Joint Diseases and Related Surgery

Jt Dis Relat Surg
2024;35(1):54-61

ORIGINAL ARTICLE

Effect of hip strategy-based motion control training on walking function restoration after ankle joint injury

Na Liu, MM[1,2*], Ming Zhang, MM[2*], Shi-Ming Feng, MM[3], Ying-Li Bi, MM[2], Hong-Wei Zhai, MB[1,2], Qing Meng, MM[2]

[1]Department of Rehabilitation Medicine, Xuzhou Central Hospital, Xuzhou, China
[2]Department of Rehabilitation Medicine, Xuzhou Rehabilitation Hospital, Xuzhou, China
[3]Department of Orthopaedics, Xuzhou Central Hospital, Xuzhou, China

ABSTRACT

Objectives: The study aimed to explore the effect of hip strategy-based motion control training on the recovery of walking function after ankle injury and the optimization of the rehabilitation program.

Patients and methods: In the study, 62 patients with ankle injuries were randomly divided into the observation group (n=30; 24 males, 6 females; mean age: 41.9±8.5 years; range, 28 to 56 years) and the control group (n=32; 26 males, 6 females; mean age: 42.0±9.3 years; range, 27 to 55 years) between September 2021 and September 2022. Both groups were treated using routine rehabilitation training, including conventional drug and rehabilitation treatment. The observation group additionally received hip strategy-based motion control training, which included hip muscle strength training, hip joint stability control training, balance testing and training system training, and three-dimensional gait analysis system training for six weeks. All patients were evaluated before and after the treatment using the balance function parameters (motion length and motion ellipse area), Berg Balance Scale, the timed up-and-go test, and three-dimensional gait analysis system (step length and step frequency).

Results: There was no significant difference in the evaluation indexes between the two groups before treatment ($p>0.05$). After treatment, the evaluation indexes of the two groups were significantly better than those before treatment ($p<0.05$), and all the indexes in the observation group were significantly better than those in the control group ($p<0.05$).

Conclusion: Hip strategy-based motion control training could significantly improve the recovery of walking function in patients with ankle injuries.

Keywords: Ankle injury, hip strategy-based motion control training, rehabilitation program, walking function.

Ankle joint injury is a common sports injury, encompassing various forms of bone fractures, dislocations, and ligament damage; such injuries can cause stiffness, pain, and reduced muscle strength in the ankle joint, significantly influencing patients' activity levels.[1,2] If proper rehabilitation is not applied to ankle injuries, 70% of patients may develop ankle instability and recurrent wounds, and 20 to 40% of acute ankle sprains develop into chronic ankle instability. This is mainly characterized by muscle weakness, ligament laxity, loss of control, intermittent pain, recurrent wounds, and decreased function, which can severely affect the patient's physical health and quality of life. Clinical rehabilitation focuses mainly on the ankle joint after fractures, thereby neglecting the essential aspect of the injury's impact on the overall functionality of the lower limb.[3] When secondary hip dysfunction is not adequately addressed, patients experience delayed healing times, subpar rehabilitation results, elevated fall risks, and

Received: June 21, 2023
Accepted: October 22, 2023
Published online: November 30, 2023

Correspondence: Hong-Wei Zhai, MD. Department of Rehabilitation Medicine, Xuzhou Rehabilitation Hospital, No. 10 of Kuizhong Lane, Yunlong District, Xuzhou 221000, China

E-mail: hongweizhai3127z@163.com

Doi: 10.52312/jdrs.2023.1277

** These authors contributed equally to this study.*

Citation: Liu N, Zhang M, Feng SM, Bi YL, Zhai HW, Meng Q. Effect of hip strategy-based motion control training on walking function restoration after ankle joint injury. Jt Dis Relat Surg 2024;35(1):54-61. doi: 10.52312/jdrs.2023.1277.

the recurrence of injuries after returning to their regular activities. These complications not only increase the burden of treatment for patients but also traumatize and distress their physical and emotional well-being.[4] The lower limb is a joint dynamic chain where the hip, knee, and ankle joints collaborate to maintain balance and achieve normal gait. It is noteworthy that distal ankle joint injury can cause proximal knee and hip joint functions to weaken, and the reduction of proximal joint function may increase the likelihood of distal joint damage. This means that the weakening of proximal joint muscle strength and the change of motion control ability can affect the occurrence and progression of lower limb injuries (e.g., ankle joint injury).[5] Furthermore, in long-term clinical practice, it has been observed that after ankle joint injury, patients often exhibit impaired hip joint motion control ability and a significant decrease in hip muscle strength.

