Effects of Pro-kin Balance System Combined with Isokinetic Closed-Chain Training on Functional Recovery and Knee Joint Biomechanics in Male Basketball Players after Anterior Cruciate Ligament Reconstruction: Postprint

Authors: Feng Yafeng

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Abstract

Objective To investigate the application effects of Pro-kin balance system combined with isokinetic closed-chain training on functional recovery and knee joint biomechanics in male basketball athletes after anterior cruciate ligament (ACL) reconstruction. Methods A total of 588 male basketball athletes who underwent ACL reconstruction were divided into Pro-kin group (196 cases, receiving Pro-kin balance system training), closed-chain group (196 cases, receiving isokinetic closed-chain training), and combined group (196 cases, receiving Pro-kin balance system combined with isokinetic closed-chain training) using the random number table method. Gait spatiotemporal parameters, lower limb muscle strength [extensor peak torque (Text) and flexor peak torque (Tflex), hamstrings-toquadriceps peak torque ratio (RH/Q)], standing balance stability [bilateral multiaxis average trajectory error difference (ATED)], range of motion, and knee function [International Knee Documentation Committee (IKDC) score, Hospital for Special Surgery (HSS) knee score] were compared among the three groups before intervention and after 12 weeks of intervention. Results After 12 weeks of intervention, stride length, stride speed, and step length were significantly greater in the combined group than in the Pro-kin group, which were significantly greater than in the closed-chain group ($P<0.05$); Text, Tflex, and RH/Q were significantly greater in the combined group than in the closed-chain group, which were significantly greater than in the Pro-kin group ($P<0.05$); ATED was significantly lower in the combined group than in the Prokin group, which was significantly lower than in the closed-chain group ($P<0.05$); range of motion was significantly greater in the combined group than in the closed-chain group and Pro-kin group ($P<0.05$); HSS and IKDC scores were significantly higher in the combined group than in the closed-chain group and Pro-kin group

(P<0.05). Conclusion Compared with single Pro-kin balance system training or isokinetic closed-chain training, the combined training mode can significantly improve knee function and range of motion, improve knee joint biomechanics, and correct abnormal gait and balance stability performance in basketball athletes after ACL reconstruction.

Full Text

The Effect of Pro-kin Balance System Combined with Isokinetic Closed-Chain Training on Functional Recovery and Knee Biomechanics of Male Basketball Players After Anterior Cruciate Ligament Reconstruction

FENG Yafeng[1], MENG Shuqiao[2], SUN Tianjiao[1], WEI Zilong[1]
[1]School of Physical Education, Henan Normal University, Xinxiang 453007, China [2]Sports Department, Xidian University, Xi' an 710126, China

Abstract: Objective To investigate the application effects of Pro-kin balance system combined with isokinetic closed-chain training on functional recovery and knee biomechanics in male basketball players following anterior cruciate ligament (ACL) reconstruction surgery. **Methods** A total of 588 male basketball athletes who underwent ACL reconstruction were randomly divided into three groups using a random number table method: the Pro-kin group (196 cases, receiving Pro-kin balance system training), the closed-chain group (196 cases, receiving isokinetic closed-chain training), and the combined group (196 cases, receiving both interventions). Comparisons were made among the three groups before intervention and after 12 weeks of intervention regarding gait spatiotemporal parameters, lower limb muscle strength [extensor peak torque (Text) and flexor peak torque (Tflex), hamstrings-to-quadriceps peak torque ratio (RH/Q)], standing balance stability [bilateral multi-axis average trajectory error difference (ATED)], joint range of motion, and knee function [International Knee Documentation Committee (IKDC) score and Hospital for Special Surgery (HSS) score]. **Results** After 12 weeks of intervention, the combined group showed significantly greater stride length, walking speed, and step length compared to the Pro-kin group, which in turn outperformed the closed-chain group ($P < 0.05$). The combined group also demonstrated superior Text, Tflex, and RH/Q values compared to the closed-chain group, which exceeded those of the Pro-kin group ($P < 0.05$). ATED values were lowest in the combined group, followed by the Pro-kin group, with the closed-chain group showing the highest values ($P < 0.05$). Joint range of motion was greater in the combined group than in both the closed-chain and Pro-kin groups ($P < 0.05$). Similarly, HSS and IKDC scores were highest in the combined group, followed by the closed-chain group, then the Pro-kin group ($P < 0.05$). **Conclusion** Compared with single-modality training using either the Pro-kin balance system or isokinetic closed-chain training alone, the combined training protocol significantly improves knee function and joint mobility, enhances knee biomechanics, and

corrects abnormal gait and balance stability performance in basketball athletes following ACL reconstruction.

