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The efficacy of 5 rehabilitation treatments after anterior cruciate ligament reconstruction
A network meta-analysis

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Abstract

Background: The efficacy of traditional rehabilitation, proprioceptive training, and neuromuscular training after anterior cruciate ligament (ACL) reconstruction is also controversial. In order to help medical staff better choose the rehabilitation treatment plan after ACL reconstruction, we conducted this network meta-analysis.

Methods: Chinese and English databases such as Wanfang, Weipu, China Zhiwang, and PubMed, Cochrane Library, Embase were retrieved. We collected clinical controlled trial papers on traditional rehabilitation therapy, proprioceptive training and neuromuscular training after ACL reconstruction for meta-analysis.

Results: In this meta-analysis, 12 studies were included, including 486 patients who received rehabilitation treatment after ACL reconstruction. Based on network meta-analysis, it was found that 4 groups of direct comparison and 6 groups of indirect comparison were formed for 5 rehabilitation treatment schemes after ACL reconstruction. The curative effect of traditional rehabilitation training combined with proprioception training is better than that of traditional rehabilitation training (mean difference value of traditional rehabilitation training combined with proprioception training vs traditional rehabilitation training was 8.00, 95% confidence interval: 2.61,13.39). The efficacy of proprioceptive training is better than that of traditional rehabilitation training (mean difference value of proprioceptive training vs traditional rehabilitation training is 11.01, 95% confidence interval: 0.62,21.39). There was no statistical significance between the other rehabilitation trainings. According to the surface under cumulative ranking curve, the therapeutic effects of the 5 rehabilitation treatment programs after ACL reconstruction were ranked as follows: proprioceptive training (72%) > traditional rehabilitation training combined with neuromuscular training (70.8%) > traditional rehabilitation training combined with proprioception training (57.1%) > neuromuscular training (45.5%) > traditional rehabilitation training (4.6%). No publication bias was found in the funnel plot.

Conclusion: Combined with the results of meta-analysis and surface under cumulative ranking efficacy sequence diagram, it can be seen that traditional rehabilitation training combined with proprioceptive training and traditional rehabilitation training combined with neuromuscular training have significant efficacy. Due to the limitations of this study, the conclusions of this network meta-analysis still need to be further confirmed by a large sample size and well-designed randomized controlled trials.

Abbreviations: ACL = anterior cruciate ligament, CI = confidence interval, LKS = Lysholm knee score, MD = mean difference, SUCRA = surface under cumulative ranking.

Keywords: anterior cruciate ligament, meta-analysis, neuromuscular training, proprioceptive training

1. Background

Anterior cruciate ligament (ACL) is the important stable structure of the knee joint and plays an important role in maintaining the normal movement of the tibial femoral joint. ACL is an important static stable structure in the knee joint.[1] Once the ACL is broken, it will cause instability of the knee joint and progressive aggravation of internal disorders such as secondary meniscus, articular cartilage damage and changes in the joint chamber, which will affect daily work and life.[2] Surgical reconstruction is the fundamental treatment.[3] The immobilization of knee joint after ACL reconstruction results in muscle atrophy and limited range of motion of the joint. Therefore, rehabilitation treatment is a decisive factor for the functional recovery of knee joint.[4] The implementation of a scientific and systematic postoperative rehabilitation plan plays an important role in the success of the operation, the joint function of the patient, the recovery of life ability and the stability of psychological state.[5]

At present, the rehabilitation methods after ACL reconstruction are mainly divided into 2 categories: modern rehabilitation and traditional rehabilitation. Proprioception training and neuromuscular training are commonly used in modern rehabilitation techniques. Although the rehabilitation treatment after ACL reconstruction is widely used at present, there is no unified rehabilitation treatment plan after ACL reconstruction. The efficacy of traditional rehabilitation, proprioceptive training, and neuromuscular training after ACL reconstruction is also controversial. In order to help medical staff better choose the rehabilitation treatment plans after ACL reconstruction, we conducted this network meta-analysis, hoping that our research results can provide evidence-based medicine evidence for clinicians in clinical work.

2. Methods

2.1. Search strategy

Search Chinese and English databases such as Wanfang, Weipu, Chinese national knowledge infrastructure, PubMed, Cochrane Library, Embase, etc. The publication time of papers is set to be from the establishment of the databases to August 2020. Keywords retrieved were "Anterior Cruciate Ligament", "Anterior Cruciate Ligament Reconstruction", "Proprioceptive Training", "Neuromuscular training".