The treatment of ankle joint injury is primarily focused on exercise and proprioception training of ankle joint muscles,[6] with few reports on motion control training of the hip mechanism.[5] Based on training for hip muscle strength, hip mechanism-based motion control training primarily refers to training for hip joint stability control, balance testing, training systems, and three-dimensional gait analysis systems.[7] This series of exercises enhances the flexibility and stability of the lower limb joints.[7] Moreover, existing research suggests that in the development of knee injury prevention and treatment programs, emphasis should be placed on hip motion control exercises rather than solely on muscle strength training.[8] However, the evidence for the application effectiveness of hip mechanism-based motion control training remains insufficient. Hence, this study aimed to investigate the impact of hip mechanism-based motion control training on the recovery of walking function after ankle joint injury. We hypothesized that hip mechanism-based motion control training can significantly improve the recovery of walking function in patients with ankle injuries by enhancing hip muscle strength, hip joint stability, and overall lower limb functionality.

PATIENTS AND METHODS

In the study, convenience sampling was used to select 62 patients with ankle joint injuries treated in the rehabilitation department of the Xuzhou Central Hospital and Xuzhou Rehabilitation Hospital between September 2021 and September 2022. According to simple randomization, a random number generator was adopted to divide the patients into two groups, with even numbers assigned to the control group (n=32; 26 males, 6 females; mean age: 42.0±9.3 years; range, 28 to 56 years) and odd numbers assigned to the observation group (n=30; 24 males, 6 females; mean age: 41.9±8.5 years; range, 27 to 55 years). The inclusion criteria were as follows: *(i)* being aged 18 to 60 years, with a disease course of six weeks to six months; *(ii)* fractures or ligament injuries that had reached clinical healing standards, with no obvious deformities in the lower limbs; *(iii)* unilateral ankle joint injury; *(iv)* no other associated injuries; *(v)* no history of trauma to both lower limbs. The exclusion criteria were as follows: *(i)* the existence of other diseases that cause walking difficulties; *(ii)* coexisting significant organ diseases (e.g., heart, liver, lung, and kidney); *(iii)* severe cognitive impairment, pathological fractures, postoperative infection, or concomitant nerve injury; *(iv)* previous standardized rehabilitation treatment being ineffective after four weeks; *(v)* inability to cooperate with the evaluation or treatment. The elimination and dropout criteria were as follows: patients who felt unable to complete relevant evaluations or rehabilitation treatments during the study or who withdrew for any reason.

Both groups of patients received a comprehensive rehabilitation treatment using conventional methods, and the observation group additionally received the hip mechanism-based motion control training program.

Conventional comprehensive rehabilitation treatment methods

Conventional drug treatment has anti-inflammatory and analgesic properties, reduces soft tissue swelling, and promotes bone health.[9] Conventional comprehensive rehabilitation treatment involved joint mobilization and joint traction techniques, muscle strength and endurance training, Chinese medicine fumigation, and proprioception training.[9]

In the joint mobilization technique, accurate and effective treatment methods should be selected according to the problems (pain or stiffness) and the degree of joint angle. When pain and stiffness coexist, level I and II techniques are generally used to relieve pain first, and then level III and IV techniques are used to improve joint mobility.[10] In the treatment process, it is advised to continuously inquire about the patient's feelings and adjust the intensity of the technique according to feedback. Each session lasts 20 min, twice per day.

In the joint traction technique, the traction force should be smooth according to the fracture and ligament healing conditions using a sitting or prone position so that the patient feels a certain degree of tension or mild pain in the local muscles without causing reflex muscle spasms. Each session lasts 10 to 20 min, once per day.