Keywords: isokinetic closed-chain training; Pro-kin balance system; basketball players; anterior cruciate ligament; anterior cruciate ligament reconstruction

1. Introduction

The anterior cruciate ligament (ACL) is one of the most commonly injured structures in sports, and basketball—characterized by high-speed movements and intense physical contact—carries a particularly high risk of ACL injury [1]. Currently, anterior cruciate ligament reconstruction (ACLR) represents the primary treatment for ACL injuries. However, postoperative complications including decreased dynamic knee stability, quadriceps atrophy, proprioceptive deficits, and altered movement patterns affect 30-40% of athletes upon return to sport, leading to reduced performance and increased risk of secondary injury. Research indicates that post-ACLR biomechanical abnormalities primarily manifest as increased coronal plane valgus loading, insufficient sagittal plane flexion moments, and disrupted hamstring-quadriceps co-contraction patterns during the gait cycle. These alterations not only impair high-intensity movements such as cutting, jumping, and sudden stops but may also accelerate articular cartilage degeneration and increase osteoarthritis risk [2]. While traditional rehabilitation protocols emphasize muscle strength recovery, they often lack targeted interventions for dynamic stability and neuromuscular control, preventing some athletes from returning to pre-injury competitive levels.

In recent years, rehabilitation techniques based on neuromuscular control theory have gained increasing attention. The Pro-kin balance system employs dynamic unstable surface training to precisely quantify postural control output and proprioceptive input, facilitating central nervous system readaptation for knee stability [3-4]. Isokinetic closed-chain training, meanwhile, utilizes multi-joint coordinated movement patterns that simulate basketball-specific biomechanical characteristics, enabling coordinated activation of eccentric-concentric muscle contractions under isokinetic resistance to improve energy transfer efficiency and lower extremity alignment [5]. However, few studies have examined the combined effects of Pro-kin balance system and isokinetic closed-chain training on post-ACLR functional recovery, and most clinical research on postoperative rehabilitation has focused on non-athletic populations, with relatively limited investigation of sport-specific protocols for basketball players.

Theoretically, combining these two approaches could overcome the limitations of single-intervention protocols: the Pro-kin system targets neuromuscular control deficits through real-time biofeedback to enhance joint position sense, while closed-chain training progressively remodels tendon-muscle stiffness through incremental loading. Together, they may repair the damaged knee functional chain from a multi-dimensional "muscle-nerve-bone" perspective. Furthermore,

basketball players require substantially greater multi-directional dynamic stability than the general population. Traditional open-chain training lacks integration of functional movements and fails to meet these athletes' specific needs. The combination of closed-chain isokinetic training and balance training could optimize ground reaction force distribution and knee valgus moment patterns during jump-landing tasks. Therefore, this study is the first to apply combined Pro-kin balance system and isokinetic closed-chain training to post-ACLR rehabilitation in male basketball players, using synchronized isokinetic muscle strength and three-dimensional motion capture analysis to quantify the interactive effects of these two interventions on knee joint kinetics, kinematics, and muscle activation patterns. Unlike previous studies focusing on single training modalities, this composite protocol may provide a theoretical foundation for establishing biomechanical criteria for competitive athletes' return to sport, thereby contributing to the development of basketball in China.

1.1 Participants

We selected 588 male basketball athletes who underwent ACL reconstruction between January 2023 and June 2024. **Inclusion criteria:** (1) male basketball players; (2) MRI-confirmed ACL injury with one-month postoperative status following ACLR; (3) voluntary participation with signed informed consent. **Exclusion criteria:** (1) other soft tissue or bone-joint injuries in the lower extremities; (2) venous thrombosis; (3) posterior cruciate ligament injury; (4) meniscal injury; (5) secondary ACL injury; (6) severe postoperative infection; (7) severe cardiopulmonary disease; (8) failure to complete the rehabilitation training program as scheduled.

All participants were fully informed of potential injury risks during the study and provided signed informed consent. This study was approved by the Ethics Committee (Approval No.: HNSD-2025BS-0109). Comparison of baseline characteristics among the three groups showed no statistically significant differences ($P > 0.05$), as presented in .

