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Immediate effect of insole on sensory integration and limit of stability in individuals with flexible flat feet

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Flatfoot is a foot problem that leads to somatosensory and balance deficits that could predispose to many injuries. This study examined the spontaneous effect of prefabricated insoles on sensory integration and the limit of stability in individuals with flexible flatfeet. Forty males and females with flexible flatfeet, aged between 16 to 24 years old participated in the study. Biodex balance system (BBS) was used to test the Sensory Integration with its sub-tests; Modified-Clinical Test of Sensory Integration of Balance (m-CTSIB), and Balance Error Scoring System (BESS); and Limit of Stability (LOS) before and after wearing Foot's insole. The results of this study revealed significant improvement in the sensory integration with its components and the limit of stability in individuals with non-structured flatfoot after instant correction of the flatfeet with prefabricated insole (P value less than 0.001). Instant correction using insole has a significant positive effect on the sensory integration and the limits of stability in individuals with flexible flatfeet.

Keywords: Balance, Sensory integration, limit of stability, Flexible flatfeet, and Insole

INTRODUCTION

Flatfoot is described as a complete or incomplete collapse of the medial longitudinal arch of the foot (Chen et al. 2010). According to the preservation of the arch in an unloaded position, flatfoot has been classified into flexible and rigid flatfoot. The medial longitudinal arch of the foot has a crucial function in natural foot mechanics. Hence, disruption of the osteo-ligamentous structure alters the pattern of planter pressure and the positional sense of the foot complex negatively affects the foot's ability to accommodate the terrain and initiate foot and body damage. (James et al. 2017).

Sensory processing, alternatively, sensory integration, is the process in which the neural system is controlling the received sensory signals through an ordered step that starts with reception then integration, modulation, and finally organization (Schaaf and Davies, 2010).

Balance, maintenance of the center of gravity within the limit of the base of support, relies on accurately received signals from visual, vestibular, and somatosensory systems (Collings et al. 2015; Feizolahi and Azarbayjani, 2015; Cote et al. 2005). Maintaining balance while standing or walking depends on the data from the somatosensory system of the foot, which consists of superficial and deep receptors.(Kavounoudias et al. 2019, Christovão et al. 2013).

Safe locomotion and activities of daily living for individuals depend on balance and postural control which act as a basis for stability prior to the accomplishment more precise activities and controlled mobility (Arifin et al. 2014). About 25% of the adolescents may experience a non-structured flatfoot (López-López et al. 2018).

Several studies have shown that flatfoot can reduce balance by disturbing the neuro-mechanical link of the kinetic chain (Mirahmadi et al. 2013; Takata et al. 2013; Rome and Brown, 2004). This reduction in balance can result from the alteration of foot mechanics which ultimately causes mechanical receptor dysfunction (Akbari et al. 2007).

Treating of foot disorders varied from conservative or non-invasive methods to surgical intervention. Foot orthosis, as an example of conservative treatment, is used widely for improving the sensation status of the plantar surface and to reduce ankle injuries (Jamali et al. 2014; De Morais et al. 2012; Hatton et al. 2011). According to sensory reweighting theory, improving foot proprioception and using insoles may compensate for the deficit of other balance pathways (Jamali et al. 2014).

Reducing pain, fatigue, and discomfort can be explained by the role of foot orthoses in enhancing the pattern of the plantar pressure distribution, positioning the foot properly, modifying bony mechanical orientation, and improving the muscular activity patterns of the lower extremity (Hung and Gross, 2014).

MATERIALS AND METHODS

SUBJECTS

The study was designed as Pre-test Post-test Control group. This study was conducted from July 2023 to October 2023. Forty subjects with ages ranging from 16 to 24 years old diagnosed by an orthopedist as flexible flatfeet, were selected from students at Deraya University, Minia, Egypt as shown in the flow chart (fig.1). Ethical approval was obtained from the Faculty of Physical Therapy, Cairo University before the study began (NO: P.T.REC/012/004704). A consent form was assigned by participants before data collection.