Muscle strength and endurance training included bodyweight resistance training, isometric training, isotonic training, and muscle endurance training (isotonic training method, isometric training method). According to the healing condition, joint condition, and tolerance to pressure and exercise, appropriate methods and intensities should be selected and applied once per day.

Chinese medicine fumigation included atomizing Chinese herbal medicine solutions, using Chinese medicine ion penetration therapy of suitable temperatures, degree of drug, and humidity for ankle joint injury, relaxing the tendons, promoting blood circulation, and relieving pain. Each session lasts 20 min, twice per day.

During proprioception training, the patient stands barefoot on a balance pad, with both feet separated at shoulder width, and the therapist ensures safety behind the patient. With knees bent and in a half-squat position, the patient taps the ball in all directions for 2 min. This is done once per day, six days a week.

Hip mechanism-based motion control training program

The hip mechanism-based control training program is visualized in Figures 1 and 2.[11] Bodyweight resistance training and progressive resistance training were utilized for hip muscle strengthening, in which resistance is placed at the far end of the limb, in the opposite direction of the motion, using appropriate and gradually increasing resistance. Once the patient cannot complete the full range of joint activity, feels pain in the resistance area, or experiences compensatory motions, such as muscle tremors during exercise, the resistance area should be changed, or the resistance strength should be reduced (10 times per set, four to six sets per day, six times per week).

The following training methods were used for hip joint stability control training: single-handed kneeling two-point support training, affected side lying forearm support training, and prone extension training. During single-handed kneeling two-point support training, the patient lies in a prone position, the left upper limb elbows are placed straight, and the right lower limb is supported in the hip-knee position. When the patient's knee is supported, the lower-middle part of the calf should be padded to avoid excessive ankle force. The left lower limb is flexed at 90°, and the right upper limb is flexed horizontally, maintained for 10 sec then restored. Support training is alternated on both sides, and the action is repeated 10 times as one set, with five sets completed each time.

FIGURE 1. Visualization of the rehabilitation process.

FIGURE 2. Walking training schematic.

During affected side lying forearm support training, the patient lies on the floor, with the shoulders abducted and the forearms on the ground, and the affected side calf is supported in the middle and lower parts with a cushion to avoid force on the ankle and foot. The patient is instructed to use force on the hip and waist to straighten the body, the hip joint is kept in a neutral position, and the body and the ground form a triangle. This is maintained for 10 sec then restored, and the action is repeated 10 times as one set, with five sets completed each time.

During prone extension training, the patient lies in a prone position, the gluteal muscles and back muscles are tightened, and the chest and legs are lifted off the ground in a ”swallow style.” This is maintained for 10 sec then restored, and the action is repeated 10 times as one set, with five sets completed each time, six times per week.

For the balance testing and training system training, the balance training mode was selected, the appropriate level was chosen, and training was conducted with the patient in an open-eyed state. The training was started on the flat tablet system before gradually progressing to the soft pad and being completed with the eyes closed. This was done once per day for 15 min, six days per week.

The three-dimensional gait analysis system training was conducted using the WALKER VIEW walking training equipment (TecnoBody, Dalmine (BG), Italy). In this training method, the patient stands on the training platform with the therapist standing beside them. The starting speed is set based on the patient’s test and training performance, and the patient is required to walk in the correct posture. The walking speed is adjusted promptly as the function improves, simulating different life scenarios. This is done once per day for 10 to 15 min, six days per week.

Evaluation methods

The same physician used the same assessment criteria to evaluate the patients before and after six weeks of rehabilitation treatment in a double-blind state. This included the balance testing and training system (motion length and motion ellipse area), the Berg Balance Scale (BBS),[12] the timed up-and-go test (TUGT),[13] and the three-dimensional gait analysis system (step length and step frequency). The balance function of the patients was evaluated using the motion length and motion ellipse area measured using the balance testing and training system. The higher the obtained numerical value, the worse the patient’s body stability and balance, and the opposite indicated better balance function.