2.2. Study selection
2.2.1. Inclusive criteria. The study was designed as a clinical control trial in the treatment of the ACL reconstruction with any 2 or more of the 3 rehabilitation treatment schemes, namely traditional rehabilitation treatment scheme, proprioceptive training, and neuromuscular training; The subjects were patients undergoing rehabilitation treatment after ACL reconstruction; The studies were evaluated by the Lysholm knee score (LKS) in patients. LKS is a questionnaire evaluation scale, which evaluates the function of patients from 8 items including claudication, support, joint locking, pain, instability, swelling, stair climbing, and squatting. LKS has been widely used to evaluate the rehabilitation effect of ACL reconstruction patients since its formulation in 1982.[6]

2.2.2. Exclusive criteria. The following were the exclusion criteria: duplicate publications in the databases; studies were conducted to treat the ACL reconstruction by trainings other than traditional rehabilitation treatment scheme, proprioceptive training and neuromuscular training; the evaluation index of the studies did not include the LKS; the subjects were animals or cells.

2.2.3. Data extraction and literature quality assessment. The researchers extracted the author's name, publication time, study area, intervention measures, sample size, mean and standard deviation of evaluation indicators, and follow-up time of the included literatures. The Cochrane bias risk assessment tool was used to evaluate the quality of the included literatures from 7 aspects, including random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other bias. Results of the literature quality assessment will be summarized using Review Manager 5.3 (The Nordic Cochrane Centre for The Cochrane Collaboration, Copenhagen, Denmark).

2.3. Statistical analysis of data

Stata 14.0 software (Stata Corp LP, College Station, TX) was used for statistical analysis of the data. The evidence network diagram was drawn, and the mean difference (MD) and 95% confidence interval (CI) of each rehabilitation treatment plan after ACL reconstruction were calculated. The surface under cumulative ranking (SUCRA) curve was drawn to predict the efficacy of each rehabilitation treatment after ACL reconstruction based on the area under the curve. Funnel plot was used to assess publication bias in the included literatures.

3. Results

3.1. Study selection

After searching Chinese and English databases, a total of 2844 related articles were retrieved. Two researchers screened the literatures by reading abstracts and full texts, and a total of 12 articles were included in this study.[7–18] The study selection flow is shown in Figure 1.

3.1.1. Characteristics of papers. The 12 studies included in this study included a total of 486 patients who received rehabilitation treatment after ACL reconstruction, and the age, gender and severity of the disease of the patients were not statistically significant. The earliest study was conducted in 1994 and the latest in 2020. The follow-up time of the study was 6.17 ± 3.65. Seven of the 12 studies compared the efficacy of traditional rehabilitation training and traditional rehabilitation training combined with proprioception training. Two studies compared the effects of traditional rehabilitation training and proprioception training. Two studies compared the efficacy of traditional rehabilitation training and neuromuscular training. One study compared the efficacy of traditional rehabilitation training with traditional rehabilitation training combined with neuromuscular training. In terms of regional distribution, there are 10 studies in China, there was 1 study in The United Kingdom and there was 1 study in Canada. The LKS was used to evaluate the efficacy of rehabilitation treatment after ACL reconstruction. The characteristics of the literatures are shown in Table 1. The results of literature quality evaluation were shown in Figures 2 and 3.

