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Postural stability efficacy of textured shoe inserts for ankle instability patients: A systematic review

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Abstract

Introduction: Postural stability disorders are one of the most important problems in ankle instability patients, which has been reported to be associated with mechanoreceptors damage. Textured shoe insert, by affecting the feet plantar skin, may improve postural stability. The aim of this study was a systematic review of studies that have investigated the impact of textured shoe insert on postural stability in ankle instability.

Methods: A systematic search was performed with the search queries that were constructed using medical subject headings in the Web of Science, Scopus, and PubMed databases. Title, abstract, and full-text review were done for article selection. Population, intervention, comparison, and outcomes data were extracted and analyzed narratively.

Results: A semicircular textured shoe insert led to decreased time required for postural stabilization and a reduction in the area of the postural sway ellipse. Furthermore, personalized inserts featuring textured surfaces and elevated ridges exhibited improvements in various clinical assessments of postural stability, including the star excursion balance, single-leg hop, and single-leg stance evaluations, resulting in increased reach distance capabilities and decreased errors.

Discussion: Shoe inserts designed with textured patterns have shown notable enhancements in postural stability for ankle instability. These results may be due to changes in spatiotemporal variables of sensory inputs.

Take-home message: The clinical importance of this finding, considering the ease of use and no need for special expertise in making this type of shoe inserts, is that textured shoe inserts can be easily recommended to individuals with ankle instability in sports or physiotherapy centers.
Keywords: ankle instability; insole; foot orthoses; postural control.

INTRODUCTION

Lateral ankle sprain is one of the most common orthopedic injuries in the physically active population [1,2], accounting for 25% of sports injuries [3]. The main mechanism of this injury is forced inversion of the ankle when the joint is in a plantar flexion position (loose pack position) [4]. After the first sprain, 50 to 70 percent of people experience residual symptoms such as pain, proprioception disorders [5], peroneal muscle weakness [6,7], and repeated sprains [8] for weeks or even years. The continuation of these symptoms for more than six months causes ankle instability [9]. One of the important problems in people with ankle instability is the decrease in postural stability in different situations, which has been suggested as a possible factor for predicting frequent sprains [10,11]. Past research has shown that static and dynamic postural stability is reduced in people with ankle instability [10]. Static postural stability refers to keeping the body's center of mass above the stationary base of support, while dynamic postural stability refers to maintaining the body's center of mass on a moving support surface or when an external perturbation is applied [12]. Postural stability control is essential to ensure safe functioning and is achieved by integrating sensory data such as vision, vestibular, and somatosensory information in the central nervous system [13].

Degradation of sensorimotor system performance is the main reason for ankle instability [11]. Freeman stated that the reason for ankle instability is damage to sensory receptors and problems with proprioception [14]. Postural stability disorders in these individuals occur due to damage to the mechanoreceptors of the lateral ligaments in the ankle [9]. These changes ultimately lead to alterations in muscle spindle sensitivity [15]. The central nervous system relies on sensory input from various receptors in the lower limb to establish movement pattern for maintaining postural stability [13]. According to the sensory reweighting theory, if one source of sensory information is damaged, the sensorimotor system automatically compensates by utilizing information from other available sources to maintain stability [16]. Since the plantar surface of the foot is the contact point with the ground during standing and dynamic postures, the sensory receptors in this area play a crucial role in maintaining postural stability [13].

By stimulating the plantar surface of the foot, it is possible to influence postural stability in these individuals [17].

The structure and geometric shape of shoe inserts can influence the feedback provided by the receptors on the foot plantar surface [18]. According to the hypothesis, textured shoe inserts may improve postural stability in individuals with ankle instability and reduce the risk of frequent ankle sprains. Review studies show that the use of this type of shoe inserts is effective in improving postural stability in different populations, including healthy elderly people [19, 20], and athletes [19], but no review study has been conducted regarding their effect on the population of people with ankle instability. The objective of this systematic review is to examine the impact of textured shoe inserts on postural stability in individuals with ankle instability.

METHODS

The current systematic review study followed the guidelines outlined by preferred reporting item for systematic reviews and meta-analysis. This included several stages such as identification, screening, eligibility, and inclusion [21].

