Journal of The Korean Society of Integrative Medicine, 2022, 10(3), 63~72
https://doi.org/10.15268/ksim.2022.10.3.063
ISSN 2288-1174(Print)
ISSN 2383-9651(Online)

Acute Effects of Dynamic Stretching and Self-Mobilization of the Ankle Joint on Dorsiflexion Range of Motion, Muscle Strength, and Balance in Healthy Adults

Kyoung-Han Kim[1] · Yun-Seo Choi[1] · Jeongwoo Jeon, PT, Ph.D[2] · Jihoen Hong, PT, Ph.D[3] · Jaeho Yu, PT, Ph.D[3] · Jinseop Kim, PT, Ph.D[3] · Seong-Gil Kim, PT, Ph.D[3] · Dongyeop Lee, PT, Ph.D[3‡]

[1]Dept. of Physical Therapy, Sunmoon University, Student

[2]Dept. of Physical Therapy, Sunmoon University, Ph.D

[3]Dept. of Physical Therapy, Sunmoon University, Professor

Abstract

Purpose : Several studies have investigated the effects of dynamic stretching (DS) and self-mobilization (SM), however, studies comparing the two interventions are rare. Therefore, the purpose of this study was to compare the effects of DS and SM on ankle strength, dorsiflexion range of motion (DFROM), and balance to determine which is superior.

Methods : Thirty-two healthy young adults participated in this study. Participants were randomly assigned to two groups (SM and DS). DS was performed for the purpose of stretching the medial gastrocnemius muscle. For the SM group, ankle joint SM was performed in three ways. For all participants, the following measurements were performed as pre- and post-tests: isometric strength of dorsiflexor and plantar flexor, weight-bearing lunge test (WBLT) to evaluate DFROM, Tetrax system to evaluate static balance, and y balance test (YBT) to evaluate dynamic balance. Differences before and after the intervention within each group were compared using paired t-test. Also, the variable's variation was compared between groups using an independent t-test.

Results : Significant differences were found in ankle dorsiflexor strength, WBLT, YBT, weight distribution index (WDI) (pillow and opened eyes; PO), and stability index (ST) (normal and closed eyes; NC) before and after intervention in the SM group ($p<.05$). In the DS group, significant differences were found in ankle dorsiflexor and plantar flexor strength, WBLT, YBT anterior, WDI (normal and opened eyes; NO, PO), and ST (NO, NC, PO, pillow and closed eyes) before and after the intervention ($p<.05$). Ankle plantar flexor strength and WDI (PO) were significantly different between groups.

Conclusion : Based on the results of this study, DS or SM can be considered as a possibility for selective use according to variables for improving ankle joint function (DFROM, muscle strength, balance).

Key Words : ankle joint, balance, dynamic stretching, self-mobilization

‡Corresponding author : Dongyeop Lee, kan717@hanmail.net

Received : July 6, 2022 | Revised : August 6, 2022 | Accepted : August 12, 2022

Ⅰ. Introduction

The ankle joint plays an important role in body stability, such as controlling sway, absorbing shock during walking, and providing momentum for movement of the lower extremities (An et al., 2018; Karagiannakis et al., 2020). In order for the ankle joint to function properly, it requires a normal range of motion, proper sensation, and strength of the surrounding muscles (An et al., 2018).

The limited range of motion of the ankle joint is an important cause of structural defects and restriction of daily activities (Lin et al., 2009). Limited dorsiflexion range of motion (DFROM) can cause hyperextension of the knee by changing the position of the foot during weight-bearing and reducing the ability to correct the center of gravity (An & Jo, 2017). The decrease in ankle flexibility and range of motion as a result of changes in the musculoskeletal system with aging negatively affects balance ability (An et al., 2018). Moreover, limited DFROM has been associated with several lower extremity injuries, including ankle joint injuries, anterior cruciate ligament ruptures, achilles tendon injuries, and hamstring sprains, and may also negatively affect athlete performance (Moreno-Pérez et al., 2020). Additionally, previous studies involving healthy young adults have shown that DFROM may be an important factor in determining dorsiflexor strength (Guillén-Rogel et al., 2017).

