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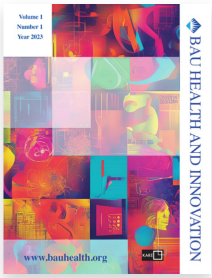

Original Article

Comparison of the Instant Effect of Different Foot Interventions on Balance and Reaction Time

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Abstract

Objectives: This study aimed to compare the instant effects of different foot interventions on balance and reaction time in healthy individuals.

Methods: The study was conducted as a single-blind randomized controlled trial. A total of 102 healthy participants who met the inclusion criteria were enrolled in the study and divided into three groups: Group I (the static stretching group), Group II (the static stretching and self-massage group), and Group III (the static stretching and massage group). Participants underwent single-leg balance tests with eyes open and closed, the Y-balance test, and the Nelson foot reaction test, both before and after the intervention. Demographic data were collected through a questionnaire.

Results: A statistically significant difference was found between pre- and post-intervention values of the single-leg standing test with eyes open and closed among the groups ($p < 0.05$). In the group comparison, it was observed that the pre-intervention values of Group III for the single-leg standing test with eyes open were higher than those of Group I and Group II ($p<0.017$). No statistically significant differences were found between pre- and post-intervention values for the Y-balance test among the groups ($p>0.05$). However, the post-intervention values of the Nelson test for Group II were found to be higher than those of Group I ($p<0.017$).

Conclusion: The findings of the study indicate that self-massage and massage applications have positive effects on balance and reaction time.

Keywords: Balance, plantar massage, reaction timeself-massage, static stretching.

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Balance is defined as the ability to maintain the body's center of mass within its base of support with minimal postural sway. The ability to maintain balance is a process based on the combination of visual, vestibular, and somatosensory inputs received by the central nervous system.[1] Reducing postural sway and enhancing the proprioceptive component of postural control are crucial for achieving balance.[2] Proprioception can be defined as the awareness of the mechanical and spatial position of the body and musculoskeletal components.[3] It allows for the perception of joint position and helps maintain balance while standing when vision is removed.[4]

The ankle plantar flexors are considered postural muscles and can influence postural control. Individuals with musculoskeletal injuries, such as plantar fasciitis or hip fractures, often exhibit reduced balance ability. Stretching can induce biomechanical and physiological changes in muscles, resulting in alterations in range of motion (ROM)

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and sensory perception. These adaptive changes in the lower extremities, including the gastrocnemius muscle, can affect postural control and balance ability.[2]

In a study conducted by Martinez et al.,[5] it was found that bilateral intermittent stretching of the ankle plantar flexors was more effective than continuous stretching for improving balance and provided an immediate enhancement in dorsiflexion and plantarflexion joint ROM. Costa et al.[6] examined the effects of static stretching on dynamic balance and found positive effects. Jung et al.[2] reported that after stretching the plantar flexor muscles, the sway area significantly decreased when the eyes were closed, and dynamic balance ability increased significantly in terms of reach distance.

The components of neuromuscular control include proprioception, muscle strength, postural control, and muscle reaction time.[7] Reaction time is defined as the time elapsed between the perception of a stimulus and the response to it.[8] Lajoie and Gallagher noted that individuals prone to falls in nursing homes had significantly slower reaction times compared to others.[9] It has been demonstrated that 5 min of cycling and static stretching of the ankle plantar flexor muscles have no significant immediate positive or negative effects on reaction time.[10]

A study showed that manual massage of the plantar region, without joint mobilization, immediately improved the dynamic balance of healthy participants, although no significant increase was found in static balance values.[11] In another study by Koblauch et al.,[12] self-massage of the plantar region immediately improved static balance compared to baseline, although more research was deemed necessary in this area.

The literature reveals a lack of studies on the effects of self-massage using a massage ball on reaction time. In addition, there are very few studies comparing the immediate effects of self-massage, stretching, and massage on static balance, dynamic balance, and foot reaction time. The aim of our study is to investigate the immediate effects of different foot interventions on balance and reaction time in healthy individuals.

Materials and Methods

Study Design and Participants

This study was conducted as a single-blind, randomized controlled study. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Non-interventional Ethics Committee at Medipol University (File Number: E-10840098-772.02-2934, date: June 21, 2021). The study was conducted from September 2022 to June 2023. Informed consent was obtained from all individual participants included in the study.

