15±1.78	11.22±1.85	0.630
	8-week	3.76±1.18	3.61±1.12	0.051
	p	<0.001	<0.001	
	Difference	7.17±2.14	7.69±2.45	0.370
90°	Baseline	11.83±1.78	11.92±1.80	0.356
	8-week	4.46±1.08	3.87±1.23	0.016
	p	<0.001	<0.001	
	Difference	7.53±2.28	8.79±2.14	0.036

SD: Standard deviation; Data are presented in millimeter (mm). The “difference” represents the difference between baseline data in each group and data of Week 8 after the intervention.

lower than their baseline eight weeks after training. However, no statistically significant difference was captured between the regular and core training groups after eight weeks of training. In addition, the result of 90° bending was similar to that of 30° bending, except that the core training group had significantly less tibial anterior translation after eight weeks of training than that of the regular training group ($p<0.05$), suggesting that core training had a more favorable effect on improving tibial anterior translation. Furthermore,

TABLE 6
Comparison of SEBT test results of injured leg and healthy leg after training between the groups

		Injured leg			Healthy leg		
		Baseline	8-week		Baseline	8-week	
Locations	Groups	Mean±SD	Mean±SD	*p*	Mean±SD	Mean±SD	*p*
ANT	Regular training	63.59±7.62	77.86±7.25	<0.001	76.52±5.61	87.37±8.25	<0.001
	Core training	64.25±7.14	82.25±7.13	<0.001	77.13±5.32	92.59±7.14	<0.001
	p	0.532	0.009		0.783	0.011	
ALAT	Regular training	59.89±6.33	76.59±8.32	<0.001	68.21±6.02	84.38±10.38	<0.001
	Core training	61.46±5.19	85.13±7.61	<0.001	68.74±5.98	88.15±7.26	<0.001
	p	0.496	0.003		0.850	0.057	
LAT	Regular training	51.39±5.78	60.36±8.09	<0.001	59.78±5.59	70.13±6.75	<0.001
	Core training	52.07±5.66	66.79±7.44	<0.001	59.97±5.72	72.28±7.16	<0.001
	p	0.957	0.017		0.875	0.256	
PLAT	Regular training	70.07±5.12	80.82±7.89	<0.001	72.64±4.75	84.25±9.37	<0.001
	Core training	69.74±5.81	84.77±7.38	<0.001	73.79±5.01	89.87±9.24	<0.001
	p	0.764	0.027		0.376	0.010	
POST	Regular training	72.03±8.14	79.48±9.13	<0.001	81.36±10.23	92.18±8.99	<0.001
	Core training	71.90±7.89	80.26±7.49	<0.001	80.90±11.15	93.65±9.14	<0.001
	p	0.651	0.293		0.179	0.223	
PMED	Regular training	75.44±6.33	82.58±7.81	<0.001	83.62±7.59	86.37±7.90	0.013
	Core training	75.18±6.70	85.56±8.89	<0.001	81.77±8.93	90.26±8.03	<0.001
	p	0.895	0.076		0.335	0.012	
MED	Regular training	69.58±7.04	78.15±6.88	<0.001	77.83±6.72	85.86±5.69	<0.001
	Core training	70.75±7.11	85.47±7.46	<0.001	78.32±7.11	88.36±6.78	<0.001
	p	0.765	0.002		0.891	0.138	
AMED	Regular training	68.83±5.54	75.76±7.58	<0.001	72.55±5.08	82.48±7.71	<0.001
	Core training	66.82±6.37	83.19±8.26	<0.001	72.16±5.45	87.92±8.03	<0.001
	p	0.129	<0.001		0.708	0.008	

SEBT: Star excursion balance test; SD: Standard deviation; ANT: Anterior; ALAT: Anterolateral; LAT: Lateral; PLAT: Posterolateral; POST: Posterior; PMED: Posteromedial; MED: Medial; AMED: Anteromedial; Data are presented in centimeter (cm).

a comparison of the score difference between the two groups before and after training showed that the score difference of the core training group was greater than that of the regular training group at 90° knee flexion ($p<0.05$) (Table 5).