Recent studies found that static stretching (SS) has a negative effect on muscle performance such as on maximal voluntary strength, muscle power, sprint time, and jump height (Ayala et al., 2015; Behm et al., 2016; Matsuo et al., 2019). On other hand, it has been demonstrated that dynamic stretching (DS) can improve performance prior to activities requiring muscle strength and power, such as jumping heights (Opplert & Babault, 2018; Peck et al., 2014). Thus, DS is preferred over SS when preparing for physical activity because it is effective in increasing ROM and increasing ankle joint flexibility without compromising strength (Behm et al., 2016; Pamboris et al., 2019). In particular, calf muscle stretching has been proven to improve the ROM of the ankle in both young and elderly (Searle et al., 2019). DS performed at a slow speed has been shown to have a greater advantage in muscle strength than at a fast speed, and consequently, a slow DS may be recommended as part of a warm-up in sports activities (Pamboris et al., 2019).

Joint mobilization is known to relieve pain and improve ROM (Landrum et al., 2008). Previous studies have shown that ankle self-mobilization (SM) increases the extension of non-contractile tissue by promoting the gliding of the tibia on a fixed talus when performing ankle dorsiflexion (Hoch et al., 2012; Howe, 2017; Park et al., 2018). As a result, it improves DFROM and increases joint play, enabling adequate functional activity. It has also been shown to be effective in improving dynamic balance, and ankle dorsiflexor muscle strength can be temporarily increased by performing Maitland grade III mobilization in healthy participants (Cruz-Díaz et al., 2020; Ersoy et al., 2019).

Although many studies have reported on the positive effects of each of DS and SM, few studies have confirmed which one is superior based on the comparison of the effects of the two interventions on various variables such as ROM, balance, and strength. Therefore, the purpose of this study was to compare the acute effects of DS and SM on DFROM, static and dynamic balance, and muscle strength in healthy adults. The data collected in this study can be useful data for professionals and patients in need of ankle joint rehabilitation.

Ⅱ. Methods

1. Participants

On the basis of a previous study investigating mobilization techniques on dorsiflexion (Marrón-Gómez et al., 2015), a power analysis (α =.05, power (1-β -error)=.95, r=.5, effect size d=1.31) was performed using statistical software (G-Power 3.1.9.7, Düsseldorf, Germany) required sample size of n = 14 for each group. To account for dropouts, we recruited 32 participants. Thirty-two healthy adults participated in this study. Participants filled out questionnaires aimed at identifying physical trauma or surgical history, neuromuscular injury, and those who were not participating in any other exercise program were selected for this study. Participants with a history of lower extremity injury, neurological diseases, vestibular organ damage, ankle instability, ankle pain, or inflammatory diseases were excluded from this study. Participants were randomly assigned to either DS or SM groups and were single-blind. All participants were provided with explanations of the procedures of this study and gave written informed consent. This study was approved by Sunmoon University institutional review board (SM-202104-022-1).

2. Experimental procedures

1) Outcome measurements

(1) Range of motion of ankle dorsiflexion

Weight-bearing lunge test (WBLT) was performed to measure the change in the weight-bearing DFROM of the ankle joint. WBLT has been reported as an appropriate method to evaluate DFROM through previous studies (Cruz-Díaz et al., 2020; Hall & Docherty, 2017). Participants placed their feet parallel to the tape measure attached to the floor and performed a forward lunge until the front knee of the leg to be measured touched the wall (Fig 1). The maximum distance at which the feet can be placed away from the wall was measured while keeping the participant's heels flat so that they do not fall off the floor and keeping the knees touching the wall. It was measured in millimeters (㎜) between the foot closest to the wall and the wall itself through a tape measure attached to the floor. Participants performed 3 test trials after 3 practice trials, and the mean value was used for analysis.

(2) Strength of the ankle dorsiflexor and plantar flexor

A hand-held dynamometer was used to measure the muscle strength of ankle DF and PF (Fig 2). The measurement procedure was performed based on previous studies (Howe, 2017). For measuring dorsiflexor muscle strength, after allowing the participant to supine position, the researcher placed the hand-held dynamometer on the top of the participant's metatarsophalangeal joint and secured it tightly with both hands to prevent movement. The participant was then asked to maintain the maximal voluntary isometric contraction for 3 to 5 seconds in a dorsiflexion 90-degree position. The muscle strength of the plantar flexor was also measured in the same way that the researcher held the hand-held dynamometer firmly on the soles of the subject's metatarsophalangeal joint and held it in place with both hands to prevent movement. One practice trial was performed prior to the test attempt. Ankle muscle strength was measured three times each at 10 seconds intervals and the mean value was used for analysis.

