Proceedings of the 4th International Conference on Global Politics and Socio-Humanities
DOI: 10.54254/2753-7048/2026.33276

Ankle Rehabilitation for Basketball Players by Combining Neuromuscular Training and Technology Support

Ruiyi Xie

Rehabilitation College, Shanghai University of Medicine & Health Sciences, Shanghai, China
XIEruiyi1221@outlook.com

Abstract. Ankle injuries are among the most common and recurrent problems for basketball players, and traditional rehabilitation methods often fall short in preventing re-injury or restoring full sport performance. This review looks at two complementary approaches—neuromuscular training and technology-assisted rehabilitation—and how they might work together. Neuromuscular training focuses on rebuilding proprioception, dynamic stability, and coordinated muscle responses through exercises like single-leg balance, plyometrics, and movement pattern correction. Evidence shows it clearly improves function and reduces deficits in chronic ankle instability. On the other hand, technologies such as biofeedback, virtual reality, and robot-assisted devices offer real-time data, immersive task-specific environments, and adjustable support that can enhance motivation, movement accuracy, and training precision. When combined, these two paths seem to reinforce each other: technology makes neuromuscular deficits visible and correctable, while task-specific training keeps the rehabilitation functional and sport-relevant. Preliminary findings suggest that integrated approaches lead to better joint function recovery, more efficient neuromuscular control, and more personalized, data-driven rehabilitation processes. That said, current research still has clear limitations—small sample sizes, limited basketball-specific data, inconsistent protocols, and a gap between collecting rich data and turning it into actionable training plans. Future work should focus on larger-scale studies, adaptive feedback systems that adjust to the athlete's real-time status, and the use of AI to support individualized, precision rehabilitation.

Keywords: Basketball Players, Ankle Rehabilitation, Neuromuscular Training, Technology Support.

1. Introduction

Among the most common ankle injuries in basketball players is around 48% to be accounted for by such an occurrence [1]. It has a high incidence rate and often recurs frequently. Main manifestations include joint swelling, pain, restricted mobility of the joints, etc. Some serious cases are full tears of ligament or cartilage damage with chronic ankle instability; then, these recurring injuries will occur repeatedly.

This accident is very bad for the competition of athletes and has had quite a large influence on their minds as well. Although the risk of death is relatively low, there may be some issues with their

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-7048/2026.33276

sports skills and concern for injury risks that prevent them from recovering to peak condition again.

With the progress of sports medicine, the idea of ankle rehabilitation for basketball players has had a basic shift in the past twenty years. The traditional model of immobilization and rest was given up because it could not stop the recurrence rate as high as 70% [2]. A new functional rehabilitation path focusing on neuromuscular exercise replaced it. This model is very good at restoring joint stability and enhancing proprioception. Through wearable equipment, including sensors and Virtual Reality (VR) technologies, to provide users with subjective data information and an even closer simulated Environment during rehabilitation assessment or training. However, the combination of the two is still limited.

For this reason, this paper focuses on the coordinated use of neuromuscular training and technology support in ankle rehabilitation for basketball players. It systematically sorts out the action mechanisms and practical progress of the two paths, and on this basis discusses the logic and ways of integrating them. To serve as a theoretical reference and practice foundation for enhancing the rehabilitation process, promoting greater success rates in returning to work at our own Courts.

2. Neuromuscular training

Neuromuscular Training, as a rehabilitation exercise system aimed at rebuilding dynamic regulation of the nervous system in muscle activities. Unlike passive-active restraint or muscle-strength training isolatedly, neuromuscular training has been designed to raise the activity Time- Coordinated Reaction Speed response pattern in leg musculature within their central nervous systems through Sensory-Motor integration processes. Therefore, through training, the common neuromuscular deficits in patients with Chronic Ankle Instability (CAI) such as weakened joint position sense, delayed muscle reaction time and problems related to dynamic posture control can be improved effectively. Specifically, there are single-leg balance, posture holding of unstable bodies, and jump-landing stability training. In order to restore the dynamical stability of the ankle joint.

Neuromuscular Control can be defined as the dynamic closed-loop mechanism of sensation input, Central Integration and Motor Output. Joints, muscles, tendons and skin sensory information that carries positional sense, movement sense, and tension sense through peripheral afferent nerve transmission to the central nervous system. After being integrated by the spinal cord and cerebral cortex, precise motor commands go down to the effectors and coordinate the activation timing and contraction strength of different muscle groups. After an ankle injury, the mechanoreceptors inside the ligament are damaged; proprioception of joints is weakened; Pain causes muscle paralysis. Together they form a "neuromuscular deficit," shown as delayed response of the peroneal muscles, not enough activation of the tibialis anterior, and weaker postural control. Neuromuscular training's purpose, then, is to break this vicious circle and restore the cooperative control capability of the central and peripheral nervous systems by repeatedly stimulating senses and practicing movements.