Comparison of the ability to balance

In Table 6, after training for eight weeks, SEBT showed that the maximum distance between injured and healthy legs was higher than their baseline data in both the regular and core training groups ($p<0.05$). For the injured leg, the farthest distance achieved by the core training group in ANT, ALAT, LAT, PLAT, MED, and AMED was greater than that of the regular training group ($p<0.05$), while for the healthy leg, the farthest distance of core training group in ANT, PLAT, PMED, and AMED was greater than that of the regular training group ($p<0.05$). Table 7 shows that for injured leg, the score difference before and after training in the core training group was higher than that in the regular training group (ALAT, LAT, MED, and AMED). For healthy leg, the score difference of the core training group was significantly higher than that of the conventional training group (ANT, PLAT, PMED, and AMED).

DISCUSSION

As the most complex, load-bearing and unstable flexion-extension joint in the whole body, the knee

TABLE 7
Comparison of score difference between the groups before and after intervention

		Difference between after intervention and baseline data			
		Injured leg		Healthy leg	
Items	Groups	Mean±SD	*p*	Mean±SD	*p*
ANT	Regular training	12.36±7.99	0.051	9.78±7.24	0.003
	Core training	17.89±8.03		14.93±7.76	
ALAT	Regular training	15.27±8.12	0.001	15.58±9.26	0.079
	Core training	23.56±6.76		16.76±7.99	
LAT	Regular training	8.28±7.12	0.009	9.29±7.31	0.126
	Core training	14.18±6.56		11.58±7.64	
PLAT	Regular training	10.51±5.79	0.170	10.53±8.12	0.011
	Core training	14.68±6.36		15.69±8.01	
POST	Regular training	6.59±8.28	0.202	10.15±9.31	0.453
	Core training	7.83±7.59		11.54±10.37	
PMED	Regular training	6.76±6.81	0.055	2.03±3.36	<0.001
	Core training	9.17±8.03		7.34±7.07	
MED	Regular training	7.89±6.25	0.001	7.69±6.87	0.249
	Core training	14.02±8.16		9.54±7.29	
AMED	Regular training	6.54±5.36	<0.001	9.10±6.73	<0.001
	Core training	15.57±8.29		15.05±7.18	

SD: Standard deviation; ANT: Anterior; ALAT: Anterolateral; LAT: Lateral; PLAT: Posterolateral; POST: Posterior; PMED: Posteromedial; MED: Medial; AMED: Anteromedial. Data are presented in centimeter (cm).

joint has always been one of the vital joints in human body.[23] Knee joint injury is a type of common multiple injury, which has a high impact on quality of life of individuals. Currently, the treatment of knee joint injury includes conservative treatment, surgical treatment, and rehabilitation treatment.[24] Systematic exercise rehabilitation after routine treatment can not only nourish articular cartilage and relieve pain, but also accelerate the recovery of the joint function. Therefore, rehabilitation therapy is also of great significance in the recovery from knee injury. According to the characteristics of patients with ligament or meniscus injury, rehabilitation requirements and other factors, combined with the opinions and suggestions of experts in related fields, this study formulated a core exercise rehabilitation program to gradually increase the load of knee joint, which is conductive to improve the participation of patients. In this study, the results showed that patients who received core training had lower VAS pain scores and higher knee functional Lysholm scores compared to patients who received regular training. Furthermore, the study also found that when the knee was bent at 90°, the tibia in the core training group moved forward less than that in the regular training group. Also, the ability of balance and stability in the core training group was higher than that of the regular training group.