All participants underwent conventional training: (1) ankle pump exercises in supine position (30 dorsiflexion-plantarflexion cycles per hour) to promote circulation; (2) quadriceps isometric contractions alternating with ankle pumps (3-second contraction, 3-second relaxation) to maintain muscle fiber strength; (3) straight leg raises to prevent vastus medialis atrophy; and (4) air cycling exercises once knee flexion-extension became comfortable. Additional rehabilitation protocols were implemented as follows:

1) Pro-kin group: Received Pro-kin balance system training (Balance model, Tecnobody) [Figure 1: see original paper]. Training progressed from static to dynamic balance and from hands-supported to hands-behind-back positions to gradually increase difficulty. The protocol included: (a) static setting: limit stability test module controlling the center-of-gravity marker on screen for 4 consecutive sets; (b) dynamic training 1: dynamic balance test module with

screen divided into 4 quadrants, controlling the center-of-gravity marker to remain in each quadrant for 30 seconds; (c) dynamic training 2: dynamic balance game module controlling character balance in the game. Training frequency: once daily, 3 times per week for 12 weeks.

2) Closed-chain group: Received isokinetic closed-chain training [Figure 2: see original paper] using the BIODEX isokinetic system (USA). Participants were seated with the affected foot fixed to the pedal, performing isokinetic flexion-extension exercises from an extended position. Initial testing at 60°/s was followed by eccentric training torque settings based on results. Training consisted of: 10 repetitions at 60°/s, 15 repetitions at 120°/s, and 20 repetitions at 180°/s as one set, with 2 sets performed per session and 3-minute intervals between sets. Frequency: 3 times per week for 12 weeks.

3) Combined group: Received both Pro-kin balance system and isokinetic closed-chain training using the same methods and frequencies as the other groups, with a 30-minute interval between the two training modalities, 3 times per week for 12 weeks.

1.3 Outcome Measures

ACL injury can cause decreased knee stability and limited joint function, significantly affecting gait, range of motion, muscle strength, and standing balance stability. Therefore, this study assessed the following parameters before and after intervention:

1) Gait spatiotemporal parameters: The P-WALK pressure platform system was used to collect stride length, walking speed, and step length during walking.

2) Isokinetic muscle strength: The HUMAC2009NORM isokinetic dynamometer (USA) measured flexor peak torque (Tflex), extensor peak torque (Text), and hamstrings-to-quadriceps peak torque ratio (RH/Q).

3) Standing balance stability: The PK254 balance test system (Tecnobody, Canada) assessed bilateral multi-axis average trajectory error (ATE) in standing position with the healthy limb on the test plate and the affected limb outside, then calculated the bilateral difference (ATED). Lower ATED values indicate higher symmetry of dynamic balance between limbs.

4) Joint range of motion: A goniometer measured maximum knee internal rotation, external rotation, and flexion-extension angles, with three measurements averaged.

5) Knee function: The Hospital for Special Surgery (HSS) score [6] and International Knee Documentation Committee (IKDC) score [7] were used. The HSS score assesses pain (30 points), functional activity (22 points), range of motion (18 points), quadriceps strength (10 points), flexion deformity (10 points), and joint stability (10 points), with total scores ranging from 0-100 (higher scores

indicating better function). The IKDC score comprises 8 ligament examination items and 10 knee assessment items, also ranging from 0-100.

1.4 Statistical Analysis

SPSS 26.0 was used for data analysis. Count data were expressed as n (%) and analyzed using ^{2} tests. Measurement data were expressed as mean $\pm$ standard deviation ($\bar{x} \pm s$). One-way ANOVA was used for multi-group comparisons, with LSD-t tests for pairwise comparisons. $P < 0.05$ was considered statistically significant.

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2. Results

2.1 Comparison of Gait Spatiotemporal Parameters Among Three Groups All three groups showed improved gait spatiotemporal parameters after 12 weeks of intervention. The combined group demonstrated significantly greater stride length, walking speed, and step length compared to the Pro-kin group, which in turn outperformed the closed-chain group ($P < 0.05$), as shown in .

2.2 Comparison of Lower Limb Muscle Strength Among Three Groups Lower limb muscle strength increased in all groups after 12 weeks. The combined group showed significantly higher Text, Tflex, and RH/Q values compared to the closed-chain group, which exceeded those of the Pro-kin group ($P < 0.05$), as presented in .