3.1.2. Evidence network chart. Four direct comparisons and 6 indirect comparisons were established among the 5 rehabilitation programs after ACL reconstruction (Fig. 4).
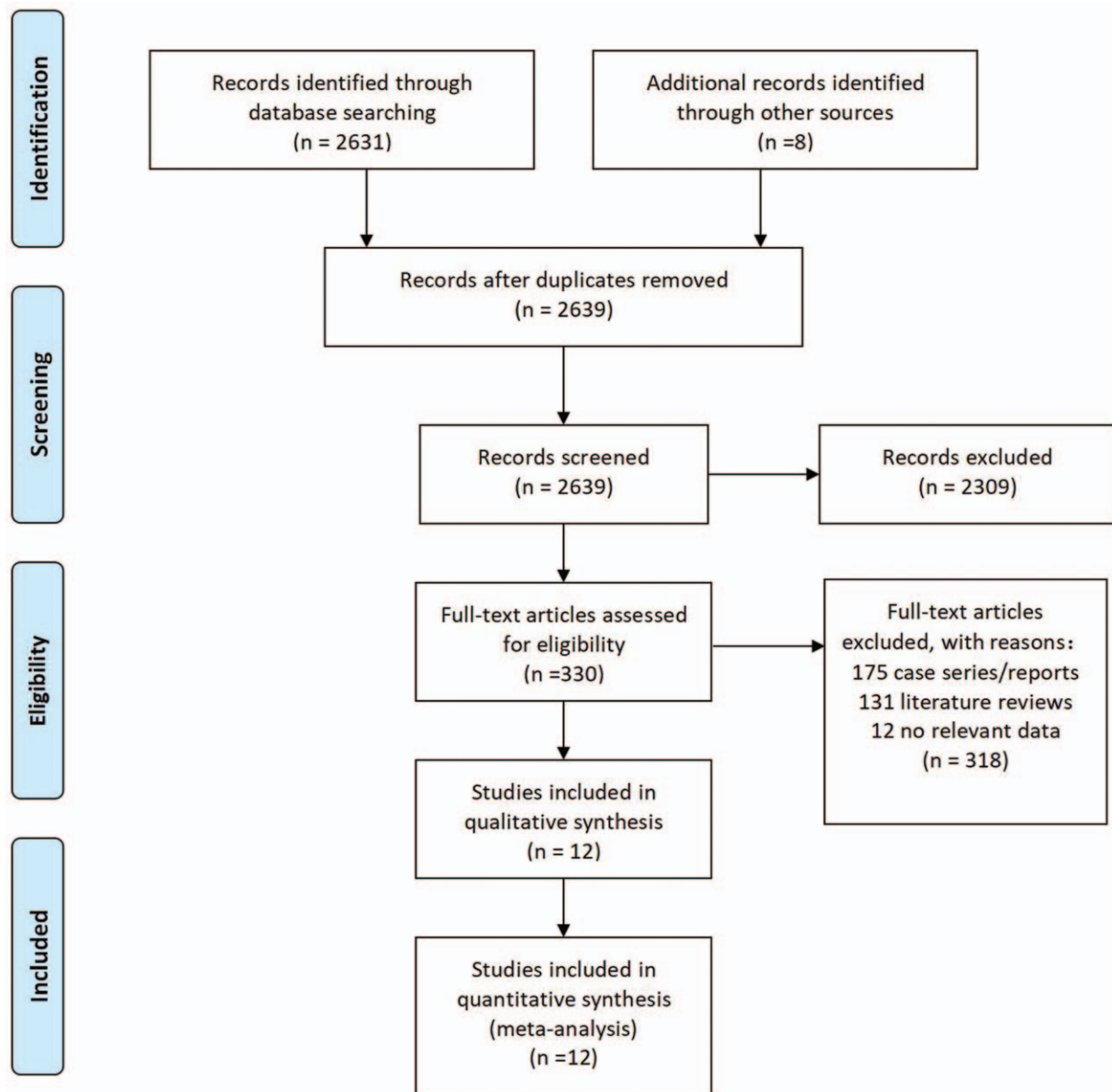
Figure 1. PRISMA flow diagram.

3.1.3. Network meta-analysis results. The results of the network meta-analysis are shown in Figure 5. The curative effect of traditional rehabilitation training combined with proprioception training is better than that of traditional rehabilitation training (the MD value of traditional rehabilitation training combined with proprioception training vs traditional rehabilitation training was 8.00, 95% CI: 2.61,13.39). The curative effect of proprioception training is better than traditional rehabilitation training (the MD value of proprioception training vs traditional rehabilitation training was 11.01, 95% CI: 0.62,21.39). There was no statistical significance between the other rehabilitation trainings.

3.1.4. SUCRA curative effect ranking curve. We used STATA 14.0 (Stata Corp LP, College Station, TX) to draw the SUCRA curve and used the area under the curve to predict the efficacy of various treatment measures. The larger the area under the curve was, the better the efficacy was. It can be seen from Figure 6 that the therapeutic effects of the 5 rehabilitation treatment schemes after ACL reconstruction are ranked as follows: proprioceptive training (72%) > traditional rehabilitation training combined with neuromuscular training (70.8%) > traditional rehabilitation training combined with proprioception training (57.1%) > neuromuscular training (45.5%) > traditional rehabilitation training (4.6%).