When the foot falls to the ground, the knee joint is in a state of flexion. At this time, the stability of the knee joint is mainly maintained by the patella and the quadriceps femoris, and the tensile tension and extrusion pressure between the articular surface are large, which often leads to ligament relaxation and joint stability decline.[25,26] For the recovery of knee injury, it is of utmost importance to consolidate the biomechanical balance of knee effectively. From the point of view of biomechanical balance, the muscle group that affects the balance stability of the knee joint is not only the quadriceps muscle, but also the hamstring muscle, the calf triceps muscle, and the hip abductor muscle.[27] Studies have shown that strengthening the calf triceps can improve knee stability and relieve joint pain.[28] Harikesavan et al.[29] found, in a randomized trial, that intensive training of the hip abductor muscle had a positive effect on the recovery of knee function in patients undergoing total knee replacement. The main goal of core training refers to improving the strength of muscle groups in the spine-pelvis-hip joint area through training, and to play the role of force transmission and coordination of the four limbs, which plays a crucial part in increasing the balance and stability of the trunk and enhancing the power transmission of upper and lower limbs.[30] There is currently evidence that decreased core stability may increase the risk of joint injury.[31] The research showed that muscle strength, muscle relaxation and core stability of knee joint affected the balance function of unilateral lower limb posture, while controlling the core strength of the trunk could reduce the abnormal lower limb mechanical performance and posture swing, which is an independent factor for improving knee joint stability.[32] As reported by Saki et al.,[33] core stabilization training could reduce knee valgus and increase knee flexion by increasing core strength, helping to reduce the risk of ACL reinjury in athletes. In this study, knee pain scores of patients after core training were lower than those in the regular training group, possibly since core training enhanced the strength of the quadriceps femoris, increased the traction stability of the quadriceps femoris to the knee joint, and further reduced the sense of pain.[34]

After knee joint injury, the reduction of activity may lead to systemic muscle apraxia atrophy and core muscle stability disorder, thereby changing the stress distribution of the knee joint and aggravating the instability of the joint, and the instability of the knee joint would inevitably increase the degree of joint disease.[35,36] Therefore, the rehabilitation plan for knee joint disease should include core training. Some authors found that, after six weeks of core muscle stabilization exercises in patients with knee arthritis, joint pain was reduced and knee function was significantly improved.[37] In this study, the local function of knee joint was estimated by the Lysholm score. Our study showed that the core training group was superior to the regular training group in relieving pain, climbing stairs, limiting squat and total scores. Core strength and core stability have important influence on the function of knee joint. The stability of the knee joint refers to the ability of the knee joint to keep the predetermined trajectory even after internal or external interference.[38] The maintenance of this ability depends on the proper motor response and accurate sensory input in order to cope with the rapid changes of the trunk movement. Zazulak et al.[39] divided 35 female athletes into core training group and control group for single-leg jump test, and they found that athletes could achieve higher single-leg jump performance after core training, which may be related to the improvement of spinal cord and pelvic stability through core training. Regarding balance disorders, many literatures have reported that core muscle training can improve trunk muscle function and some balance tests. For instance, patients with multiple sclerosis experience a significant improvement in their dynamic and static balance after core muscle training.[40] The SEBT is an objective dynamic postural control test that tests the ultimate extension of human lower limbs. It is often used to detect and evaluate the dynamic postural control ability of patients, and requires single leg support to complete the closed chain movement to evaluate the dynamic balance ability of patients.[41] In this study, the dynamic postural balance control of patients was assessed by SEBT, and we found that for healthy legs, the extension distance increased after core training in four of the eight directions. For the injured leg, the core training group stretched longer in six directions than the regular training group. These results showed that it is not only beneficial to the recovery of the injured knee joint, but also the overall balance ability of the uninjured knee joint after core training was obviously greater than that of the regular training group.

Nonetheless, there are some limitations to this study. First, the sample size of this study is limited, all from the same hospital, and it fails to include more patients from other regions or hospitals. Therefore, there may be bias in data results, which is not conducive to the promotion of research results. Second, the study intervention was concentrated in the hospital and lacked follow-up evaluation; thus, the long-term effect of exercise intervention remains to be verified. Third, this study lacked objective clinical outcome measures, such as knee range of motion and muscle strength. Therefore, in future studies, we still need to carry out multi-center large-sample studies to evaluate the impact of core movement on knee functional recovery.

In conclusion, core training can improve joint injury rehabilitation by strengthening the spine, pelvis, and muscle groups to improve joint pain, improve knee joint function and enhance dynamic balance stability. Our study results suggest that for clinical rehabilitation workers, appropriate increase of core training can promote the recovery of physical functions in the rehabilitation stage of patients with knee injury, indicating that the core training is more conducive to the recovery of knee function than the regular training.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Carried out the concepts, design and definition of intellectual content: Y.W., S.Y.H.; Provided assistance for data acquisition, data analysis and statistical analysis: H.L., S.H.W., B.Y., D.S.; Revised the manuscript critically for important intellectual content: S.Y.H. All authors performed the experiment, and draft of the manuscript. All authors have read and approved the content of the manuscript.

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