2.3 Comparison of Standing Balance Stability Among Three Groups Before intervention, ATED values were (5.62 ± 0.82) for the Pro-kin group, (5.54 ± 0.75) for the closed-chain group, and (5.63 ± 0.83) for the combined group, with no significant differences ($P > 0.05$). After 12 weeks, ATED values decreased to (3.26 ± 0.53), (4.13 ± 0.48), and (2.32 ± 0.41) respectively, with the combined group showing the lowest values, followed by the Pro-kin group, then the closed-chain group ($P < 0.05$).

2.4 Comparison of Joint Range of Motion Among Three Groups All groups showed increased joint range of motion after 12 weeks. The combined group demonstrated significantly greater range of motion compared to both the closed-chain and Pro-kin groups ($P < 0.05$), while no significant difference was observed between the latter two groups ($P > 0.05$), as shown in .

2.5 Comparison of Knee Function Scores Among Three Groups HSS and IKDC scores increased in all groups after 12 weeks. The combined group achieved significantly higher scores than both the closed-chain and Pro-kin

groups ($P < 0.05$), while no significant difference was found between the closed-chain and Pro-kin groups ($P > 0.05$), as presented in .

3. Analysis and Discussion

Currently, post-ACLR rehabilitation in Chinese orthopedics primarily consists of conventional exercises including straight leg raises, ankle pumps, lateral leg raises, and static squats. Given the numerous postoperative complications and functional deficits, as well as basketball players' urgent need to return to competition, conventional rehabilitation protocols outlined in orthopedic guidelines no longer meet athletes' rehabilitation requirements [8]. Therefore, scientifically designed training programs tailored to the specific postoperative stage are undoubtedly valuable for athletes' functional recovery.

The Pro-kin balance training system is a rehabilitation platform for balance assessment and training that provides comprehensive balance training through visual feedback. Zhao et al. [9-10] found that visual feedback balance training improved gait and balance in Parkinson' s disease and stroke patients. Other researchers have applied it to post-ACLR patients and observed significant improvements in knee function [11]. Isokinetic closed-chain training is a recently emerging specific exercise method that combines closed-chain characteristics with constant velocity or resistance, enabling muscle strength training at various speeds [12-13]. In recent years, both Pro-kin balance training and isokinetic closed-chain training have been widely applied after ACL reconstruction, achieving significant effects in promoting knee function and motor recovery. However, whether their combination produces synergistic benefits remains unknown.

Moreover, Pro-kin balance training primarily focuses on comprehensive balance training, while isokinetic closed-chain training emphasizes improving joint stability, neuromuscular coordination, and muscle strength. This study is the first to combine these two modalities for post-ACLR rehabilitation in basketball players to leverage their synergistic effects. The results showed that the combined group achieved superior gait spatiotemporal parameters compared to the Pro-kin group, which in turn outperformed the closed-chain group ($P < 0.05$), demonstrating that the combination of Pro-kin balance system and isokinetic closed-chain training produces synergistic effects that further improve postoperative gait abnormalities in basketball players.

This improvement can be attributed to several mechanisms. Isokinetic closed-chain training transforms conventional rotational movements into linear motions, providing functional knee training while protecting the joint and avoiding increased shear forces. This effectively stimulates joint proprioceptors to restore their function. The multi-joint coordinated movement pattern simulates functional basketball movements, promoting balanced force transmission in both coronal and sagittal planes. Additionally, it enhances hamstring-quadriceps co-contraction, reducing anterior tibial shear force and ACL re-injury risk, thereby

improving mechanical symmetry during swing and stance phases [14-15]. The Pro-kin balance system improves hip-knee-ankle linkage stability during single-leg stance, reduces mediolateral center of pressure (COP) excursion during gait cycles, enhances proprioceptive input, decreases knee reaction time, and improves neuromuscular control efficiency during gait initiation [16]. Compared to single-modality training, the combined approach achieves synergistic adjustments through dynamic balance reconstruction, mechanical chain optimization, and spatiotemporal parameter modulation, effectively restoring postoperative gait biomechanics.