3.1.5. Publication bias detection. Funnel plot was used to detect the publication bias of the included literatures. And the publication bias of the included literatures was detected by observing the symmetry of funnel plot. It can be seen from Figure 7 that the funnel plot is basically symmetric and there is no publication bias.

Table 1

Characteristics of the 12 included trials. A: traditional rehabilitation training; B: proprioceptive training; C: neuromuscular training.

First author	Year	Country	Interventions	No. patients	Follow-up (mo)	Research type	Evaluation criterion
Wu Hua[7]	2014	China	a	15	2	RCT	LKS
			a+b	15			
Hao Yonghong[8]	2012	China	a	15	6	RCT	LKS
			a+b	15			
Shan Ping[9]	2016	China	a	35	6	RCT	LKS
			b	35			
Feng Guozhi[10]	2018	China	a	15	3	RCT	LKS
			a+b	15			
Wu Lang[11]	2020	China	a	33	3	RCT	LKS
			a+b	33			
Ma Yanhong[12]	2005	China	a	16	6	Non-RCT	LKS
			a+b	26			
Guan Jian[13]	2013	China	a	37	6	RCT	LKS
			a+b	38			
David J. Beard[14]	1994	England	a	20	3	RCT	LKS
			a+b	23			
T. Liu-Ambrose[15]	2003	Canada	a	5	3	RCT	LKS
			b	5			
Zhang Xiaohui[16]	2015	China	a	10	12	RCT	LKS
			c	10			
Zhang Xiaohui[17]	2014	China	a	5	12	RCT	LKS
			c	5			
Ye Yusong[18]	2017	China	a	30	12	RCT	LKS
			a+c	30			

LKS = Lysholm knee score, non-RCT = non-randomized controlled trial, RCT = randomized controlled trial.

4. Discussion

As the main weight-bearing and moving joint, knee joint injury is very common. ACL injuries accounted for 50% of knee injuries.[19] After ACL injury, the tissue structure and biomechanics of the knee joint will change, leading to the injury of other ligaments, iliac bone, meniscus and muscles of the knee joint, thus increasing the risk of knee joint degeneration.[20] ACL injury can seriously affect the function of the knee joint, and the long-term efficacy of ACL reconstruction depends on regular postoperative rehabilitation training. Studies have shown that systematic and regular rehabilitation training can effectively reduce pain, nourish articular cartilage, reduce contracture and scar formation of knee joint, reduce the incidence of postoperative patellofemoral joint pain, and enhance motor function, which is of equal importance to the operation itself.[21]
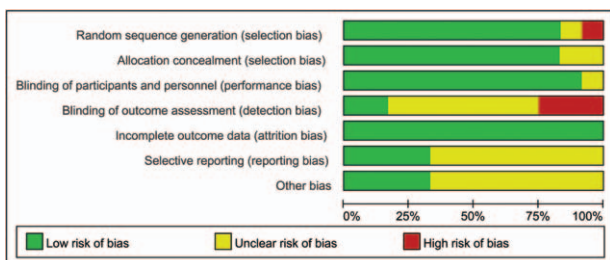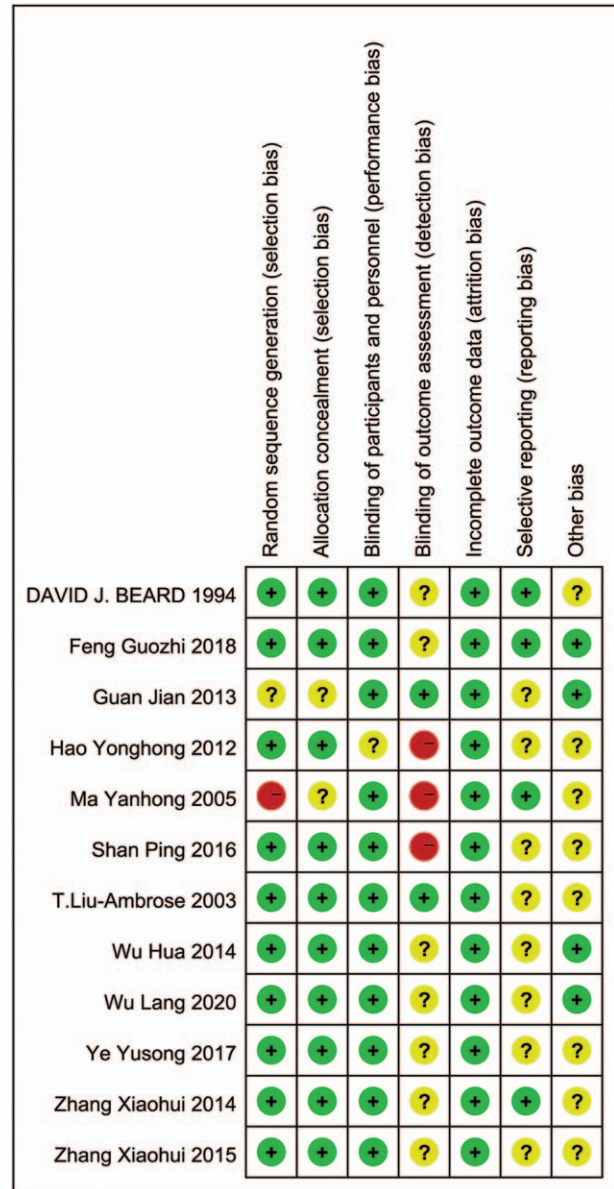