A total of 102 adults aged 18–50 who signed a written informed consent form were evaluated to determine eligibility for inclusion in our study. Inclusion criteria were being between 18 and 50 years of age, having a body mass index (BMI) of 20–25, having a normal ankle joint ROM, having a foot score between 0 and +5 according to the foot posture index, and having a score between 90 and 100 according to the Ankle-Hindfoot Scale. Exclusion criteria were having had foot and ankle surgery within the last 6 months, history of lower extremity injury with residual symptoms within the last year, having diseases affecting balance such as rheumatic disease, osteoarthritis, multiple sclerosis, being a professional athlete, being pregnant, being in the menopausal period, and having hip flexor muscle shortness on the sole.

Among 18 of the 120 individuals evaluated for inclusion in the study were excluded from the study because they did not meet the inclusion criteria. About 102 individuals who met the inclusion criteria were randomly divided into three groups: Static stretching group (Group I) (n=34), static stretching (Group II) and self-massage group (n=34), and static stretching and massage (Group III) (n=34). The "random.org" website and block randomization method were used for randomization. The algorithm for allocating participants to the study groups is shown in Figure 1.

Evaluation Parameters

Participants' physical information such as age (years), gender, height (m), and body weight (kg) were recorded. BMI was calculated by dividing body weight by height squared (kg/m^2). In addition, participants' educational status, marital status, and detailed medical histories were also recorded.

To determine the dominance of their lower extremities, participants were asked to kick a ball placed on the ground and their dominant side was determined after three trials. Foot posture index score, Thomas test, goniometric measurements, manual muscle test, and Ankle-Hindfoot Scale (AOFAS) were recorded only within the inclusion criteria before the interventions.

Thomas Test

This test was conducted to identify individuals with hip flexor muscle tightness before the study. While the patient is lying in a supine position, they flex one hip and keep the same knee maximally flexed against the chest. A gap between the leg and the table or noticeable hip