The BBS score ranges from 0 to 56 points, with a higher score indicating a better balance function. A score <40 suggests a risk of falling, while a score >40 indicates a good balance function. The TUGT score criteria were as follows: <10 sec, freely mobile; <20 sec, mostly independent mobility; 20-29 sec, unstable mobility; >30 sec, mobility impairment. A three-dimensional gait analyzer was used to evaluate the patient's walking ability before and after treatment by selecting the step length (cm) and frequency (steps/min). A larger increase in the measurement results indicated better walking rhythm and stability, and vice versa.[14]

Statistical analysis

Data were analyzed using IBM SPSS version 19.0 software (IBM Corp., Armonk, NY, USA). The Shapiro-Wilk test was performed to test the normality of the measurement data. Measurement data obeying normal distribution were expressed as mean ± standard deviation (SD). Independent sample t-tests were used for between-group mean comparisons, and paired t-tests were used for within-group mean comparisons. Measurement data disobeying normal distribution were analyzed using rank-sum tests, and chi-square tests were used for categorical data comparisons. A p-value <0.05 indicated a statistically significant difference.

RESULTS

The control group had a mean disease duration of 3.54±0.51 months, mean joint mobility of 25.55±3.33°, 22 ankle fractures, and 10 ankle ligament injuries. The observation group had a mean disease duration of 3.50±0.56 months, mean joint mobility of 23.20±3.01°, 20 ankle fractures, and 10 ankle ligament injuries. There was no significant difference in the clinical data between the two groups (p>0.05, Table I).

Evaluation of the balance testing and training system

After treatment, the observation group's motion length and motion ellipse area were 196.20±68.50 (p<0.05) and 169.60±42.62 (p<0.05), respectively. The control group's motion length and motion ellipse area were 271.36±78.09 and 227.36±69.33, respectively, both of which were longer than those of the observation group. Furthermore, the motion length and motion ellipse area of both groups improved after treatment (p<0.05, Table II).

Berg Balance Scale evaluation

After treatment, the BBS evaluation of the observation group was 45.10±3.38, which was higher than that in the control group (40.55±3.67, p<0.05). In addition, the BBS evaluation of both groups improved after treatment (p<0.05, Table III).

The timed up-and-go test evaluation

Following treatment, the observation group's TUGT evaluation considerably improved compared to the control group (p<0.05). Additionally, both groups' TUGT evaluations were better after treatment (p<0.05, Table III).

Evaluation of the three-dimensional gait analysis system

Following treatment, the observation group's step length and frequency were both better than those of the control group (p<0.05). Additionally, both

TABLE I
Baseline characteristics of participants

	Observation group (n=30)		Control group (n=32)			
Variables	n	Mean±SD	n	Mean±SD	χ^2	*p*
Age (year)		41.9±8.5		42.0±9.3	0.071	0.641
Sex						
Male	24		26			
Female	6		6			
Disease duration (month)		3.50±0.56		3.54±0.51	0.034	0.824
Joint mobility (°)		23.20±3.01		25.55±3.33	1.067	0.137
Type of ankle joint injury					0.031	0.861
Ankle fracture	20		22			
Ankle ligament injury	10		10			

SD: Standard deviation.

TABLE II
Comparison of evaluation indexes of the balance system between the two groups

	Observation group (n=30)	Control group (n=32)		
Variables	Mean±SD	Mean±SD	t	*p*
Motion length (mm)				
Before treatment	284.90±82.18	324.55±75.93	1.15	0.27
After treatment	196.20±68.50*	271.36±78.09*	24.19	<0.001
Motion elliptic area (mm^2)				
Before treatment	251.90±62.89	264.55±71.50	0.43	0.67
After treatment	169.60±42.62*	227.36±69.33*	9.88	<0.001

SD: Standard deviation; Compared with before treatment, * p<0.05.

TABLE III
Comparison of evaluation indexes of BBS and TUGT between the two groups

	Observation group (n=30)	Control group (n=32)		
Variables	Mean±SD	Mean±SD	t	*p*
BBS score				
Before treatment	35.00±4.52	33.91±4.04	0.58	0.566
After treatment	45.10±3.38*	40.55±3.67*	2.95	0.008
TUGT score				
Before treatment	18.22±2.21	16.81±2.26	1.44	0.165
After treatment	10.82±1.49*	12.75±1.86*	21.09	<0.001

SD: Standard deviation; BBS: Berg Balance Scale; TUGT: Time 'Up and Go' Test; Compared with before treatment, * p<0.05.