Search strategy

To find relevant studies, we conducted searches in the PubMed, Web of Science, and Scopus databases. Additionally, Google Scholar was used for the final review. For each database, a search query was developed using the medical subject heading keywords (Table 1).

No	Search query	database	Result
1	(Foot orthos* [title/abstract] or insole [title/abstract] or shoe insert [title/abstract]) and (postural stability [title/abstract] or postural control [title/abstract] or balance [title/abstract]) and (ankle sprain [title/abstract] or ankle strain [title/abstract] or ankle instability [title/abstract])	PubMed	11
2	(TS= (Foot orthoses) OR TS=(insole) OR TS= (shoe insert)) AND (TS= (postural stability) OR TS= (postural control) OR TS=(balance)) AND (TS= (ankle sprain) OR TS= (ankle strain) OR TS= (ankle instability))	Web of Science	61
3	(TITLE-ABS-KEY (Foot orthos*) OR TITLE-ABS-KEY (insole) OR TITLE-ABS-KEY (shoe insert) AND (TITLE-ABS-KEY (postural stability) OR TITLE-ABS-KEY (postural control) OR TITLE-ABS-KEY (balance)) AND (TITLE-ABS-KEY (ankle sprain) OR TITLE-ABS-KEY (ankle strain) OR TITLE-ABS-KEY (ankle instability))	Scopus	69
4	allintitle: "postural stability" "ankle instability"	Google Scholar	103

The search process had no time limit, and all potentially relevant studies published until April 22, 2024, were identified. The information from these studies was then transferred to EndNote 20 software. An alert was also set up to monitor important databases such as PubMed and Scopus for any newly published articles during the study. Furthermore, to guarantee the inclusion of all relevant studies, we manually reviewed the references cited in the selected articles.

Study selection

To ensure accuracy and minimize errors, two researchers independently performed all the necessary steps, including searching for articles, selecting studies, conducting qualitative evaluations, and extracting data. In cases where there was disagreement between the researchers regarding the inclusion of certain articles, a final agreement was reached through discussions, and in some instances, with the involvement and input of all authors. After completing the search in the databases, duplicate articles were removed. Then, in order to avoid the risk of bias in the selection of studies, the names of the authors and the title of the journals were removed and a checklist was prepared based on the title and abstract of the studies. In the next step, two of the authors independently examined the title and abstract of the studies and excluded the studies not related to the research based on the inclusion and exclusion criteria. Then the full text of the remaining articles was evaluated.

Eligibility Criteria

The inclusion criteria were: 1) studies that examined the impact of textured shoe inserts on variables related to postural stability in individuals with ankle instability, 2) used quantitative analysis, 3) were accessible in full text, 4) were published in a peer-reviewed journal, and 5) were written in either English or Persian.

The exclusion criteria were as follows: 1) studies in the form of a thesis, conference paper, expert opinion, or letter to the editor, and 2) without full text availability.

Methodological quality assessment

The qualitative evaluation of the studies was done using PEDro's checklist, which is a suitable tool for the qualitative evaluation of clinical trial studies. This checklist has 11 items, but the first item, which is related to eligibility criteria, is not included in scoring. Grades 1 to 4 will be considered poor, grades 5 and 6 will be considered fair, grades 7 and 8 will be considered good, and grades 9 and 10 will be considered excellent [22].