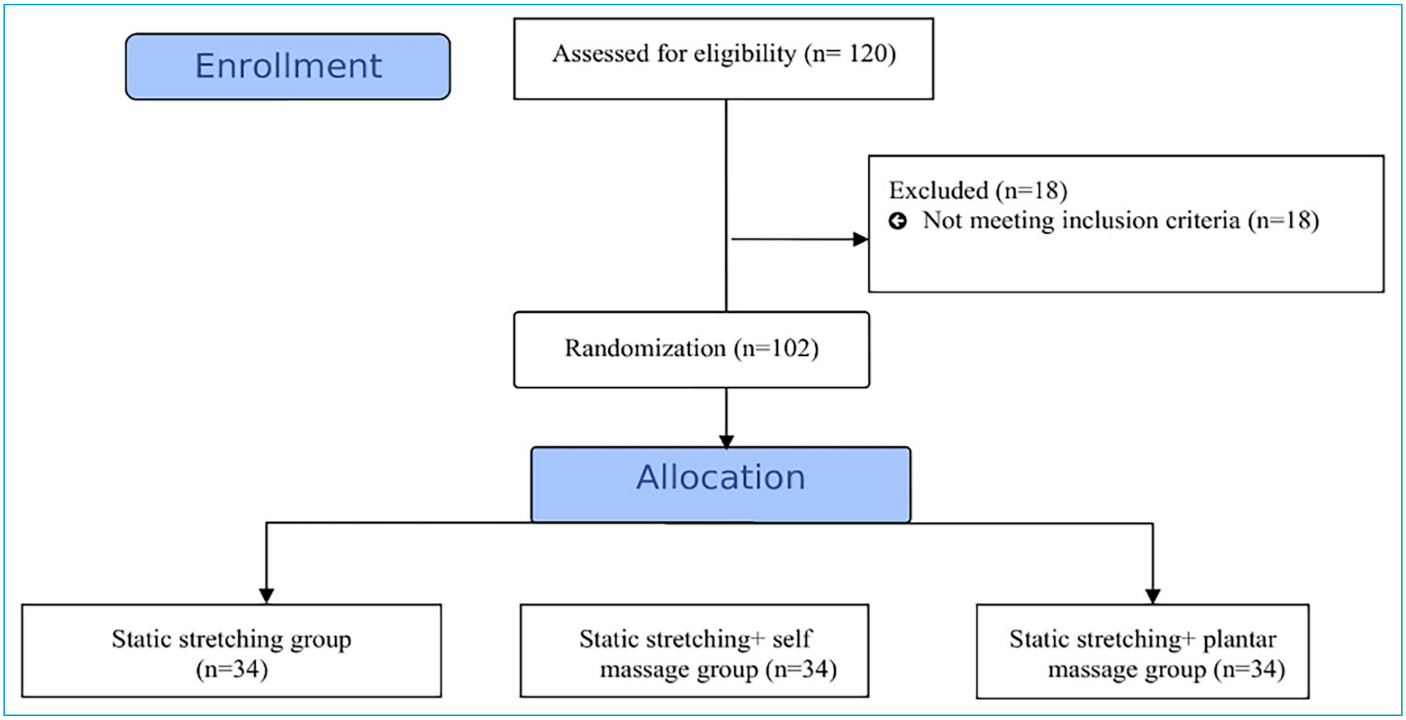

Figure 1. Flow chart of the study.

flexion in the contralateral leg can be observed as an indicator of hip flexor muscle tightness.[13]

The Foot Posture Index

Palpation of the talus head, supra- and infra-malleolar curvature, calcaneus position in the frontal plane, prominence in the talonavicular joint region, medial longitudinal arch congruence, and abduction/adduction of the forefoot on the rearfoot are among the characteristics evaluated. Each criterion is scored on a scale ranging from –2 to +2, and a total score between 0 and 5 indicates a neutral foot posture. Therefore, individuals with foot posture index scores within this range were included in the study.[14]

The AOFAS

It is a 100-point scoring system used to evaluate the ankle, hindfoot, midfoot, and hallux metatarsophalangeal-interphalangeal areas of the foot in terms of pain, function, and alignment. Scores between 0 and 69 are considered poor, 70–79 are fair, 80–89 are good, and 90–100 are excellent.[15] The AOFAS was assessed before the start of the study.

Manual Muscle Testing

Muscle strength of the gastrocnemius, tibialis anterior, and inversion and eversion muscles was assessed using manual muscle testing while the participants were in prone, supine, and seated positions.[16] Manual muscle testing was completed before the study.

Goniometric Measurements

The angles of dorsiflexion, plantarflexion, inversion, and eversion of the participants were measured using a goniometer before the study, and only feet with a normal ROM were included in the study.[16]

Outcome Measurements

Single-leg Balance Test with Eyes Open and Closed

The participant lifts one foot without touching the opposite leg and maintains it in flexion. The test is stopped if the lifted leg touches the standing leg, the raised foot makes contact with the ground, there is any hopping, or if support is taken from any surrounding object. The duration for which the participant maintains the position is measured in seconds using a stopwatch.[17] The single-leg standing test was performed before and immediately after the intervention.

Y-balance Test

The Y-balance test measures the dynamic limits of stability and asymmetric balance. While maintaining balance on one leg, the participant is instructed to reach with the toes of the opposite foot in three directions: Anterior, posteromedial, and posterolateral. Care is taken to ensure that the participant does not lose balance, the heel of the supporting foot does not lift off the ground, the reaching toes lightly touch the ground without bearing weight, and the foot is returned to the standing position without contact. The test is repeated 3 times in each direction, and the average reach distance for each direction is recorded in centimeters.[18] The test was performed both before and immediately after the intervention.

Nelson Foot Reaction Time Test

In this test, participants are seated with their toes positioned 2.5 cm away from the wall and their heels 5 cm from it. The evaluator holds a 30 cm plastic ruler between the participant's foot and the wall and releases it when the participant is ready. The participant attempts to catch the falling ruler by pressing it against the wall with their toes.[19] The Nelson foot reaction time test was conducted before and immediately after the intervention. Five measurements were taken for each foot, and the best scores were recorded.

Intervention

Participants were randomly assigned into three groups: The static stretching group (n=34), the static stretching and self-massage group (n=34), and the static stretching and massage group (n=34). The interventions were applied to the dominant foot. A wooden board measuring 67×27×10/15 cm was used for the stretching exercises.