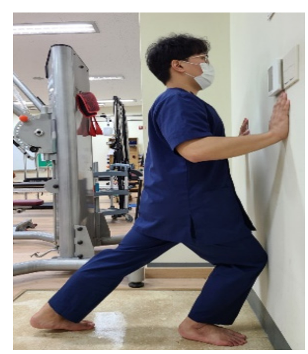

Fig 1. Weight-bearing lunge test

Fig 2. Isometric strength measurement of ankle dorsiflexor and plantar flexor

(3) Static balance

Fig 3. TETRAX system

The static balance was measured using TETRAX (Sunlight Medical Ltd, Ramat Gan, Israel)(Fig 3). The participant was asked to position the toes and heels of both feet on each platform (A-B-C-D) for the measurement of the static balance and to remain in a standing position for 32 seconds. Measurements were made in four ways: normal position with eyes open (NO), normal position with eyes closed (NC), eyes open on pillows (PO), and eyes closed on pillows (PC). The participants were asked to open their eyes and focus on the points marked about a meter ahead during the measurement. TETRAX pillow was used for measurement on unstable support surfaces. The stability index (ST) and weight distribution index (WDI) were used to assess static balance. WDI is a percentage of the weight load, and ST is a measure of the change in posture due to the change in weight, indicating stability. The lower the value, the higher the ability to balance.

(4) Dynamic balance

Dynamic balance was evaluated using the Y-Balance kit (Fig 4). Measurements were made based on previous studies (Hartley et al., 2018; Nakagawa & Petersen, 2018). The leg length was measured before the Y-balance test to data normalize. For the measurement of leg length, the length from the anterior superior iliac spine to the medial malleolus on the dominant leg of the subject was measured in centimeters using a tape measure. Participants were instructed to maintain barefoot in the middle of the Y-balance board and push the board as far as possible in the orientation of the anterior (Ant), posteromedial (PM), and posterolateral (PL) with their hands on the iliac crest (Fig 4). Participants were given four practice opportunities per direction, followed by three tests for each direction. In addition, the measured distance (㎝) in each direction was converted to a percentage of the leg length (%) and applied in the analysis.

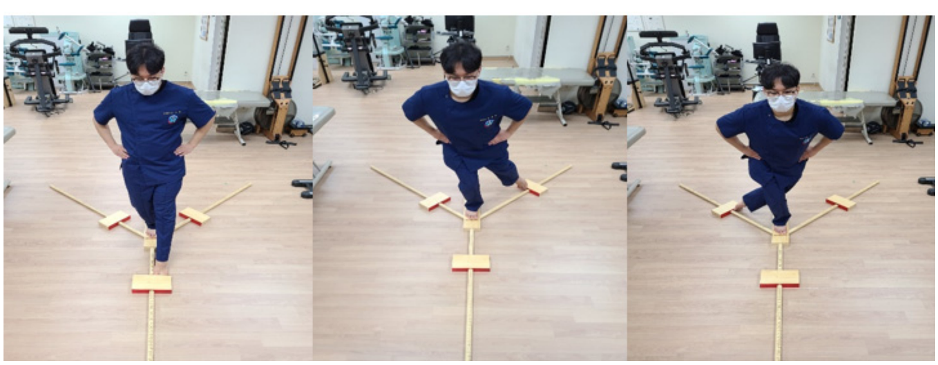

Fig 4. Y balance test

2) Intervention

(1) Dynamic stretching

DS was performed for the purpose of stretching the medial gastrocnemius muscle. The participants stood with their toes on the edge of the stairs and held the safety bar loosely for safety. Participants performed 3 sets of repeating the heel lowering and lifting 20 times according to the metronome of 50 BPM. The subjects lowered their heels once they heard the sound and lifted them to the next sound. The break time for each set was set to 5 seconds (Fig 5).