Data extraction and synthesis

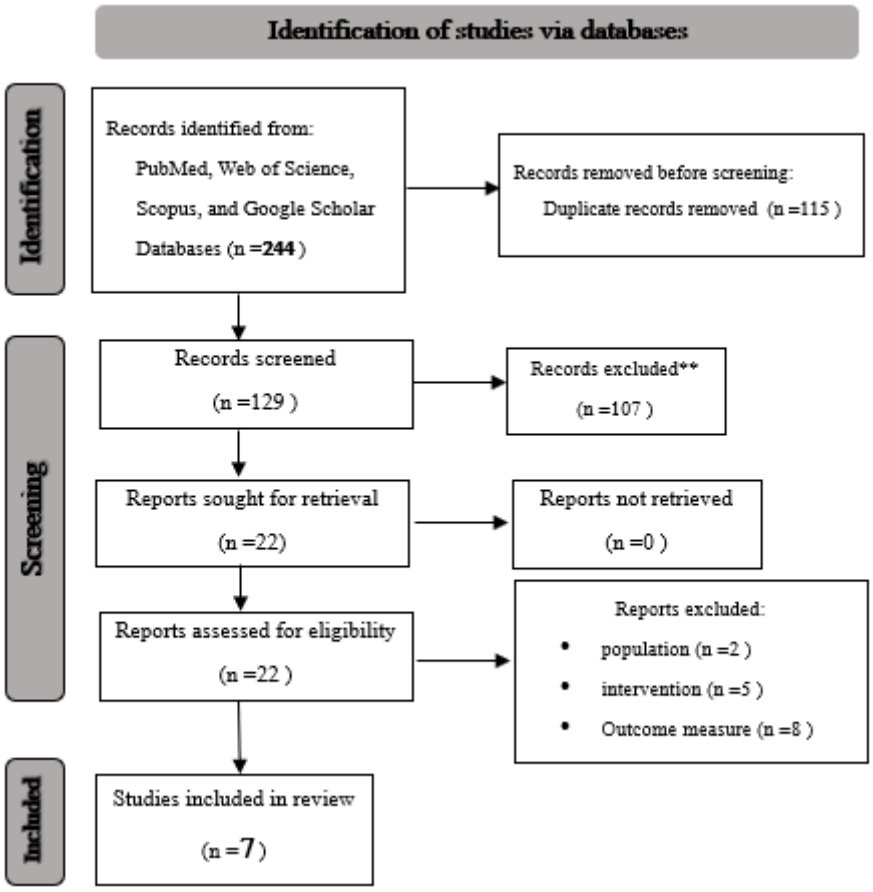
After selecting the studies to enter the systematic review process, data extraction of the studies were done. For this purpose, an electronic checklist was prepared and information related to the population, intervention, comparison, outcomes and results of the studies were extracted. Finally, a narrative synthesis of the obtained data was done, and the results are given in the form of tables and text in the results section.

RESULTS

Search findings

The collective search across all databases resulted in 244 articles. After removing duplicates, 129 articles were left. Subsequently, 107 articles were excluded after reviewing their titles and abstracts. Out of the remaining 22 full-text articles, 15 were further excluded. Specifically, two were excluded because the participants had acute sprains, five because the interventions involved ankle orthoses and other types of shoe inserts, and eight articles because the outcomes were related to muscle activity, pain, and satisfaction.

Figure 1. PRISMA checklist illustrating the study selection process.



Methodological quality

Seven randomized controlled trials were evaluated for methodological quality, with the PEDro items score provided in Table 2. One study was classified as poor quality [23], three were classified as fair [24,26,28], and three were classified as good quality [25,27,29]. The mean score for all the studies is 6.14, indicating an overall fair quality for the total studies.

Table 2. PEDro assessment result.

Author, year	1	2	3	4	5	6	7	8	9	10	11	12	13
McKeon et al, 2012 [23]	+	+	-	-	-	-	-	+	+	-	+	4	Poor
Jamali et al, 2014 [24]	+	+	-	-	-	-	-	+	+	+	+	5	Fair
Abassi et al, 2018 [25]	+	+	+	+	-	-	-	+	+	+	+	7	Good
Jamali et al, 2019 [26]	+	+	-	+	-	-	-	+	+	+	+	6	Fair
Khaliliyan et al, 2023 [27]	+	+	-	+	+	+	+	+	+	+	-	8	Good
Tang et al, 2023 [28]	+	+	-	-	-	-	-	+	+	+	+	5	Fair
Khaliliyan et al, 2024 [29]	+	+	+	+	-	+	+	+	+	+	-	8	Good

Note: Pedro items; 1: Eligibility criteria, 2: Random allocation, 3: Concealed allocation, 4: Similar groups at baseline, 5: Subject blinding, 6: Therapist blinding, 7: Assessor blinding, 8: > 85% key outcomes, 9: Intension to treat, 10: Between-group statistical analysis, 11: Point and variability measures, column 12: final score; column 13: quality level

Population

In this study, 185 individuals with ankle instability participated, including 90 men and 95 women. The mean age ± SD was 20.65 ± 2.754, the mean weight ± SD was 67.35 ± 7.85, and the mean height ± SD was 169.66 ± 4.27. The detailed demographic characteristics of each study are shown in Table 3.