Group I (n=34) (static stretching)

Participants in Group I performed a static stretching exercise. During the stretch, both forefeet were placed on an elevated platform whereas the heels were lowered off the platform without touching the ground, creating a static stretch. This position was held for 1 min with five repetitions, each separated by a 15-s rest period.

Group II (n=34) (static stretching and plantar self-massage)

In addition to the stretching performed by Group I, participants in Group II also engaged in plantar self-massage. The self-massage was done using a 7 cm spiky massage ball and was applied to the plantar surface of the foot for 5 min.

Group III (n=34) (static stretching and foot massage)

Participants in Group III received both stretching and massage interventions. Following the same stretching protocol as Group I, they then underwent a 10-min manual massage applied by a physiotherapist. To minimize bias, an analog dynamometer (Loyka, model NK 50) with a pressure value of 48 N was used during the massage protocol.

Massage Protocol

The technique was applied with both thumbs in the following sequence:

Table 1. Comparison of demographic characteristics of participants by group

	Group I (n=34) Mean±SD	Group II (n=34) Mean±SD	Group III (n=34) Mean±SD	F	p
Age (years)	29.50±9.81	30.00±8.26	26.00±8.91	1.84	0.164
Height (cm)	169.50±7.98	170.0±11.30	170.0±8.98	0.25	0.773
Weight (kg)	66.00±9.91	68.50±12.40	65.00±10.54	0.08	0.915
BMI	24.33±2.06	23.99±1.87	23.05±1.93	0.32	0.727

SD: Standard deviation, BMI: Body mass index.

A) Pressure was applied in a vertical direction with a sliding motion across each interdigital space and along the longitudinal arch (five repetitions of 10 s each).

B) Pressure was applied with horizontal sliding motion across the metatarsal heads (five repetitions of 5 s each).

C) Five repetitions of 10 s each were used to apply static pressure to the heel, the middle of the midfoot, and the first and fifth metatarsal heads.

Statistical Analysis

Data obtained in the study were analyzed using the Statistical Package for Social Sciences for Windows 25.0 software. Descriptive statistical methods (number, percentage, median, mean, and standard deviation) were used to evaluate the data. The normality of the data distribution was tested. The suitability for normal distribution was examined using Q-Q Plot analysis.[20] In addition, the normality of the data was determined by skewness and kurtosis values being within ±3.[21] One-way analysis of variance was used to compare pre- and post-treatments results between three groups, and the paired sample t-test was used to compare pre- and post-treatment results within groups. The level of statistical significance was determined as $p<0.05$.

Results

A total of 102 individuals who volunteered, met the inclusion criteria and completed the assessments were included in the study. Participants were divided into three groups: The static stretching group, the static stretching and self-massage group, and the static stretching and massage group.

Table 1 displays the demographic information (age, height, weight, and BMI) compared between the groups. A comparison of the groups' age, height, weight, and BMI values revealed no statistically significant differences ($p>0.05$).

Table 2. Comparison of single-leg standing test values between and within groups

	Group I			Group II			Group III			F	p	Bonferroni
	Mean	X̄	SD	Mean	X̄	SD	Mean	X̄	SD			
Eyes open												
Pre	57.00	60.70	15.95	75.00	70.97	22.19	84.00	82.41	19.42	10.699	0.000*	III>I, III>II
Post	70.00	71.18	13.31	76.50	74.94	18.14	81.00	81.85	19.71	3.343	0.039*	III>I
t	-3.398	-2.176	0.281									
p	0.002*	0.037*	0.781									
Eyes closed												
Pre	22.00	21.68	4.59	25.00	23.35	4.92	21.50	20.62	4.42	2.993	0.055	
Post	21.50	21.97	5.22	25.00	24.91	3.46	23.00	22.56	4.05	4.445	0.014*	II>I
t	-0.433	-2.302	-3.466									
p	0.668	0.028*	0.001*									

*: p<0.05. SD: Standard deviation.

The comparison of single-leg standing test values between and within groups is shown in Table 2. A statistically significant difference was observed in the pre- and post-intervention values of the single-leg standing test with eyes open among the groups (p<0.05). In the intergroup comparison, it was found that Group III had higher pre-intervention values for the single-leg standing test with eyes open compared to Groups I and II (p<0.017). A statistically significant difference was also found in the post-intervention values of the single-leg standing test with eyes closed among the groups (p<0.05). It was determined that Group II had higher post-intervention values for the single-leg standing test with eyes closed compared to Group I (p<0.017). In intragroup comparisons, statistically significant differences were observed in the pre- and post-intervention values for the single-leg standing test with eyes open and closed in Group II (p<0.05). The post-intervention values of Group II for the single-leg standing test with eyes open and closed were found to be higher than their pre-intervention values (p<0.017).