Fig 5. Dynamic stretching

(2) Self-mobilization

SM was performed in the following three ways. First, talus self-mobilization to increase DFROM was performed by applying tibia anterior-posterior gliding on fixed feet that actively support weight during dorsiflexion mobilization (Landrum et al., 2008). The participant made a 90-degree knee flexion with the foot on the step box and hung a resistance band on his ankle. At this time, the resistance band was tied to the lower part of the post in the back. The subject was asked to move the COG forward and perform dorsiflexion and return to its starting position (Fig 3). Second, the participant made 90 degrees of knee bending with one leg in front, and took a posture where the other knee touched the floor. Next, the participant was asked to put a 10 kg kettlebell on the knee of the foreleg, move the center of gravity forward, perform foot bending, and return to its starting position (Fig 4). Third, while the participant stretched his legs and sat on the floor, a band tied to a pillar was wrapped around his ankle to apply caudal distraction force. Another band wrapped around the soles of the feet was directly held by the subject, pulled the band toward the cranial, and asked to return to its starting position (Fig 5). Participants performed the above three methods 10 times and 3 sets, respectively, and the break time between each set was set to 1 minute (Cruz-Díaz et al., 2020).

Fig 6. Self-mobilization

3. Statistical Analysis

Descriptive statistics were used to calculate the mean and standard deviations of each group. To confirm that the collected data follows the normal distribution, we conducted the test of normality by using the Shapiro-Wilk test. As a result, we proved that the collected data follows a normal distribution which allowed us to use parametric statistics. Paired t-test was used to compare the differences before and after the intervention within the group, and an independent t-test was used to compare the differences in outcomes between each group. For statistical analysis, IBM SPSS statistical software version 22.0 was used, and the statistical significance level was set to α =.05.

Ⅲ. Results

The general characteristics of the participants are presented in Table 1. Table 2 shows a pre- and post-comparison of SM and DS for the strength, WBLT, YBT, and Tetrax. Significant differences were found in ankle dorsiflexor strength, WBLT, YBT, WDI (PO), and ST (NC) before and after intervention in the SM group ($p<.05$). In the DS group, significant differences were found in ankle dorsiflexor and plantar flexor strength, WBLT, YBT Ant, WDI (NO, PO), and ST (NO, NC, PO, PC) before and after the intervention ($p<.05$).

Table 3 shows the difference between groups in the amount of variation of each variable. Ankle plantar flexor strength and WDI (PO) were significantly different between groups.

Table 1. General characteristics of subjects (n=32)

Characteristics	Self-mobilization	Dynamic stretching	*p*
Sex (male / female)	8 / 8	8 / 8	
Age (years)	20.25±1.77	19.94±1.39	.654
Height (㎝)	168.06±9.08	168.44±8.96	.944
Weight (㎏)	65.56±16.65	67.25±13.04	.726
Leg length (㎝)	86.25±5.12	86.31±5.51	.967

M±SD; mean±standard deviation

Table 2. Comparison of ankle strength, dorsiflexion range of motion, and balance (static and dynamic) within group (n=32)

			Self-mobilization (n=16)			Dynamic stretching (n=16)		
			Pre	Post	*p*	Pre	Post	*p*
Strength (lbf)	DF		13.76±2.68	14.65±3.14	.005	14.12±2.22	16.09±2.99	.001
	PF		14.15±4.47	14.71±4.02	.150	13.43±5.05	15.96±4.75	<.001
WBLT (㎝)			12.09±3.71	13.59±3.21	<.001	12.00±4.38	13.53±3.93	<.001
YBT (% leg length)	Ant		70.04±7.73	75.28±7.43	.002	69.98±9.64	73.69±13.09	.006
	PM		107.89±10.01	113.71±10.77	<.001	111.91±9.08	114.71±11.88	.099
	PL		105.11±13.62	111.21±13.95	<.001	105.50±9.31	108.93±13.51	.067
Tetrax (scores)	WDI	NO	6.17±3.45	6.12±3.29	.471	8.43±2.79	6.75±3.80	.004
		NC	4.99±2.96	6.27±3.02	.497	7.84±2.80	6.73±3.16	.081
		PO	5.47±2.28	5.45±2.84	.599	5.93±3.06	7.46±3.22	.029
		PC	4.48±2.22	4.57±2.48	.307	5.13±2.81	6.63±2.92	.067
	ST	NO	15.06±5.25	15.07±5.71	.488	14.11±4.71	13.14±4.20	.014
		NC	17.56±5.17	17.09±5.63	.025	19.65±7.10	17.37±5.79	.004
		PO	17.61±3.90	15.91±5.11	.447	16.57±5.42	14.16±4.38	.009
		PC	25.38±7.91	25.41±5.73	.492	30.12±13.47	26.42±9.13	.032