Figure 2. Risk of bias graph.

Figure 3. Risk of bias summary.

The traditional rehabilitation training after ACL reconstruction mainly focuses on the improvement of range of motion and the training of increasing muscle strength. Due to the different materials and surgical methods of ACL reconstruction, the postoperative routine rehabilitation training measures are not the same.[22] According to the time of intervention and the quantity of training, the traditional rehabilitation training can be divided into conservative training and radical training.[23] Conservative training usually requires wearing braces for at least 3 months, starting joint exercise at the second week after surgery, antigravity strength training and partial weight-bearing exercises, allowing complete weight-bearing only at 4 weeks, starting lower limb strength training at 8 weeks, and gradually taking part in sports activities such as jogging, swimming and so on after 6 months so as to return to normal exercise after 1 year. The radical training began immediately after the operation of joint range of motion and knee joint isometric contraction, and immediately
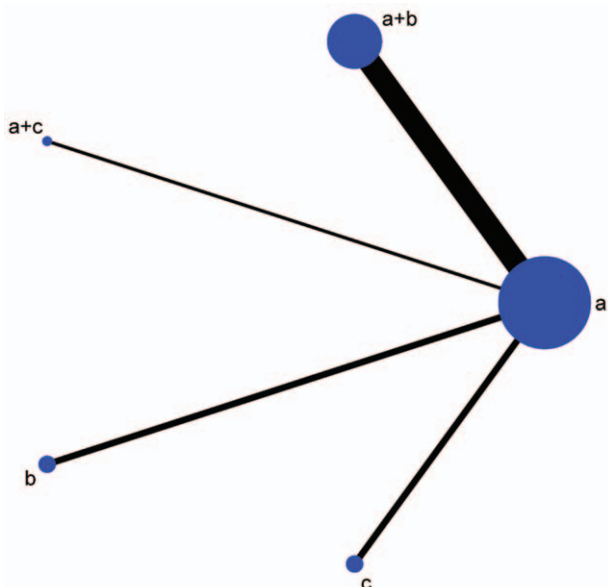
Figure 4. Evidence network chart.

weight bearing, basically restored the range of motion of the whole joint at 2 to 4 weeks, began intensive training at 5 weeks, and fully resumed normal activities at 3 months. From different perspectives, the conservative treatment focuses more on the compatibility of graft and tissue, whereas the radical training focuses more on the early recovery of joint function and reconstruction of motor ability.[24]

However, although ACL reconstruction can restore the stability of the knee joint, the functional recovery of patients is unsatisfactory. According to data, only 40% to 60% of patients can recover the previous exercise level after ACL reconstruction.[19] With the deepening understanding of ACL as a signal transduction device, the important role of proprioception in the function of knee joints has attracted more and more attention. It is believed that good proprioception of knee joint is the basis of accurate and efficient functional movement.[25] The faulty action pattern caused by the decrease of neuromuscular control may be one of the main causes of ACL primary or secondary injury. However, the loss of proprioception of the knee caused by ACL injury leads to the loss of the neuromuscular control ability of the joint, which can further cause the decline of the functional stability of the knee joint. Traditional rehabilitation training emphasizes more on the recovery of joint and muscle strength and lacks specific training to promote proprioception and neuromuscular control.[26] Therefore, in recent years, the restoration of proprioception and neuromuscular control after ACL reconstruction has attracted the attention of researchers.