No statistically significant differences were found between the pre- and post-intervention values for the anterior, posteromedial, and posterolateral directions of the Y-balance test among the groups (p>0.05). However, Group I showed statistically significant differences between pre- and post-intervention values for the anterior, posteromedial, and posterolateral directions of the Y-balance test (p<0.05). The post-intervention values for Group I were higher than the pre-intervention values for all three directions (p<0.017). Group II exhibited an increase in the post-intervention values for the posterolateral direction of the Y-balance test compared to pre-intervention values. Similarly, Group III demonstrated higher post-intervention values for the posterolateral direction of the Y-balance test compared to pre-intervention values (p<0.017) (Table 3).

There was a statistically significant difference in the post-intervention values of the Nelson test among the groups (p<0.05). Group II had higher post-intervention values for the Nelson test compared to Group I (p<0.017). In intragroup comparisons, statistically significant differences were found between pre- and post-intervention values for the Nelson test in all three groups (p<0.05). It was observed that the pre-intervention values for the Nelson test were higher than the post-intervention values across all groups (p< 0.017) (Table 4).

Discussion

In our study examining the instant effects of different foot interventions on balance and reaction time, the impact of each intervention and their relative superiority to each other were compared. The results demonstrated that the group receiving static stretching and foot massage had higher pre- and post-intervention values for the single-leg standing test with eyes open compared to the other groups. The group that underwent static stretching and self-massage showed higher post-intervention values for the single-leg standing test with eyes closed, as well as for the posteromedial and posterolateral directions of the Y-balance test, compared to their pre-intervention values. All three groups exhibited positive improvements in the Nelson test results, with the static stretching and self-massage group achieving the highest post-intervention values among the groups.

Awareness of the acute effects of different exercise methods is essential for recommending them in an exercise program in a discretionary sequence. However, there is limited

Table 3. Comparison of Y-balance test values between and within groups

	Group I			Group II			Group III			F	p
	Mean	X̄	SD	Mean	X̄	SD	Mean	X̄	SD		
Anterior											
Pre	73.49	74.12	11.21	78.66	77.86	13.47	76.16	75.14	12.54	0.820	0.443
Post	75.33	76.95	12.23	75.99	77.75	14.41	76.50	76.32	11.73	0.106	0.900
t	-5.033	0.238	-1.466								
p	0.000*	0.814	0.152								
Posteromedial											
Pre	72.33	74.39	12.34	74.33	77.63	20.83	70.99	73.05	16.24	0.666	0.516
Post	76.66	78.99	12.28	78.16	79.50	19.61	67.33	73.44	17.02	1.395	0.253
t	-5.168	-3.107	-0.338								
p	0.000*	0.004*	0.738								
Posterolateral											
Pre	66.00	67.06	14.87	67.33	73.16	21.49	58.16	65.16	16.66	1.855	0.162
Post	69.33	70.33	14.33	71.00	74.85	20.54	63.66	67.13	15.71	1.753	0.179
t	-3.232	-2.436	-2.112								
p	0.003*	0.020*	0.042*								

*: p<0.05.

Table 4. Comparison of nelson test values between and within groups

	Group I			Group II			Group III			F	p	Bonferroni
	Mean	X̄	SD	Mean	X̄	SD	Mean	X̄	SD			
Nelson test												
Pre	10.00	9.68	5.81	11.00	11.12	6.35	7.00	8.00	5.81	2.300	0.106	
Post	1.50	2.59	2.67	3.00	4.03	4.12	0.50	1.73	2.35	4.619	0.012*	II>I
t	9.592	7.885	8.177									
p	0.000*	0.000*	0.000*									

*: p<0.05.

information regarding the acute effects of these methods on the ankle. Existing studies reveal inconsistencies that may stem from differences in participants, measurement tools, and intervention protocols.[22,23] Most studies in the literature have been conducted on patients with specific diagnoses.[22,24] There are only a limited number of studies, similar in nature to ours, that investigate different foot interventions in healthy adults.