Subjects were examined to meet the following criteria: Both males and females were diagnosed with flexible flatfeet, with a score of more than +6 flatfeet according to foot-posture index, and BMI between 22-26 kg/m^2.The participants with the following criteria were excluded: balance deficits, neural pathologies, a previous usage of any insole in the last month, or any drugs that influence balance, foot surgery, or being a professional athlete.

METHODS:

Initially, the subjects were assessed with anthropometric measures (Age, weight, and height). Based on the foot posture index (FPI), the participants had been enrolled in the study. The validity and reliability of this index have already been approved (Redmond et al. 2006). The FPI evaluated foot in three planes with scores -12 to +12, subjects with score more than +6 were enrolled in the study.

The participant was informed to stand on his forefoot and presence of medial foot arch was a precursor of flexible flatfoot. Biodex balance system (BBS) was used to evaluate balance. It a reliable assessment tool (Patterson et al. 2014).

The outcomes were assessed by the BBS using sub-tests m-CTSIB, and BESS to measure sensory integration depending on sway index, and limit of stability test (LOS) of balance. After taking a break for 5 minutes, and then wearing the insole, the same assessments were repeated.

Regarding m-CTSIB, a consistent foot position of the participants was recorded using a coordinate system printed on the platform. The test consists of a total of 4 trials each of which lasts for 30 seconds, in which the patient is instructed to remain as motionless as possible for the duration of the test in four conditions with open and closed eye on the Biodex hard platform and repeat the same conditions on a foam platform. (Miner et al. 2022; Dounskaia et al. 2018). BESS is a valid clinical assessment composed of six conditions with duration of 20 seconds each, carried out on a firm and foam surface (Patterson et al. 2014).

There are three stances in the Balance Error Scoring System (BESS): double-limb support (hands on hips, feet together), single-limb stance, and tandem stance. The stances are completed with the eyes closed on a hard surface and a foam surface, with errors recorded throughout each 20-second trial. Errors include opening eyes, raising hands off hips, falling out of position, lifting the forefoot or heel, abducting the hip by more than 30 degrees, and failing to return to the test posture in more than 5 seconds (Manaseer et al. 2020) as shown in (fig. 2)

The limit of stability (LOS) test examines a patient's ability to control their center of gravity within the area of support by measuring how far the patient can sway from the center. Concerning Biodex LOS test, the subject moves a cursor, displayed on screen, toward a target while standing on static platform. Participants were instructed to "complete the test as quickly and accurately as possible, keeping their bodies in a straight line, using the ankles as the primary axis of rotation". The LOS test records the time and accuracy of transferring their estimated COG (from ground reaction force and height data), moving the cursor to intercept each of 8 successive targets on the display screen. The targets are ordered at 45° intervals around a central target which represents the subject's center of pressure under static conditions. Each target is highlighted randomly, and the participant catches the target by swaying returns to the initial position and then moving to the next displayed target. The test is completed after the eight displayed targets (Pickerill et al. 2011).

STATISTICAL ANALYSIS

Statistical Package for the Social Sciences (SPSS) version 26 was selected to analyze the collected data. 40 subjects were enrolled in the current study. The mean value of ages was 18.53 ± 2.21 years, weight was 76.03 ± 7.21 Kg, height was 172.07 ± 6.12 Cm, and body mass index (BMI) was 25.23 ± 2.61 Kg/m^2 as shown in table (1). A paired "T-test was used to identify the significant difference between the same group pre- and post-usage of the insole. The alpha level of significance (α) was set to less than (0.05)

Table 1: Demographic data of the study group

Variable	Mean ± SD
Age (years)	18.53 ± 2.21
Weight (Kg)	76.03 ± 7.21
Height (Cm)	172.07 ± 6.12
BMI (Kg/m^2)	25.23 ± 2.61

RESULTS

Regarding the sensory integration, the results revealed that there was a highly significant difference in m-CTSIB and BESS pre and post-using Insole (P value <0.001). Also, regarding the limit of stability, there was a highly significant difference between pre-and post-using Insole (P. value <0.001), as shown in table (2) and fig. (3) Show these differences.