Although regular muscle strength training can stimulate the regeneration of proprioceptors in joints to a certain extent, and thus improve proprioception function, it is far from enough. To improve proprioception comprehensively and effectively, we need to carry out more specific proprioception training. The training of proprioception is mainly aimed at balancing function, flexibility and agility. At present the main training methods are: closed power
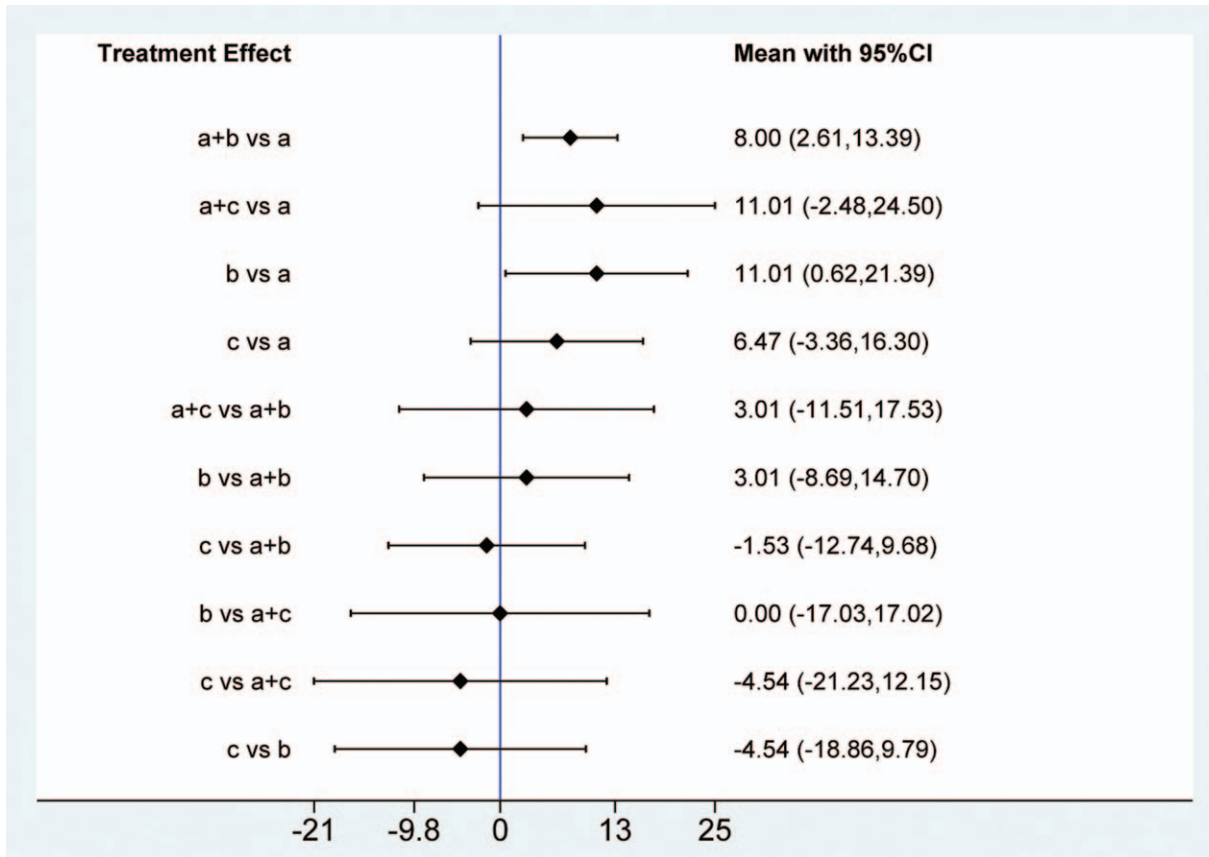