Static balance is maintained by the muscles located in the anterior part of the body, whereas dynamic balance is maintained by the muscles in the posterior part.[25] Flexibility of the lower extremities has been shown to be crucial for the successful performance of sports and daily life activities. Joint flexibility, bilateral asymmetries in flexibility, and asymmetries in Y-balance test performance have been associated with injuries.[26] In a study by Endo et al.,[27] the relationship between lower extremity balance, measured by the Star Balance test, and lower extremity muscle tightness was examined in middle school baseball players. A significant relationship was found between lower extremity muscle tightness and dynamic balance performance. In our study, the Thomas test was used to identify hip flexor muscle tightness in the participants. The absence of hip flexor muscle tightness was set as an inclusion criterion to ensure that participants' balance was not affected.

In a study by Vaillant et al.[28] involving older adults, it was observed that a single session of manual therapy applied to the foot and ankle had positive effects on both static and dynamic balance. Similarly, Ruescas-Nicolau et al.[11] reported that a 10-min manual plantar massage protocol applied to ninety-eight healthy feet stimulated plantar cutaneous mechanoreceptors. This protocol, performed without joint mobilization, was highlighted for its beneficial effects on dynamic balance. Notably, this improvement was observed bilaterally despite stimulation only on the plantar surface. In the study conducted by Martínez-Jiménez et al.,[29] balance values increased following interventions involving pressure and traction applied to the plantar fascia of the foot. As emphasized in other studies, changes in the amount of feedback from the plantar surface can lead to alterations in postural responses and stability. The findings of these studies are in significant alignment with the balanced outcomes observed in our intervention. In our study, the post-intervention values for the single-leg standing test with eyes open in Group III, which received manual plantar massage combined with static stretching, were higher compared to Group I, which only received static stretching, reflecting similar results.

According to other findings of the study, the group that received self-massage showed higher post-intervention values for the single-leg standing test with eyes open and closed compared to the group that received static stretching. The literature on the effects of self-massage on the plantar surface of the foot is limited. In a study by Gabriel et al.,[30] it was observed that a 10-min self-massage applied to the plantar surface of healthy adults aged 18 to 30 years could influence performance in the dorsal kinetic chain. While previous studies have shown that self-massage increases flexibility, its impact on force production remains unclear. This study explored the effects of self-massage on the dorsal kinetic chain performance of the treated dominant leg, finding a negative impact, whereas mild improvements were observed in the untreated non-dominant leg. Our findings provide important insights into how self-massage can be utilized in training and rehabilitation. Russo et al.[31] also demonstrated that the effects of self-massage on the plantar surface can last up to an hour after the intervention and that the magnitude of changes in muscle chain flexibility depends on individual flexibility levels. Therefore, future studies could explore effects lasting up to 1 h, though our study focused on immediate values.

In our study, the Nelson test was used to measure reaction time in the dominant lower extremity. Statistically significant differences were observed in the post-intervention values of the Nelson test among the groups. The group that received static stretching and self-massage showed higher post-intervention values than the static stretching group. Reaction time is defined as the period between the arrival of a stimulus in the central nervous system, its evaluation, the necessary adjustments, and the appropriate response. Jehu et al.[32] studied the effects of balance training on postural sway and reaction time in healthy adults and assessed whether these improvements could be maintained over a 12-week follow-up period. They reported that reaction time improved following the intervention and that its effects persisted for 12 weeks. The literature predominantly examines the long-term effects of interventions on reaction time in healthy feet rather than immediate effects. In the study by Alpkaya et al.,[10] no significant changes in force production and reaction time were observed in the immediate measurements following static stretching of the soleus and gastrocnemius muscles in 15 participants. In contrast, improvements in reaction time were observed in all three groups following the interventions in our study.

The present study has some limitations. It focused solely on the acute effects of the intervention groups, and ankle joint ROM values were not available. Future research could explore repeating the same protocol and testing the flexibility of plantar muscles. In addition, future studies could examine the flexibility of not only the plantar muscles but also the gastrocnemius, hamstring, and quadriceps muscles. Another limitation of our study was the use of non-computerized assessment methods.