Table 3. Demographic characteristics of participants in each study.

Author, year	n	Sex (male/female)	Mean ± SD age (years)	Mean± SD weight (kg)	Mean height (cm)
McKeon et al, 2012 [23]	20	12/8	21.5±5.51	80.2±17.2	175.6±9
Jamali et al,2014 [24]	21	10/10	25.3±4.73	65.95±14.09	172±0.12
Abassi et al, 2018 [25]	30	13/17	22.3±2.7	66±11.7	172.1±8.6
Jamali et al,2019 [26]	21	11/11	25.6±4.8	67.3±15.3	170±0.1
Khaliliyan et al, 2023 [27]	45	23/22	23.91±4.9	65.8±11.3	161.8±4.7
Tang et al, 2023 [28]	18	8/10	20.9±1.6	68.2 ± 6.7	176.1±5.4
Khaliliyan et al, 2024 [29]	30	13/17	25.73±2.49	63.8±6.85	163.06±9.69

The collective search across all databases resulted in 244 articles. After removing duplicates, 129 articles were left. Subsequently, 107 articles were excluded after reviewing their titles and abstracts. Out of the remaining 22 full-text articles, 15 were further excluded. Specifically, two were excluded because the participants had acute sprains, five because the interventions involved ankle orthoses and other types of shoe inserts, and eight articles because the outcomes were related to muscle activity, pain, and satisfaction.

Intervention

In three studies, the textured shoe insert was constructed from a negative cast molding of patients and polypropylene material [25,27,29]. In the other four studies, the orthosis was constructed from ethylene vinyl acetate [23,24,26,28]. The thickness of the orthotic shell was consistently 3 mm across all studies [23-29]. The primary parameters of the textured

surface were the diameter, height, and center-to-center distance of the raised semicircular points. In four studies, the diameter was 2 mm, the height was 1 mm, and the center-to-center distance was 4 mm [23-26]. One study compared the 0-, 1-, and 2-mm heights [28]. Two studies used a special type of textured surface called a peripheral raised ridge [27,29]. This involved attaching a tube with a 3 mm diameter at a distance of 1 cm from the periphery of the orthosis. The purpose of this was to stimulate the peripheral mechanoreceptors when the center of mass reached the boundaries of the base of support [30].

Comparison

The types of shoe inserts that were compared with each other in each study are detailed in Table 4.

Table 4. Types of shoe inserts were compared with each other in the included studies.

Author, year	Comparison
McKeon et al, 2012 [23]	-Textured - Flat EVA -Control (no intervention)
Jamali et al,2014 [24]	-Textured EVA -Flat EVA
Abassi et al, 2018 [25]	-Custom mold with textured surface -Custom mold -Prefabricated
Jamali et al,2019 [26]	-Flat EVA -Flat textured EVA -Prefabricated lateral heel wedge -Textured lateral heel wedge
Khaliliyan et al, 2023 [27]	-Custom mold with a raised ridge around the perimeter -Custom mold
Tang et al, 2023 [28]	-Flat EVA -Textured with protrusion height of 1mm - Textured with protrusion height of 2mm
Khaliliyan et al, 2024 [29]	-Custom mold with a raised ridge around the perimeter -Custom mold -Control (no intervention)

Outcomes

The variables related to the concept of postural stability were categorized as COP (center of pressure) variables and clinical test variables.

COP variables

The mean of the center of pressure (COP) time to stabilization in the mediolateral direction exhibited a significant decrease with the use of a 1 mm height semicircular textured surface (mean ± SD (mm): 1.8±0.4) in comparison to a flat EVA shoe insert (mean ± SD (mm): 2.1±1.8) ($F_{2,38}=3.66$, $p=0.4$) [23]. Furthermore, the COP ellipse area was significantly reduced when utilizing the textured shoe insert compared to the flat shoe insert (433/99 ± 243/86 vs. 621/44±440/03, $p=0.03$) [24]. Observations also indicated a tendency towards a higher coefficient of multiple correlation of COP values (indicating reduced movement variability) when employing textured shoe inserts (0.933±0.048) rather than smooth ones (0.913±0.077), particularly evident in movements within the frontal plane ($p=0.0015$) [26]. Similarly, a tendency was noted towards higher intraclass correlation values (indicating reduced movement variability) when using textured shoe inserts compared to smooth types, specifically noticeable for angles 200 ms prior to initial contact (0.959 ± 0.037 vs. 0.901 ±

0.026, p=0.012) [26]. The textured shoe insert was observed to significantly impact COP stability (F (1.404, 23.870) = 8.44, P=0.004, $\eta 2$=0.333) after landing, showing a substantial effect, particularly with the 2 mm protrusion offering greater stability compared to those with 1 mm (P=0.002) and 0 mm (P=0.001) protrusions [28].