Figure 5. The forest figure of the network meta-analysis. CI = confidence interval.
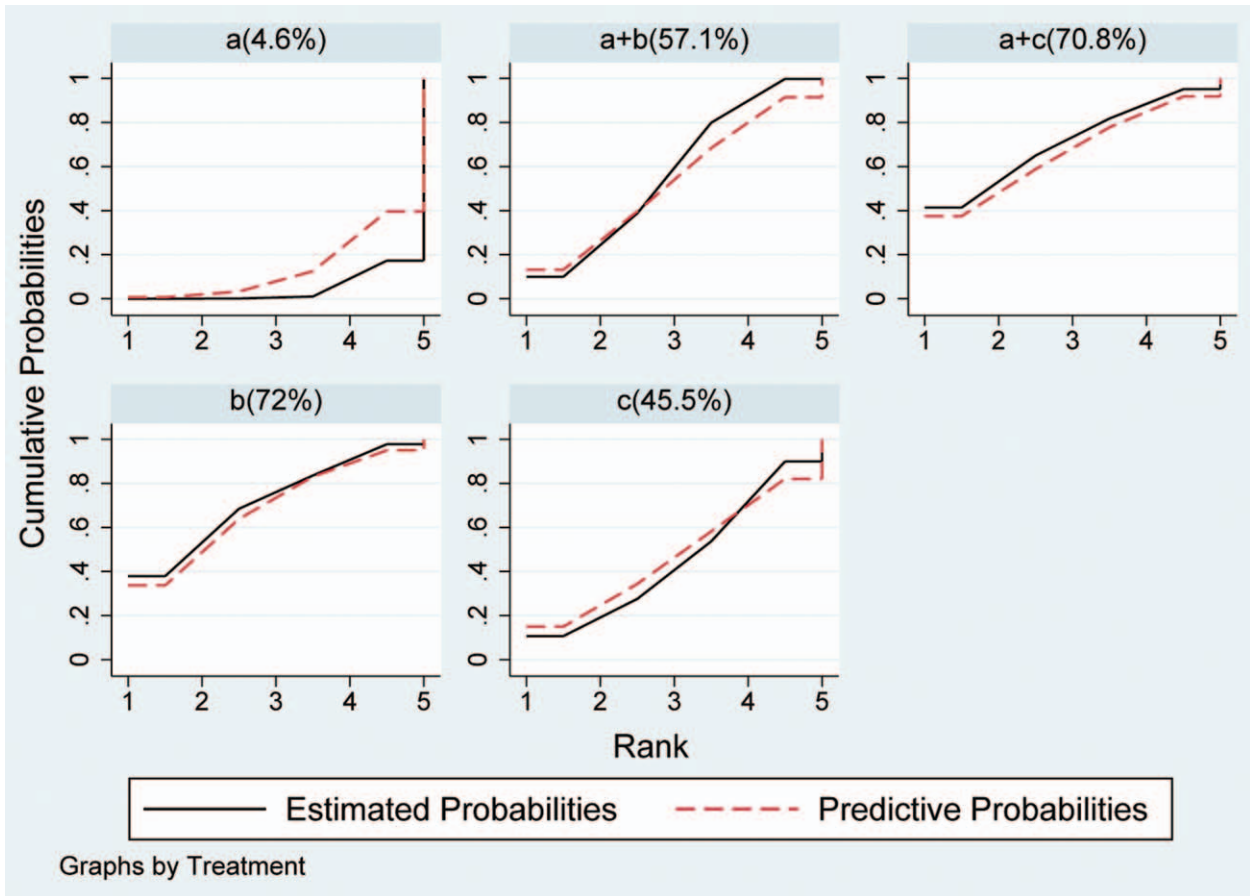
Figure 6. SUCRA curative effect ranking curve. SUCRA = surface under cumulative ranking.

bicycle chain, the balance on the balance board to adjust and control, stability of joint training, visual feedback action program, curve surrounded exercise training on foot, knee, lateral span jumping exercises, different direction and speed of running transformation training such as lateral run, run back, variable speed run, reverse layup, "S" shape run, etc.[12] Although current proprioception training after ACL reconstruction is rich and varied, its specificity and sensitivity still need to be further studied.

Figure 7. Funnel plot of the network meta-analysis.