M±SD; mean±standard deviation, DF; dorsiflexor, PF; plantar flexor, WBLT; weight bearing lunge test, YBT; y balance test, Ant; anterior, PM; posteromedial, PL; posterolateral, WDI; weight distribution index, ST; stability index, NO; normal and opened eyes, NC; normal and closed eyes, PO; pillow and opened eyes, PC; pillow and closed eyes

Table 3. Comparison of variations in ankle strength, dorsiflexion range, and balance (static and dynamic) between groups (n=32)

			Self-mobilization (n=16)	Dynamic stretching (n=16)	*p*
Strength (lbf)	DF		.89±1.21	1.97±2.12	.086
	PF		.56±2.10	2.53±1.88	.009
WBLT (㎝)			1.50±1.34	1.53±1.06	.942
YBT (% leg length)	Ant		5.24±6.07	3.71±5.22	.450
	PM		5.82±6.17	2.79±8.29	.251
	PL		6.10±5.50	3.43±8.88	.332
Tetrax (scores)	WDI	NO	-.05±2.79	-1.69±2.24	.077
		NC	1.29±2.62	-1.12±2.17	.269
		PO	-.02±2.34	1.52±2.50	.083
		PC	.09±2.54	1.50±2.27	.108
	ST	NO	.01±3.63	-.97±2.63	.391
		NC	-.47±3.65	-2.28±5.75	.296
		PO	-1.70±3.20	-2.41±3.10	.528
		PC	.03±6.31	-3.70±7.41	.135

M±SD; mean±standard deviation, DF; dorsiflexor, PF; plantar flexor, WBLT; weight bearing lunge test, YBT; y balance test, Ant; anterior, PM; posteromedial, PL; posterolateral, WDI; weight distribution index, ST; stability index, NO; normal and opened eyes, NC; normal and closed eyes, PO; pillow and opened eyes, PC; pillow and closed eyes

Ⅳ. Discussion

This study was conducted to compare the acute effects of SM and DS on ankle muscle strength, DFROM, and dynamic and static balance in healthy young adults.

In the DS group, similar to the previous study, there was a significant improvement in both muscle strength of the dorsiflexor and plantar flexor (Pamboris et al., 2019). This is consistent with the results of previous studies and is thought to be due to several existing mechanisms that improve performance due to increased muscle and core temperature, increased neuromuscular activity, and improved stimulation of the nervous system after dynamic stretching (Azeem & Sharma, 2014; Chatzopoulos et al., 2014). In addition, according to previous studies, dynamic stretching increases ROM and reduces stiffness in a continuous manner (Opplert & Babault, 2018).

In this study, there was also a significant improvement in DFROM immediately after dynamic stretching. This was consistent with the results of previous studies that dynamic stretching was effective in improving ROM (Behm et al., 2016; Chatzopoulos et al., 2014; Pamboris et al., 2019; Searle et al., 2019). Moreover, it has been previously reported that dynamic stretching increases muscle and core temperature, stimulates the nervous system, and increases neuromuscular activity, which has been proposed as a mechanism for improving balance ability (Chatzopoulos et al., 2014). For this reason, it is believed that DS showed a significant improvement in static balance unlike SM in the experimental results.

Additionally, correcting posture sway and placing the

COG in the base of support requires proper ankle muscle strength (Kim & Kim, 2018; Winter et al., 1990). In this study, the muscle strength of the ankle showed a greater improvement in DS overall than in SM, so it is believed that this may have an effect. On the other hand, dynamic stretching did not show a significant effect on dynamic balance. Previous studies have shown that fatigue in plantar flexors reduces the score of the star excursion balance test, and that fatigue in calf muscles in healthy students causes balance disorder. It is known that fatigue of the plantar flexor has a greater effect on dynamic balance than other muscles (Ghotbi et al., 2021). The DS method of calf muscles conducted in this study uses calf muscles to move the body up and down, and since dynamic balance was measured immediately after muscle use, it is believed that the repetitive stretching caused muscle fatigue.

In SM, there was a significant improvement in the muscle strength of the dorsiflexor. On the other hand, there was no significant difference in muscle strength of plantar flexor. This is consistent with the results of previous studies showing temporary muscle strength improvement immediately after mobilization (Ersoy et al., 2019). This is believed to be because posterior gliding among the methods of SM conducted based on previous studies increased dorsiflexion, but anterior gliding to increase plantar flexion was not included. In addition, according to previous studies, an increase in DFROM was observed immediately after mobilization (Gilbreath et al., 2014). As such, this study also showed a significant improvement in DFROM immediately after SM. The results of this study were consistent with the results of previous studies that mobilization is effective in increasing ROM (Hoch et al., 2012; Howe, 2017; Park et al., 2018).