TABLE IV
Comparison of evaluation indexes of step length and step frequency between the two groups

	Observation group (n=30)	Control group (n=32)		
Variables	Mean±SD	Mean±SD	t	*p*
Step length (cm)				
Before treatment	24.04±2.77	23.78±2.31	0.23	0.818
After treatment	34.01±2.99*	30.75±2.24*	27.21	<0.001
Step frequency (step/min)				
Before treatment	85.60±6.77	84.09±6.95	0.50	0.621
After treatment	105.20±7.96*	97.64±6.85*	57.77	<0.001

SD: Standard deviation; Compared with before treatment, * p<0.05.

groups' step frequency increased after treatment ($p<0.05$, Table IV).

Adverse reactions

All participants in the experiment had no adverse reactions, no patients experienced falls or sports injuries, and all completed the experiment smoothly.

DISCUSSION

The ankle joint serves as a pivot point for motion and is a significant weight-bearing joint in the human body. Although this joint is prone to injury, its stability and flexibility allow the human body to undertake a variety of motions like standing, walking, sprinting, and jumping. A reduction in the body's ability to balance and coordinate itself as well as aberrant walking function may result from the ankle joint's dysfunction.[15,16] The ankle, hip, and stride regulation mechanisms are the three basic mechanisms the human body uses to maintain balance. The body relies on the hip regulation mechanism to maintain stability if the ankle regulation mechanism is unable to keep balance. Therefore, after ankle joint injury, the hip joint may act as a compensatory regulation mechanism to maintain balance and allow patients to perform various functional activities.[17]

Most rehabilitation treatments focus on local ankle muscle strength training while neglecting the auxiliary role of hip muscle strength improvement in lower limb function. In fact, hip joint motion control plays an important role in the function of the lower limbs.[15] Muscles around the hip joint, also known as the core muscles, help control body posture and efficiently transmit muscle strength.[18,19] The gluteus medius and contralateral adductor muscles form the lateral stability system of the hip, while the gluteus maximus and the paraspinal muscles on the contralateral trunk form the posterior stability system of the hip.[9] Good hip joint control, particularly of the gluteus maximus and gluteus medius, provides important protection for the function of the knee, ankle, and foot. It maintains stability in the sagittal and coronal planes during daily activities, effectively resists external interference, and prevents lower limb injury.[20,21] This study compared differences in the improvement of the motion length and elliptical area of the balance test system between the control group and the observation group based on conventional treatment through hip muscle strengthening training using bodyweight and progressive resistance training of the hip-surrounding muscles. The observation group improved more significantly than the control group, demonstrating how strengthening exercises for the hip muscles can dramatically speed up the functional recovery of patients with ankle joint injuries. Therefore, through hip muscle strength training, the peak torque of hip adduction and extension muscles can be significantly increased, which greatly improves the posture control ability and ankle function activity of patients.[9]

As mentioned above, after ankle joint injury, the hip joint may serve as a compensatory mechanism to maintain balance and allow patients to complete various functional activities.[16] Therefore, stability control strengthening training of the hip joint can significantly improve the balance and walking function of ankle injury patients. This study showed that after adopting a hip mechanism-based motion control training program and performing hip joint stability control strengthening training, the step length and frequency, BBS score, and TUGT score in the observation group improved more than that in the control group. In addition, the hip, knee, and ankle joints form an integral lower limb kinetic chain, and distal ankle joint injury may lead to proximal knee and hip joint dysfunction. Therefore, ankle joint injury cannot be viewed as a local injury only. Hass et al.[22] stated that therapists should provide patients with an overall or central treatment plan. Furthermore, ankle joint injury can cause damage to proprioceptors, leading to a decrease in balance and coordination ability, which seriously affects walking function.[16] This study emphasizes that improving the overall lower limb kinetic chain function of the hip, knee, and ankle joints is beneficial for the comprehensive recovery of ankle function after injury. It can improve patient motivation, strengthen hip muscle group strength and control, train overall lower limb balance function, improve ankle joint function, and enhance lower limb stability and flexibility. It can also correct abnormal gait, improve adaptability to different scenarios, further improve walking function, reduce falls, and prevent secondary injuries using a balance testing and training system and a three-dimensional gait analysis system.