The ACL is a crucial ligament connecting the tibia and femur, essential for normal walking. Although ACLR restores ligament structure and stability, additional rehabilitation is required for normal balance stability [17-18]. Studies show that balance stability is closely related to periarticular muscles and limb control ability [19]. Therefore, after surgical restoration of ligament structure and function, this study implemented targeted rehabilitation training. On one hand, the Pro-kin system monitors COP displacement in real-time, and combined with multi-joint coordinated movements in closed-chain training, enhances lower extremity muscle compensation for COP shifts, reducing postural sway and improving stability [20-21]. On the other hand, isokinetic closed-chain training strengthens isometric contraction capacity of hamstrings and quadriceps, increasing Text and RH/Q to optimize periarticular muscle balance and reduce anterior tibial translation risk. The multi-joint linkage pattern in closed-chain training also improves force transmission efficiency during knee flexion-extension, reducing local stress concentration [22]. Combined with dynamic balance stimulation from the Pro-kin system, proprioceptive feedback is further enhanced, promoting adaptive regulation of ligaments and joint capsules to abnormal loads and improving stability limit parameters. Our results showing lower ATED values in the combined group confirm that this combination effectively improves balance stability.

ACL injury reduces muscle activity, causing atrophy—particularly in hamstrings and quadriceps—which decreases joint stability and increases re-injury risk [23-24]. Isokinetic closed-chain training is an effective method for assessing and training muscle power, endurance, and strength through constant-velocity movements. Shao et al. [25] demonstrated that compared to isokinetic open-chain exercise, isokinetic closed-chain training more effectively restored balance function and enhanced lower limb strength in stroke patients with motor disorders. Our study further revealed that isokinetic closed-chain training significantly improved lower limb strength compared to Pro-kin balance training alone. This occurs because constant-velocity movements under varying loads provide greater muscle stimulation, promoting strength gains. Repeated contractions at the same velocity provide adequate stimulation to both slow-twitch and fast-twitch fibers, enhancing muscle endurance. When combined with the Pro-kin balance system, patients can apply PNF rhythmic stabilization techniques on the vibration platform, increasing sensory input and activating lower extremity and core muscle isometric contractions, thereby further strengthening muscles. This

demonstrates the synergistic effect of combined training on muscle strength improvement. Additionally, after 12 weeks of intervention, the combined group showed superior joint range of motion and HSS/IKDC scores compared to both other groups ($P < 0.05$), indicating that the combination of Pro-kin balance system and isokinetic closed-chain training offers outstanding benefits for restoring knee function and mobility in basketball players after ACLR.

4. Conclusion

Compared with single-modality training using either the Pro-kin balance system or isokinetic closed-chain training alone, the combined training protocol significantly improves knee function and joint mobility, enhances knee biomechanics, and corrects abnormal gait and balance stability performance in basketball athletes after ACL reconstruction, warranting clinical promotion. This study has limitations, including the lack of long-term follow-up; the sustained effects of this protocol in long-term rehabilitation require further investigation to continuously refine the approach.

References

[1] KOHN L, REMBECK E, RAUCH A. Verletzung des vorderen kreuzbandes beim erwachsenen. *Der Orthopäde*, 2020, 49(11): 1095-1105.

[2] BEARD D J, DAVIES L, COOK J A, et al. Rehabilitation versus surgical reconstruction for non-acute anterior cruciate ligament injury (ACL SNNAP): a pragmatic randomised controlled trial. *The Lancet*, 2022, 400(10352): 605-615.

[3] HAN T T, LIU Q, HU Y G, et al. Effect of Pro-kin visual feedback balance training on balance function of individuals with early Parkinson' s disease: a randomized controlled pilot trial. *African Health Sciences*, 2023, 23(2): 582-588.

[4] REN Y, GUO X, LI W, et al. Effects of isokinetic closed chain training combined with short needling on postoperative joint range of motion and functional recovery in patients with knee anterior cruciate ligament injury. *Laboratory Medicine and Clinic*, 2023, 20(17): 2496-2500.

[5] CHEON S, LEE J H, JUN H P, et al. Acute effects of open kinetic chain exercise versus those of closed kinetic chain exercise on quadriceps muscle thickness in healthy adults. *International Journal of Environmental Research and Public Health*, 2020, 17(13): 4669.

[6] AHSANUDDIN S, SNYDER D J, HUANG H H, et al. Surgical care costs for patients undergoing total hip and knee arthroplasty scheduling impacts hospital length of stay and associated health. *HSS Journal*, 2022, 18(3): 385-392.

[7] KAYA S, UNAL Y C, GUVEN N, et al. The impact of early weight-bearing on results following anterior cruciate ligament reconstruction. *BMC Musculoskeletal Disorders*, 2024, 25(1): 395.