Conclusion

This study is one of the limited works in the literature exploring the combined effects of self-massage, stretching, and massage, contributing to filling a knowledge gap in this area. The findings of the study indicate that self-massage and massage applications have more positive effects on balance and reaction time. The results highlight the effectiveness of different foot interventions in enhancing balance and improving reaction time, offering significant contributions to the fields of physical rehabilitation and sports performance enhancement.

Disclosures

Ethics Committee Approval: The study was approved by the Medipol University Non-interventional Cilinical Research Ethics Committee (no: E-10840098-772.02-2934, date: 21/06/2021).

Authorship Contributions: Concept – B.N.S.; Design – B.N.S., M.Y.M.; Supervision – M.Y.M.; Funding – B.N.S., M.Y.M.; Materials – B.N.S., M.Y.M.; Data collection and/or processing – B.N.S.; Data analysis and/or interpretation – M.Y.M.; Writing – B.N.S., M.Y.M.; Literature search – B.N.S., M.Y.M.; Writing – B.N.S., M.Y.M.; Critical review – M.Y.M.; Writing – B.N.S., M.Y.M.; Critical review – M.Y.M.

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References

1. Alashram AR, Annino G, Raju M, Padua E. Effects of physical therapy interventions on balance ability in people with traumatic brain injury: A systematic review. NeuroRehabilitation 2020;46(4):455–66.
2. Jung EY, Jung JH, Cho HY, Kim SH. Effects of Plantar Flexor Stretching on Static and Dynamic Balance in Healthy Adults. Int J Environ Res Public Health 2023;20(2):1462.
3. Héroux ME, Butler AA, Robertson LS, Fisher G, Gandevia SC. Proprioception: a new look at an old concept. J Appl Physiol (1985) 2022 Mar;132(3):811–4.
4. Akay T, Murray AJ. Relative Contribution of Proprioceptive and Vestibular Sensory Systems to Locomotion: Opportunities for Discovery in the Age of Molecular Science. Int J Mol Sci 2021;22(3):1467.
5. Martínez-Jiménez EM, Losa-Iglesias ME, Becerro-de-Bengoa-Vallejo R, Díaz-Velázquez JI, López-López D, Calvo-Lobo C, et al. Immediate Effects of Intermittent Bilateral Ankle Plantar Flexors Static Stretching on Balance and Plantar Pressures. J Manipulative Physiol Ther 2020;43(1):24–31.
6. Costa PB, Graves BS, Whitehurst M, Jacobs PL. The acute effects of different durations of static stretching on dynamic balance performance. J Strength Cond Res 2009;23(1):141–7.
7. Denyer JR, Hewitt NL, Mitchell AC. Foot structure and muscle reaction time to a simulated ankle sprain. J Athl Train 2013;48(3):326–30.
8. Zwierko T, Florkiewicz B, Fogtman S, Kszak-Krzyżanowska A. The ability to maintain attention during visuomotor task performance in handball players and nonathletes. Cent Eur J Sport Sci Med 2014;3(7):99–106.
9. Lajoie Y, Gallagher SP. Predicting falls within the elderly community: comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. Arch Gerontol Geriatr 2004;38(1):11–26.
10. Alpkaya U, Koceja D. The effects of acute static stretching on reaction time and force. J Sports Med Phys Fitness 2007;47(2):147–50.
11. Ruescas-Nicolau MA, Sánchez-Sánchez ML, Marques-Sule E, Espí-López GV. The immediate effect of plantar stimulation on dynamic and static balance: A randomized controlled trial. J Back Musculoskelet Rehabil 2019;32(3):453–61.
12. Koblauch H, Samuelsen JA, Sporsheim SB. The effect of three different foot interventions on standing balance in healthy adults. Eur J Physiother 2017;20:1–5.
13. Vigotsky AD, Lehman GJ, Beardsley C, Contreras B, Chung B, Feser EH. The modified Thomas test is not a valid measure of hip extension unless pelvic tilt is controlled. PeerJ 2016;4:e2325.
14. Keenan AM, Redmond AC, Horton M, Conaghan PG, Tennant A. The Foot Posture Index: Rasch analysis of a novel, foot-specific outcome measure. Arch Phys Med Rehabil 2007;88(1):88–93.
15. Analay Akbaba Y, Celik D, Ogut RT. Translation, Cross-Cultural Adaptation, Reliability, and Validity of Turkish Version of the American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale. J Foot Ankle Surg 2016;55(6):1139–42.
16. Otman S, Köse N. Tedavi Hareketlerinde Temel Değerlendirme Prensipleri. Ankara: Pelikan Yayıncılık: 2015. p. 85–92
17. Choi YM, Dobson F, Martin J, Bennell KL, Hinman RS. Interrater and intrarater reliability of common clinical standing balance tests for people with hip osteoarthritis. Phys Ther 2014;94(5):696–704.
18. Powden CJ, Dodds TK, Gabriel EH. THE RELIABILITY OF THE STAR EXCURSION BALANCE TEST AND LOWER QUARTER Y-BALANCE TEST IN HEALTHY ADULTS: A SYSTEMATIC REVIEW. Int J Sports Phys Ther 2019;14(5):683–94.
19. Reddy VB, Valli SK. Effect of meditational practices on movement time, reaction time, anxiety and perception among elite athletes of Andhra Pradesh. Int J Health, Phys Educa and Comput Sci in Sports 2014;15:71–2.
20. Chan YH. Biostatistics 101: data presentation. Singapore Med J 2003;44(6):280-5.
21. Shao AT. Marketing Research: An Aid to Decision Making, Cincinnati, Ohio: South-Western/Thomson Learning. 2002.
22. Smajla D, García-Ramos A, Tomažin K, Strojnik V. Selective effect of static stretching, concentric contractions, and a balance task on ankle force sense. PLoS One 2019;14(1):e0210881.
23. Prasertsakul T, Kaimuk P, Chinjenpradit W, Limroongreungrat W, Charoensuk W. The effect of virtual reality-based balance training on motor learning and postural control in healthy adults: a randomized preliminary study. Biomed Eng Online 2018;17(1):124.
24. Navarro-Peternella FM, Teston EF, Dos Santos Santiago Ribeiro BM, Marcon SS. Plantar Cutaneous Sensory Stimulation Improves Foot Sensibility and Gait Speed in Older Adults With Diabetes: A Clinical Trial. Adv Skin Wound Care 2019;32(12):568–73.
25. Shin HJ, Jung JH, Kim SH, Hahm SC, Cho HY. A Comparison of the Transient Effect of Complex and Core Stability Exercises on Static Balance Ability and Muscle Activation during Static Standing in Healthy Male Adults. Healthcare (Basel) 2020;8(4):375.
26. Overmoyer GV, Reiser RF 2nd. Relationships between lower-extremity flexibility, asymmetries, and the Y balance test. J Strength Cond Res 2015;29(5):1240–7.
27. Endo Y, Sakamoto M. Relationship between Lower Extremity Tightness and Star Excursion Balance Test Performance in Junior High School Baseball Players. J Phys Ther Sci 2014;26(5):661–3.