Clinical tests variables

It was observed that utilizing a custom mold with a textured surface shoe insert resulted in a noticeable increase in the posteromedial reach distance of the star excursion balance test when compared to both the custom mold (mean difference± SD: 0.0015±0.004, p=0.0009) and prefabricated shoe inserts (mean difference ±SD: 0.0015±0.003, p=0.001) [25]. Furthermore, the use of a custom mold with a raised ridge around the perimeter was found to enhance star excursion balance test reach distances in both the anteromedial (0.82±0.05 vs. 0.87±0.07, p=0.001) and posteromedial (0.95±0.03 vs. 0.89±0.04, p=0.02) directions when compared to the custom mold shoe insert [27]. Additionally, this custom mold design led to a decrease in errors during the single leg stance test (8.42±5.4 vs. 2.96±2.1, p=0.001, effect size: 2.18) and an increase in the distance covered during the single leg hop test compared to the custom mold shoe insert (88.2±20.4 vs. 110.8±18.1, p=0.001, effect size: 1.96) [29]. The study characteristics are stated in Table 5.

Table 5. Study characteristics.

Author, year	Study design	Type of instability	Adaptation time for textured FO	Assessment	Outcomes	Results
McKeon et al, 2012 [23]	Repeated measured within group	Chronic	Immediate	In each testing condition, every participant's foot was precisely placed at the center of the force-plate grid. They were directed to stand on one foot for a total of six conditions: three with eyes open (texture insole, sham insole, and control) and three with eyes closed.	COP time to stabilization	A shoe insert with a textured surface influences a wide range of postural stability aspects in ankle instability
Jamali et al, 2014 [24]	Repeated measured within group	Functional	Immediate	Postural stability test while standing on two legs using force plate Kistler instrument corp, Amherst, with dimensions of 65 × 25 cm and frequency Of 1555 Hz was done.	The average distance traveled by COP Average velocity of COP COP ellipse area	Textured shoe inserts lead to improved static postural stability
Abbasi et al, 2018 [25]	Repeated measured within group	chronic	5 minutes	Participants executed the assessment by positioning their affected foot at the center of a test grid, ensuring precise alignment of the geometric midpoint of their standing foot with the point where the lines intersected. Subsequently, they extended their unaffected foot	The anteromedial, medial, and posteromedial direction of SEBT	The custom-molded shoe insert, featuring a textured surface, exhibits notable distinctions when compared to prefabricated ones (p=0.001) across all assessed orientations and with custom-molded foot orthoses (p<0.01) specifically in the medial and posteromedial orientations.

				as distant as achievable in the intended direction before reverting to the initial stance.		
Jamali et al, 2019 [26]	Repeated measured within group	Functional	immediate	A motion capture setup comprising seven cameras operated at a frequency of 100 Hz was employed to capture three-dimensional kinematic information of the foot and leg. Concurrently, ground reaction force measurements were recorded at 1000 Hz using a Kistler force plate.	Coefficient of multiple correlation and Intraclass correlation	The textured shoe inserts show promise in reducing variability, while incorporating texture alongside a lateral wedge could further enhance variability among athletes with FAI.
Khaliliyan et al, 2023 [27]	Repeated measured within between interaction	Chronic	4 weeks	The participants performed the SEBT before and after one month. They placed their affected leg in the center of an 8-directional star and extended their other leg as far as possible without losing stability in the posteromedial, medial, and anteromedial directions.	Reach distance of SEBT	Custom mold textured shoe insert has the ability to place the subtalar joint in ideal settings and modify the level of stimuli generated by the activation of mechanoreceptors in the plantar region of the foot, thereby enhancing the dynamic postural control.
Tang et al, 2023 [28]	Repeated measured within group	functional	immediate	The results were derived from the ground reaction force data obtained from the Kistler force platform within the initial three-second period of the landing trials.	The anterior-posterior, mediolateral and vertical stability index	The utilization of textured shoe inserts featuring protrusion heights of 1 millimeter has the potential to improve the dynamic stability of persons with FAI, thereby reducing the likelihood of ankle sprains.
Khaliliyan et al, 2024 [29]	Repeated measured within between interaction	Chronic	4 weeks	Single leg hop test was used to assess dynamic balance. Participants instruct to jump as far as possible. Single leg stance leg was used to assess static balance. Subjects assumed a stance on their impacted lower limb, placing their hands on the iliac crest, with the uninjured knee bent but not in contact with the weight-bearing leg. The aim was to uphold this	The reach distance of single leg hop test Number of errors of SLST	The textured shoe insert has the potential to improve balance. This adjustment could additionally boost stability.