Based on the mechanism above, neuromuscular training in practice can be further divided into the following four kinds: First, proprioceptive training, mainly using single-leg standing, standing with eyes closed, and standing on a soft pad, with focus on improving joint position sense and movement sense. After eight weeks of proprioception exercises, the patients' ankle-joint position-sense error decreased by about 30 per cent compared with before training. Second, balance and dynamic stability training, including Star Excursion Balance Test training, single-leg jump-landing control, and posture keeping on unstable surfaces. This kind of training creates "controlled disturbances" to make lower limb muscles respond rapidly in order to maintain stability of the centre of gravity; thus improving dynamic posture control. Third, plyometric and reactive training, including box jumps, single-leg jumps, and lateral hop steps. Stress on quick eccentric-contraction changes in muscle

DOI: 10.54254/2753-7048/2026.33276

activities and simulates the need for direction change, takeoff and landing in basketball as much as possible. Six weeks of plyometrics have significantly improved the athlete's landing stability; Reaction time has also decreased [3]. Fourth, movement pattern correction training. According to the analysis of sports biomechanics, identify and correct abnormal movement patterns, such as knee valgus or ankle eversion during landing; And build a programme of good movement by repeating deliberate practice.

Khadije Kāzimī in her study divided the chronic-unstable ankle of the 34 patients into two groups. One group received conventional rehabilitation training, and the other group received conventional rehabilitation plus extra neuromuscular training. After 12 intervention sessions, the study found that the experimental group with added neuromuscular training had more obvious improvements than the control group in the cross-sectional area of the tibialis anterior, the posteromedial reach distance in the Y-Balance Test, and foot-ankle function scores. Among them, the experimental group increased by 21.45 points in the FAOS sports subscale score, while the control group increased by only 8.67 points. In terms of total scores, there was an increase of 14.15 in the experimental group and only 7.96 in the control group. Thus, incorporating neuromuscular training increased the effectiveness of rehabilitation for ankle functions in this study [4]. Direct support to the extra value of neuromuscular training in promoting functional recovery following an ankle injury.

Another research, involving sixteen male basketball players. The eight participants who received plyometric exercises and basketball training; The other eight participants were not trained at all. After six weeks, or twelve sessions, of plyometric neuromuscular training, it was found through this research that both the training and control groups had shown some improvement in each direction; In contrast, only the basketball-trained group did not show any improvements in their SEBT performance [5].

3. Technological methods

The arrival of the technology age means that rehabilitation training methods are developing and changing all the time, so the CAI problem in basketball players can be handled more effectively and players can return to the court. Some common new ankle rehabilitation training methods are described below.

3.1. Biofeedback technology

Biofeedback technology uses electromyography or inertial sensors to periodically monitor the degree of muscle activity in the area around the feet and changes in joint angles; then, it displays this information for the athlete through visual or auditory means regularly. In landing or cutting training in basketball, athletes can judge from the feedback signals whether the ankle is in a neutral position and whether the target muscles contract in time, so they can actively correct wrong posture and improve the accuracy of proprioceptive training. At the same time, the monitoring device during training can provide real-time charts of muscle use, helping athletes adjust posture and force more directly.

This feedback mechanism lets athletes clearly see the gap between their own movement and the ideal pattern, so they can adjust actively. This closed-loop process of trial, error and correction is used to accelerate the reprogramming of motors and improve training efficiency and rehabilitation results more effectively. This method is very suitable for high-risk movements training, including landings cushioning, lateral cuts and defensive slide.

DOI: 10.54254/2753-7048/2026.33276

Research shows that Kim et al. gave 30 patients with chronic ankle instability a six-week gait training program, twice a week, with visual and auditory feedback. The results showed that the intervention group improved its foot and ankle ability measure-activities of daily living (FAAM-ADL) score from 88.66% to 92.60% ($p = 0.002$), and its sports score from 80.79% to 85.67% ($p < 0.001$) [6]. This shows that training combined with real-time biofeedback can effectively improve ankle function and dynamic stability.

3.2. Virtual Reality (VR) training

Virtual Reality (VR) is used to recreate the actual scene of defending against slides, recovering from landing after catching balls, etc., for patients' ankle rehabilitation exercises within a simulated environment. This way of training can increase patients' participation and interest, improve the training effect, and at the same time strengthen ankle stability.

Meta-analysis of 52 studies between 2015 and 2024 that covered 1,650 top-class athletes and 620 rehabilitation clients. The study found that there was 18% increase in the speed of decision making for athletes after VR training ($p<0.001$; 95%CI: 12%-24%) compared to before; Rehabilitation Patients were more engaged with VR Training than conventional Training [7]. The study shows that, in terms of rehabilitation training effects with VR technology.