However, this study has certain limitations. First, the research participants were selected using convenience sampling, which may lead to bias. Second, the small sample size may not represent the overall picture. Third, the severity of the research participants' injuries was not considered, which may influence the results. Therefore, larger samples and multicenter studies should be carried out to further the research.

In conclusion, based on clinical experience and relevant theories, the existing conventional rehabilitation program was improved, and a hip strategy-based motor control training program was proposed, which significantly improved the walking function of patients with ankle injuries. This study suggests that the focus should not only be on the localization of the ankle joint in rehabilitation as patients mostly suffer from a significant decrease in the periprosthetic muscle strength and the ability of motor control of the hip. Ankle injuries should be seen from a holistic point of view, and a new model of rehabilitation should be explored from the view of the lower limb. This will provide a more effective and standardized rehabilitation program for patients with ankle injuries to recover their walking function and reduce the risk of falls and secondary injuries. Through walking rehabilitation, the recovery period can be shortened, the prognosis can be improved, the incidence of falls and secondary injuries can be reduced, the cost of treatment can be decreased, and the quality of life can be increased. Moreover, through the popularization of the results of this study, healthy people will be advised to prevent ankle injuries in daily activities and sports, which will contribute to the realization of the national health strategy and the integration of medicine and sports.

Ethics Committee Approval: The study protocol was approved by the Xuzhou Rehabilitation Hospital Ethics Committee (date: 28.04.2020, no: XK-LW-20200428-007). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from the patients.

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

Author Contributions: Conception and design: L.N., Z.M.; Administrative support: M.Q.; Provision of study materials or patients: F.S.M., B.Y.L.; Collection and assembly of data: Z.H.W.; Data analysis and interpretation: L.N., Z.M., Z.H.W.; Manuscript writing, final approval of manuscript: All authors.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: This work was supported by Xuzhou promotes technological innovation projects (grant no.: KC21228).