Neuromuscular training also makes up for the deficiency of traditional rehabilitation training to some extent. Neuromuscular training is an integrated concept that aims to improve lower limb biomechanics, improve neuromuscular control and dynamic stability at the affected area, reduce the risk of motor injury, and thus improve overall motor performance.[16] It includes strength training, balance training, rapid expansion and contraction compound training, proximal control training and agility training. The training starts from static control and gradually develops to dynamic control. It is generally divided into 6 stages, mainly including early postoperative recovery stage (1-2 weeks), walking stage (2-4 weeks), balanced and dynamic knee stability training stage (5-10 weeks), muscle strength training stage (11-18 weeks), running and jumping training stage (19-24 weeks), progressive training and agility training stage (25-48 weeks). Although neuromuscular training has advantages in promoting isokinetic strength and motor recovery, early initiation of neuromuscular training increases the risk of joint swelling. Therefore, the optimal intensity and implementation time of early neuromuscular training still need to be further studied.

A total of 12 articles including 486 patients were included in this network meta-analysis. Through rigorous literature retrieval and scientific statistical analysis, this study has drawn a relatively objective and true conclusion. However, this study also has limitations: The research population is mainly distributed in China, Canada and the United Kingdom, so the research conclusions have regional and ethnic limitations. Due to the
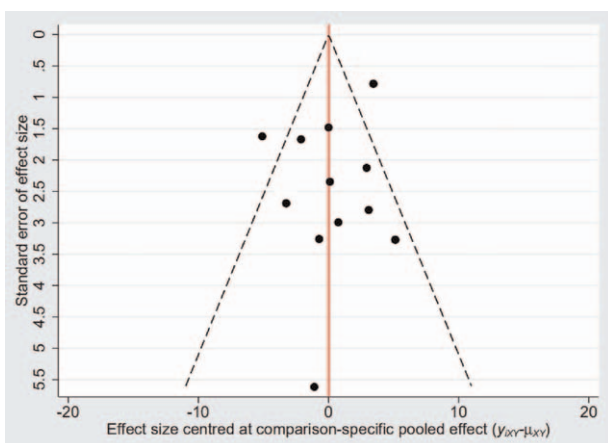
limitations of the original data, we used the LKS as the evaluation standard for the curative effect of rehabilitation training after ACL reconstruction, and did not include other evaluation indexes of the rehabilitation trainings. Although the funnel plot obtained in meta-analysis are relatively symmetric, the existence of potential publication bias cannot be completely excluded. The ACL reconstruction methods and materials used in the studies included in the meta-analysis are not the same. Due to data limitations, subgroup analysis cannot be carried out to evaluate the effect of ACL reconstruction methods and surgical materials on the efficacy of rehabilitation training. The quality of the literatures included in this study are uneven, and the rehabilitation training programs used are also different. These factors also affect the reliability of the final conclusion. A large difference in the sample size of the studies included in this meta-analysis. Among them, the sample size of T. Liu-Ambrose's study[15] and Zhang Xiaohui's study[17] was relatively small. Each of the 2 studies included 10 patients who underwent ACL reconstruction. Different sample sizes, especially those with relatively small sample sizes, increase the heterogeneity of this meta-analysis. Although we used a random effects model to analyze the data, the influence of potential heterogeneity on the conclusions of this study cannot be excluded.

5. Conclusions

This network meta-analysis scientifically and systematically analyzed the clinical efficacy of the 5 rehabilitation treatment schemes after ACL reconstruction, such as traditional rehabilitation treatment, proprioceptive training, neuromuscular training, traditional rehabilitation training combined with proprioceptive training, traditional rehabilitation training combined with neuromuscular training. Combined with the conclusions of meta-analysis and SUCRA curative effect ranking curve, it can be seen that traditional rehabilitation training combined with proprioceptive training and traditional rehabilitation training combined with neuromuscular training have significant efficacy. Therefore, in the future rehabilitation training after ACL reconstruction, we recommend these 2 combined training programs. Due to the limitations of this study, the conclusions of this network meta-analysis still need to be further confirmed by a large sample size and well-designed randomized controlled trials (Supplemental Content, http://links.lww.com/MD2/A651).

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Supervision: Shuyan Qie.
Validation: Shuyan Qie.
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Writing – review & editing: Qiaorong Zhang, Shuyan Qie.

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