Virtual Reality technology creates an immersion of a three-dimensional Space through the head-worn display device and so on; At this time, Athletes need not risk real-life operations for their training purposes. VR training is generally more effective than traditional ones. Firstly, it is very close to real match situations: it can simulate the visual input, sound, and time pressure in matches, so the training content matches real play very well and improves the transfer of sports skills. Secondly, add some gamelike components that motivate users by giving them scores or levels to raise motivation. Thirdly, it is possible to set the difficulty of the environment; that is, the level of opponents' Speed, Defend power, etc., can be changed accurately to achieve a gradual increase in workload.

The Design of VR Training for Basketball Ankle Rehabilitation is mainly divided into three parts: first, Action specificality, meaning that there must be some essential basketball skills in the training scenario, such as defensive slide, rebound landing and breakaway Directional transformation; Second, Immediacy feedback, it requires that each action receive an immediate judgment after execution, for example, "Good Land angle", center-of-gravity shifting too much;" third, matching challenge with ability, meaning task difficulty should be dynamically adjusted to the athlete's current functional level, so a flow state can be kept and training benefit can be maximized.

3.3. Robot-assisted training

Programmable ankle rehabilitation robots can be used to provide athletes with precise assistance and resistance training for basketball-specific actions. According to the athlete's real-time performance, the robot can dynamically adjust training intensity and motion path and give safety protection and movement guidance in actions like cutting in, sudden stopping, and take-off. In this way, it helps athletes rebuild dynamic stability in a controllable environment.

Asna Kalsoom systematically reviewed the progress in mechanical design, driving mode, and control strategy of ankle rehabilitation robots over the last nearly twenty years. As a key structure for body weight bearing and dynamic stability, the ankle has very high requirements for precise control and repetitive training in rehabilitation. Robot-assisted training can provide objective quantitative assessment and accurately monitor ankle range of motion, torque output, and muscle

DOI: 10.54254/2753-7048/2026.33276

synergy patterns. At the same time, it reduces the therapist's workload in repetitive movement guidance and makes personalized and standardized rehabilitation plans possible. Among these, the Assist-as-needed (AAN) control strategy is especially important. It can dynamically adjust the assistive force according to the patient's real-time ankle performance, give necessary support when the patient's ability is not enough, and reduce intervention in time when ability recovers, so active participation can be effectively promoted [8]. Although current data on robot rehabilitation studies for the ankle is still not enough, the technical advantages above provide important theoretical support for improving rehabilitation efficiency and return-to-sport rate after ankle injury.

4. Integration and moving toward synergy

The demands of modern basketball are no longer only that athletes can walk and run, but that they can still keep joint stability under high-intensity confrontation and high-speed direction changes. Removing symptoms is only the start; returning to peak performance is the final point. Neuromuscular training alone is hard to achieve full-process quantitative monitoring, and technology assistance alone cannot replace the proprioceptive stimulation of functional training. Therefore, integrating the two is the key.

The essence of neuromuscular control is a circulating pathway of sensory information input, central integration, and motor command output. With the help of technology assistance, sensory information that is hard to catch, such as plantar pressure distribution and ankle angle deviation, can be turned in real time into visual or auditory signals, so athletes can actively correct wrong posture. With repeated correction training, abnormal movement patterns can gradually fade and new habits can form.

This mechanism has been preliminarily verified. In a randomized controlled trial of 32 athletes with chronic ankle instability, Faghihi found that VR game training and balance training had similar effects in improving perceived ankle instability and dynamic balance, and the VR group also showed significant improvement in muscle activation timing, with earlier activation time of the biceps femoris ($P = 0.043$). This proves that technology assistance can effectively strengthen neuromuscular control [9]. Faghihi's study reveals an important phenomenon: technology assistance does not simply replace traditional training. Instead, by improving the efficiency of neuromuscular control, such as optimizing muscle activation timing, it achieved a rehabilitation effect that was equal to traditional training but more efficient. This shows that the value of technologies such as VR is not only to increase interest and compliance, but also that they can precisely intervene in the timing part of neuromuscular control. It cannot be realized solely by the old methods of education.

Study of 100 athletes with an ankle injury. In combination with basic rehabilitation exercises such as range-of-motion training for joints, neuromuscular training, and one-legged balance training using VR technology, robots and biofeedback equipment, etc., the athletes' physiological data and training results can be unified, and personalised rehabilitation plans can be generated via a data analysis system. The results showed that, in the severe injury group, under the comprehensive model of basic plus biomechanics plus technology assistance, the recovery range of dorsiflexion angle reached 16-20 degrees, which was almost double compared with 8-11 degrees in the basic training model. Balance performance improved by about 2-3 seconds relative to the basic training group (1.2-2.1 seconds) [10]. It can be seen from this that integrating technology aid with basics training helps speed up recovery of the job market and builds functionality for re-entry into workplace at judges.