28. Vaillant J, Rouland A, Martigné P, Braujou R, Nissen MJ, Caillat-Miousse JL, et al. Massage and mobilization of the feet and ankles in elderly adults: effect on clinical balance performance. Man Ther 2009;14(6):661–4.
29. Martínez-Jiménez EM, Becerro-de-Bengoa-Vallejo R, Losa-Iglesias ME, Díaz-Velázquez JI, Palomo-López P, Rodríguez-Sanz D, et al. Pressure and Traction Technique Improves Postural Control More Than Tactile Stimulation in Foot Plantar Fascia: A Randomized Single-Blind Trial. Arch Phys Med Rehabil 2020;101(6):978–84.
30. Gabriel A, Konrad A, Roidl A, Queisser J, Schleip R, Horstmann T, et al. Myofascial Treatment Techniques on the Plantar Surface Influence Functional Performance in the Dorsal Kinetic Chain. J Sports Sci Med 2022;21(1):13–22.
31. Russo L, Montagnani E, Pietrantuono D, D'Angona F, Fratini T, Di Giminiani R, et al. Self-Myofascial Release of the Foot Plantar Surface: The Effects of a Single Exercise Session on the Posterior Muscular Chain Flexibility after One Hour. Int J Environ Res Public Health 2023;20(2):974.
32. Jehu D, Paquet N, Lajoie Y. Balance and mobility training with or without concurrent cognitive training does not improve posture, but improves reaction time in healthy older adults. Gait Posture 2017;52:227–32.