This study has several limitations. First, the number of sample groups was small with 32 participants, and caution is needed in generalizing it to all age groups by conducting it for healthy men and women in their 20s. Second, due to the different types of exercise between the two groups, the intensity and time required for exercise between the groups could not be completely matched. Third, this study compares only the acute effects of DS and SM, and it is difficult to find out the long-term effects. Therefore, future studies need to revise and supplement these limitations.

Ⅴ. Conclusion

This study was conducted to investigate the acute effects of DS and SM on the DFROM, muscle strength, static balance, and dynamic balance of the ankle joint. As a result of the study, it was found that both DS and SM were effective in improving DFROM. DS was found to be effective in improving DF and PF muscle strength, and SM including posterior gliding was found to be effective in improving DF muscle strength. In addition, it was confirmed that DS was effective in static balance, and SM was effective in dynamic balance. Based on the results of this study, DS or SM can be considered as a possibility for selective use according to variables for improving ankle joint function (DFROM, muscle strength, balance).

Reference

An CM, Jo SO(2017). Effects of talocrural mobilization with movement on ankle strength, mobility, and weight-bearing ability in hemiplegic patients with chronic stroke: a randomized controlled trial. J Stroke Cerebrovasc Dis, 26(1), 169-176. https://doi.org/10.1016/j.jstrokecerebrovasdis.2016.09.005.

An HJ, Kim JS, Choi JH(2018). Influence of talocrural joint mobilization on balance and proprioception of adults with limited ankle joint dorsiflexion. J Int Acad Phys Ther Res, 9(4), 1651-1656. https://doi.org/10.20540/JIAPTR.2018.9.4.1651.

Ayala F, Croix MD, De Baranda PS, et al(2015). Acute effects of two different stretching techniques on isokinetic strength and power. Rev Andal Med Deport, 8(3), 93-102. https://doi.org/10.1016/j.ramd.2014.06.003.

Azeem Z, Sharma R(2014). Comparison of dynamic and static stretching on dynamic balance performance in recreational football players. Saudi J Sports Med, 14(2), 134-139. https://doi.org/10.4103/1319-6308.142370.

Behm DG, Blazevich AJ, Kay AD, et al(2016). Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. Appl Physiol Nutr Metab, 41(1), 1-11. https://doi.org/10.1139/apnm-2015-0235.

Chatzopoulos D, Galazoulas C, Patikas D, et al(2014). Acute effects of static and dynamic stretching on balance, agility, reaction time and movement time. J Sports Sci Med, 13(2), 403-409.

Cruz-Díaz D, Hita-Contreras F, Martínez-Amat A, et al(2020). Ankle-joint self-mobilization and CrossFit training in patients with chronic ankle instability: a randomized controlled trial. J Athl Train, 55(2), 159-168. https://doi.org/10.4085/1062-6050-181-18.

Ersoy U, Kocak UZ, Unuvar E, et al(2019). The acute effect of talocrural joint mobilization on dorsiflexor muscle strength in healthy individuals: a randomized controlled single-blind study. J Sport Rehabil, 28(6), 601-605. https://doi.org/10.1123/jsr.2018-0124.

Ghotbi N, Bayat M, Malmir K, et al(2021). The effects of lower extremity muscle fatigue on dynamic balance in volleyball players. Iran Rehabil J, 19(1), 51-58. https://doi.org/10.32598/irj.19.1.1003.1.

Gilbreath JP, Gaven SL, Van Lunen BL, et al(2014). The effects of mobilization with movement on dorsiflexion range of motion, dynamic balance, and self-reported function in individuals with chronic ankle instability. Man Ther, 19(2), 152-157. https://doi.org/10.1016/j.math.2013.10.001.

Guillén-Rogel P, San Emeterio C, Marín PJ(2017). Associations between ankle dorsiflexion range of motion and foot and ankle strength in young adults. J Phys Ther Sci, 29(8), 1363-1367. https://doi.org/10.1589/jpts.29.1363.

Hall EA, Docherty CL(2017). Validity of clinical outcome measures to evaluate ankle range of motion during the weight-bearing lunge test. J Sci Med Sport, 20(7), 618-621. https://doi.org/10.1016/j.jsams.2016.11.001.