DOI: 10.54254/2753-7048/2026.33276

5. Conclusion

Ankle injuries often occur in basketballers and recur frequently, so their requirements for the rehabilitation effect are also relatively demanding. Combined neuromuscular training and technological support have achieved a much better rehabilitation outcome than using the former alone. The advantages of their combination are shown in quantified improvement of joint function recovery, micro-level optimization of neuromuscular control efficiency, and full-process quantification and personalized matching of the rehabilitation process. This pushes ankle rehabilitation for basketball players from being driven by experience only to being driven by both data and experience. Real-time biofeedback technology, virtual reality scene-based training, robot-assisted training, etc., have also provided some evidence in practice that the integrated path is valuable for returning athletes to the court quickly.

However, current research still faces many bottlenecks: most studies are small-sample explorations, and data specifically from basketball are limited; the stability of device test results still needs improvement; clear standards have not been fixed and individualized integration plans are lacking; data are rich but hard to turn into precise training prescriptions.

Therefore, future work needs to focus on carrying out multi-center and large-sample studies, building dynamic parameter models for ankle rehabilitation; promoting technology from people adapting to devices to devices adapting to people, so adaptive feedback can be achieved; and introducing AI-assisted decision making. Through the construction of a large-scale rehabilitation database, we hope to advance towards precision rehabilitation in the future.

References

[1] Aksović, N., Bubanj, S., Bjelica, B., Kocić, M., Lilić, L., Zelenović, M., Stanković, D., Milanović, F., Pajović, L., Čaprić, I., Milić, V., Dobrescu, T., & Sufaru, C. (2024). Sports Injuries in Basketball Players: A Systematic Review. Life (Basel, Switzerland), 14(7), 898. https: //doi.org/10.3390/life14070898

[2] Fu, C., & Wang, R. (2026). Multidimensional treatment strategies for acute ankle sports injuries: Innovative integration from emergency care to functional rehabilitation. Chinese Journal of Typical Cases, preprint. https: //doi.org/10.20256/j.cnki.zgdxbl.20260126.016

[3] Lynch, B. M., Owen, N., Newman, B., Pakenham, K., Leggett, B., Dunn, J., & Aitken, J. F. (2006). Reliability of a measure of prediagnosis physical activity for cancer survivors. Medicine and science in sports and exercise, 38(4), 715–719. https: //doi.org/10.1249/01.mss.0000210196.94952.8b

[4] Kazemi, K., Javanshir, K., Saadi, F., Goharpey, S., Shaterzadeh Yazdi, M. J., Calvo-Lobo, C., López-López, D., & Nassadj, G. (2025). The Effect of Additional Neuromuscular Training on Peri-Ankle Muscle Morphology and Function in Chronic Ankle Instability Subjects: A Randomized Controlled Trial. Sports health, 17(3), 572–584. https: //doi.org/10.1177/19417381241258467

[5] Asadi, A., Saez de Villarreal, E., & Arazi, H. (2015). The Effects of Plyometric Type Neuromuscular Training on Postural Control Performance of Male Team Basketball Players. Journal of strength and conditioning research, 29(7), 1870–1875. https: //doi.org/10.1519/JSC.0000000000000832

[6] Kim, B. H., Kang, T. K., & Lee, S. Y. (2025). Integrating Biofeedback in Dynamic Biomechanical Gait Training for Chronic Ankle Instability. Applied Sciences, 15(4), 1688. https: //doi.org/10.3390/app15041688

[7] Peng, Y., Zheng, L., & Li, Y. (2026). VR/AR in sports science: Enhancing performance and rehabilitation. International Journal of Physical Activity and Health, A046.

[8] Kalsoom, A., Shah, M. F., & Farooq, M. U. (2025). Advancements in State-of-the-Art Ankle Rehabilitation Robotic Devices: A Review of Design, Actuation and Control Strategies. Machines, 13(5), 429. https: //doi.org/10.3390/machines13050429

[9] Faghihi, R., & Khanmohammadi, R. (2024). Comparing virtual reality and balance training effects on postural strategies during ball kicking in soccer players with chronic ankle instability. Scientific reports, 14(1), 31448. https: //doi.org/10.1038/s41598-024-83071-6

[10] Zhang, Y. (2025).Research on early rehabilitation intervention for ankle sprains in football players. Gansu Sports Science Research, (3), 123–128.