	position for a period of 30 seconds with closed eyes.

Note: Abbreviations; COP: Center of Pressure, SEBT: Star Excursion Balance Test

DISCUSSION

Shoe inserts with textured surfaces have demonstrated significant improvements in postural stability for individuals with ankle instability. Using a 1 mm height semicircular textured surface reduced the COP time to stabilization [23] and COP ellipse area [24]. Additionally, custom molds with textured surfaces and raised ridges showed enhancements in clinical postural stability tests, such as the star excursion balance [25,7], single leg hop [29], and single leg stance [29] tests, leading to improved reach distances and reduced errors.

The sensorimotor system can selectively replace sensory inputs based on available information to maintain postural stability in case of damage to one sensory source [16]. This issue has been investigated in some pathologies. For example, in people with back pain, the information is provided by the receptors of the ankle muscles instead of being taken from the paraspinal muscles [31]. Based on the results of the present study, textured inserts led to the improvement of some parameters of postural stability, which may be due to the increase in sensory input from the foot plantar surface, the provision of relevant information, and the strengthening of proprioceptive feedback [32]. This is because the inclusion of raised semicircular points on the plantar surface enhances pressure on the mechanoreceptors [33]. Recent studies on people with ankle instability have mentioned damage to the sense of the plantar surface of the foot and its relationship with the loss of postural stability [34].

The mechanisms of the effect of custom mold shoe inserts to maintain postural stability include reducing the range of motion, maintaining the correct alignment of the foot, and reducing stress on the muscles [35]. Meanwhile, improving the sense of touch of the foot's plantar surface skin is one of the main reasons for the effect of textured shoe inserts on people with ankle instability. These types of orthoses change the amount of input resulting from the stimulation of the sensory receptors for the central nervous system or change in the temporal and spatial patterns of the start of afferent fibers stimulation [36-39]. This issue is confirmed in studies conducted in different populations. For example, elderly people are among the people with reduced plantar sensation, in which textured shoe inserts improve postural stability [20]. Among the other groups in which the effect of textured shoe inserts on postural stability has been investigated are healthy athletes and healthy young people [19]. The results of these studies are also in line with the present study and show improvement in postural stability.

While in some of these studies the shoe inserts were prefabricated and in others custom-made, no study has been done to compare these two types of orthoses to find the superior intervention. Also, in these studies, there is no standard manufacturing method for textured shoe inserts.

CONCLUSIONS

These findings emphasize the potential of tailored shoe inserts to optimize postural stability in individuals with ankle instability. The introduction of a semicircular patterned surface resulted in a reduced time needed for postural stabilization and a decrease in the size of the postural sway ellipse. Additionally, customized shoe inserts with textured surfaces and raised edges showed enhancements in different clinical evaluations of postural stability, such as the star excursion balance, single-leg hop, and single-leg stance tests, leading to improved reach distances and reduced mistakes. Further research is needed to explore the broader applicability and long-term effects of these interventions across diverse populations and clinical settings.

Author Contributions: Conceptualization: MB; methodology: MB, HK; validation: MB; formal analysis: MB; investigation: HK; resources: MB, HK; data curation: MB; writing—original draft preparation: HK; writing—review and editing: FG, AS, MK; supervision: MB. All authors have read and agreed to the published version of the manuscript.

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