Hartley EM, Hoch MC, Boling MC(2018). Y-balance test performance and BMI are associated with ankle sprain injury in collegiate male athletes. J Sci Med Sport, 21(7), 676-680. https://doi.org/10.1016/j.jsams.2017.10.014.

Hoch MC, Andreatta RD, Mullineaux DR, et al(2012). Two-week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. J Orthop Res, 30(11), 1798-1804. https://doi.org/10.1002/jor.22150.

Howe LP(2017). The acute effects of ankle mobilisations on lower extremity joint kinematics. J Bodyw Mov Ther, 21(4), 775-780. https://doi.org/10.1016/j.jbmt.2016.11.007.

Karagiannakis DN, Iatridou KI, Mandalidis DG(2020). Ankle muscles activation and postural stability with star excursion balance test in healthy individuals. Hum Mov Sci, 69, Printed Online. https://doi.org/10.1016/j.humov.2019.102563.

Kim SG, Kim WS(2018). Effect of ankle range of motion (ROM) and lower-extremity muscle strength on static balance control ability in young adults: a regression analysis. Med Sci Monit, 24, 3168-3175. https://doi.org/10.12659/MSM.908260.

Landrum EL, Kelln BM, Parente WR, et al(2008). Immediate effects of anterior-to-posterior talocrural joint mobilization after prolonged ankle immobilization: a preliminary study. J Man Manip Ther, 16(2), 100-105. https://doi.org/10.1179/106698108790818413.

Lin CW, Moseley AM, Herbert RD, et al(2009). Pain and dorsiflexion range of motion predict short-and medium-term activity limitation in people receiving physiotherapy intervention after ankle fracture: an observational study. Austr J Physiother, 55(1), 31-37. https://doi.org/10.1016/S0004-9514(09)70058-3.

Marrón-Gómez D, Rodríguez-Fernández ÁL, Martín-Urrialde JA(2015). The effect of two mobilization techniques on dorsiflexion in people with chronic ankle instability. Phys Ther Sport, 16(1), 10-15. https://doi.org/10.1016/j.ptsp.2014.02.001.

Matsuo S, Iwata M, Miyazaki M, et al(2019). Changes in flexibility and force are not different after static versus dynamic stretching. Sports Med Int open, 3(3), E89-95. https://doi.org/10.1055/a-1021-7893.

Moreno-Pérez V, Soler A, Ansa A, et al(2020). Acute and chronic effects of competition on ankle dorsiflexion ROM in professional football players. Eur J Sport Sci, 20(1), 51-60. https://doi.org/10.1080/17461391.2019.1611930.

Nakagawa TH, Petersen RS(2018). Relationship of hip and ankle range of motion, trunk muscle endurance with knee valgus and dynamic balance in males. Phys Ther Sport, 34, 174-179. https://doi.org/10.1016/j.ptsp.2018.10.006.

Opplert J, Babault N(2018). Acute effects of dynamic stretching on muscle flexibility and performance: an analysis of the current literature. Sports Med, 48(2), 299-325. https://doi.org/10.1007/s40279-017-0797-9.

Pamboris GM, Noorkoiv M, Baltzopoulos V, et al(2019). Dynamic stretching is not detrimental to neuromechanical and sensorimotor performance of ankle plantarflexors. Scand J Med Sci Sports, 29(2), 200-212. https://doi.org/10.1111/sms.13321.

Park D, Lee JH, Kang TW, et al(2018). Effects of a 4-week self-ankle mobilization with movement intervention on ankle passive range of motion, balance, gait, and activities of daily living in patients with chronic stroke: a randomized controlled study. J Stroke Cerebrovasc Dis, 27(12), 3451-3459. https://doi.org/10.1016/j.jstrokecerebrovasdis.2018.08.010.

Peck E, Chomko G, Gaz DV, et al(2014). The effects of stretching on performance. Curr Sports Medicine Rep, 13(3), 179-185. https://doi.org/10.1249/JSR.0000000000000052.

Searle A, Spink MJ, Oldmeadow C, et al(2019). Calf muscle stretching is ineffective in increasing ankle range of motion or reducing plantar pressures in people with diabetes and ankle equinus: a randomised controlled trial. Clin Biomech, 69, 52-57. https://doi.org/10.1016/j.clinbiomech.2019.07.005.

Winter DA, Patla AE, Frank JS(1990). Assessment of balance control in humans. Med prog technol, 16(1-2), 31-51.