REFERENCES

1. Wu X, Gu Q. Comparison of different treatment methods for supination-lateral rotation ankle fractures. Jt Dis Relat Surg 2023;34:16-23. doi: 10.52312/jdrs.2023.814.
2. Çetin BV, Kaptan AY, Orhan Ö, Altay MA, Altay N, Demir S, et al. Comparison of the effectiveness of the WALANT method in soft tissue and bone tissue surgeries in lower extremities. Jt Dis Relat Surg 2023;34:439-44. doi: 10.52312/jdrs.2023.1025.
3. Hou H, Zhou M, Zhou X, Guo W, Zhuang R, Yin H, et al. Comparison arthroscopic reconstruction and percutaneous reconstruction of ankle lateral ligament for chronic ankle lateral instability: A protocol for a meta-analysis of comparative studies. Medicine (Baltimore) 2022;101:e31926. doi: 10.1097/MD.0000000000031926.
4. Pawik Ł, Pawik M, Wysoczańska E, Schabowska A, Morasiewicz P, Fink-Lwow F. In patients with grade I and II ankle sprains, dynamic taping seems to be helpful during certain tasks, exercises and tests in selected phases of the rehabilitation process: A preliminary report. Int J Environ Res Public Health 2022;19:5291. doi: 10.3390/ijerph19095291.
5. Lu J, Cai B, Fan S. Research progress on hip joint function in patients with chronic ankle instability. Chinese Journal of Rehabilitation 2019;34:328-32. doi: 10.3870/zgkf.2019.06.013.
6. Liu B, Zhang Y. Research progress on rehabilitation treatment for functional ankle instability with exercise intervention. Chinese Journal of Rehabilitation Medicine 2020;35:758-763. doi: 10.3969/j.issn.1001-1242.2020.06.025.
7. Palmer K, Hebron C, Williams JM. A randomised trial into the effect of an isolated hip abductor strengthening programme and a functional motor control programme on knee kinematics and hip muscle strength. BMC Musculoskelet Disord 2015;16:105. doi: 10.1186/s12891-015-0563-9.
8. Lafrance S, Ouellet P, Alaoui R, Roy JS, Lewis J, Christiansen DH, et al. Motor control exercises compared to strengthening exercises for upper- and lower-extremity musculoskeletal disorders: A systematic review with meta-analyses of randomized controlled trials. Phys Ther 2021;101:pzab072. doi: 10.1093/ptj/pzab072.
9. Pilskog K, Gote TB, Odland HEJ, Fjeldsgaard KA, Dale H, Inderhaug E, et al. Traditional approach vs posterior approach for ankle fractures involving the posterior malleolus. Foot Ankle Int 2021;42:389-99. doi: 10.1177/1071100720969431.
10. Maitland G, Hengeveld E, Banks K, English K. Maitland's vertebral manipulation. Edinburgh: Churchill Livingston; 2005.
11. Sahabuddin FNA, Jamaludin NI, Amir NH, Shaharudin S. The effects of hip- and ankle-focused exercise intervention on dynamic knee valgus: A systematic review. PeerJ 2021;9:e11731. doi: 10.7717/peerj.11731.
12. Jin D, Yan T, Zeng H. Validity and reliability of Berg balance scale on assessing balance function. Chinese Journal of Rehabilitation Medicine 2003;18:25-7. doi: 10.3969/j.issn.1001-1242.2003.01.009.
13. Yan T. Introduction to the timed "up & to" test, a rapid quantitative evaluation method for functional walking ability. Chin J Rehabil Therory Pract 2000;6:115-7. doi: 10.3969/j.issn.1006-9771.2000.03.006.
14. Sung YH, Kim CJ, Yu BK, Kim KM. A hippotherapy simulator is effective to shift weight bearing toward the affected side during gait in patients with stroke. NeuroRehabilitation 2013;33:407-12. doi: 10.3233/NRE-130971.
15. Luo L, Sun W, Zhao X, Xu L, Cai Q, Xiao Q, et al. Effect of hip muscle strength strengthening training on functional ankle instability. Chin J Rehabil Therory Pract 2017;23:1195-1199. doi: 10.3969/j.issn.1006-9771.2017.10.015
16. Chen K, Wang X, Zhang Y, Tang L, Xu K, Ma YH. Study on hip and knee muscle strength and dynamic postural control in patients with chronic ankle instability. Chinese Journal of Rehabilitation 2022;37:363-366. doi: 10.3870/zgkf.2022.06.010.
17. Atik OŞ. Writing for Joint Diseases and Related Surgery (JDRS): There is something new and interesting in this article! Jt Dis Relat Surg 2023;34:533. doi: 10.52312/jdrs.2023.57916.
18. Yang XL, Bai X, Wang J, Wang ZB. Analysis of research status on ankle joint proprioception rehabilitation evaluation and training. Journal of Practical Orthopaedics 2014;20:922-24. doi: CNKI:SUN:SGKZ.0.2014-10-021
19. Zhai HW, Sun J, Gong ZK, Zhou JJ, Zhang M, Chen J, et al. Effect of proprioception training on recovery of ankle joint function impairment. Chin J Phys Med Rehabil 2016;38:147-49. doi: 10.3760/cma.j.issn.0254-1424.2016.02.017.
20. Brown CN, Padua DA, Marshall SW, Guskiewicz KM. Hip kinematics during a stop-jump task in patients with chronic ankle instability. J Athl Train 2011;46:461-7. doi: 10.4085/1062-6050-46.5.461.
21. Hu X, Mou X, Duan Q, Mao L, Jin ML, Li HL, et al. Effects of intensive lower extremity motor control training on function of lower extremities in stroke patients. Chin J Phys Med Rehabil 2015;21:552-6. doi: 10.3969/j.issn.1006-9771.2015.05.013.
22. Hass CJ, Bishop MD, Doidge D, Wikstrom EA. Chronic ankle instability alters central organization of movement. Am J Sports Med 2010;38:829-34. doi: 10.1177/0363546509351562.