[8] DIERMEIER T, ROTHRAUFF B B, ENGEBRETSEN L, et al. Treatment after anterior cruciate ligament injury: Panther Symposium ACL Treatment Consensus Group. *Knee Surgery, Sports Traumatology, Arthroscopy*, 2020, 28(8): 2390-2402.

[9] ZHAO W, LI Y, YOU H, et al. The effect of repetitive transcranial magnetic stimulation combined with visual feedback balance training on balance and gait in Parkinson' s disease patients. *Chinese Journal of Rehabilitation Medicine*, 2024, 39(9): 1327-1331.

[10] JIAO A, ZHAO W, WEN S, et al. Effects of pro-kin visual feedback balance training on balance and gait in stroke patients. *Chinese Journal of Rehabilitation*, 2022, 37(10): 579-583.

[11] ZHANG N, NITSCHE M A, MIAO Y, et al. Transcranial direct-current stimulation over the primary motor cortex and cerebellum improves balance and shooting accuracy in elite ice hockey players. *International Journal of Sports Physiology and Performance*, 2024, 19(10): 1107-1114.

[12] GRONWALD T, KLEIN C, HOENIG T, et al. Hamstring injury patterns in professional male football (soccer): a systematic video analysis of 52 cases. *British Journal of Sports Medicine*, 2022, 56(3): 165-171.

[13] KIM J S, LEE M Y. The effect of short foot exercise using visual feedback on the balance and accuracy of knee joint movement in subjects with flexible flatfoot. *Medicine*, 2020, 99(13): e19260.

[14] HORII O, SASAKI M. Influences of trunk stability on exercise performance of closed kinetic chain of upper and lower limbs. *Journal of Physical Therapy Science*, 2023, 35(5): 379-383.

[15] AMIROUCHE F, DOLAN M, PRADHAN S, et al. Assessment of cervical and lumbar kinematics in simulated open and closed kinetic chain. *International Journal of Spine Surgery*, 2023, 17(1): 109-118.

[16] MARVULLI R, IANIERI G, PIGNATELLI G, et al. Electronic method (pro-kin) for improving and speeding up the recovery after ankle sprain. *Endocrine, Metabolic & Immune Disorders-Drug Targets*, 2024, 24(13): 1572-1580.

[17] STONE A V, MARX S, CONLEY C W. Management of partial tears of the anterior cruciate ligament: a review of the anatomy, diagnosis, and treatment. *Journal of the American Academy of Orthopaedic Surgeons*, 2021, 29(2): 60-70.

[18] BRAM J T, MAGEE L C, MEHTA N N, et al. Anterior cruciate ligament injury incidence in adolescent athletes: a systematic review and meta-analysis. *The American Journal of Sports Medicine*, 2021, 49(7): 1962-1972.

[19] BØE B. Nonoperative anterior cruciate ligament injury treatment. *Clinics in Sports Medicine*, 2024, 43(3): 343-354.

[20] LU W, WEN M M, LI Y X, et al. Effects of visual feedback balance system combined with weight loss training system on balance and walking ability in the

early rehabilitation stage of stroke: a randomized controlled exploratory study. *Therapeutic Advances in Neurological Disorders*, 2024, 17: 1-11.

[21] ZHANG M, YOU H, ZHANG H X, et al. Effects of visual feedback balance training with the pro-kin system on walking and self-care abilities in stroke patients. *Medicine*, 2020, 99(39): e22425.

[22] GRAHAM M C, REEVES K A, JANATOVA T, et al. The relationship of open- and closed-kinetic-chain rate of force development with jump performance following anterior cruciate ligament reconstruction. *International Journal of Sports Physiology and Performance*, 2024, 19(6): 585-592.

[23] GRASSI A, MACCHIAROLA L, FILIPPINI M, et al. Epidemiology of anterior cruciate ligament injury in Italian first division soccer players. *Sports Health*, 2020, 12(3): 279-288.

[24] MANCINO F, GABR A, PLASTOW R, et al. Anterior cruciate ligament injuries in female athletes. *The Bone & Joint Journal*, 2023, 105-B(10): 1033-1037.

[25] SHAO J, ZHANG C, SUN D, et al. Isokinetic chain closing training and isokinetic chain opening training for patients with poststroke dyskinesia influence of muscle strength, balance function and walking ability of lower limbs. *Clinical Journal of Medical Officers*, 2022, 50(3): 267-269.

Note: Figure translations are in progress. See original paper for figures.