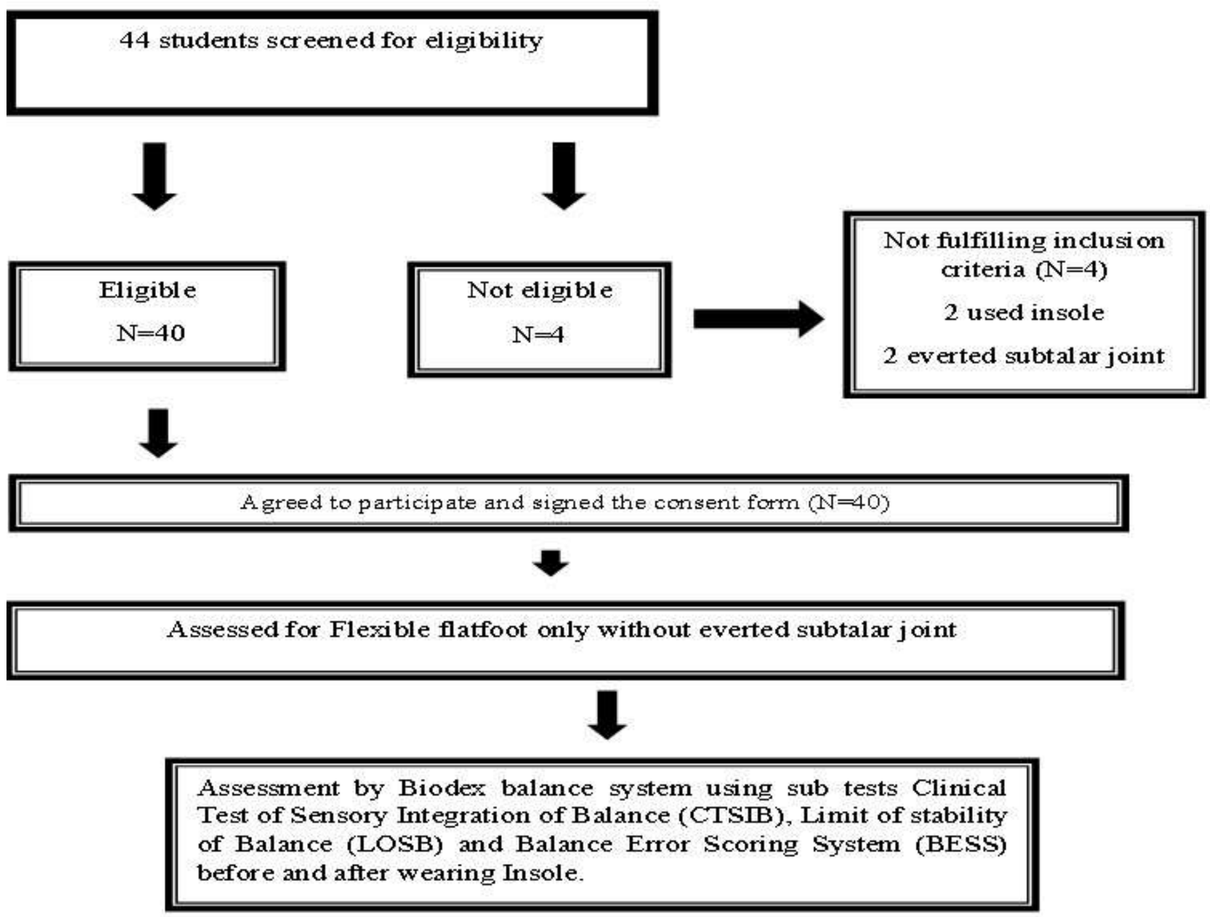

Figure 1: Flow Chart

Figure 2: BBS in the assessment of BESS

Table 2: Comparison between pre and post usage of insole

Variable	Pre-using insole	Post-using insole	T-value	P-value
	Mean + SD	Mean + SD		
Modified-Clinical Test of Sensory Integration of Balance (m-CTSIB)	1.86 + 0.11	1.63 + 0.08	4.27	<0.001
Balance Error Scoring System (BESS)	1.27 + 0.06	1.09 + 0.09	4.77	<0.001
Limit of Stability (LOS)	5.93 + 0.95	7.17 + 0.9	-7.5	<0.001

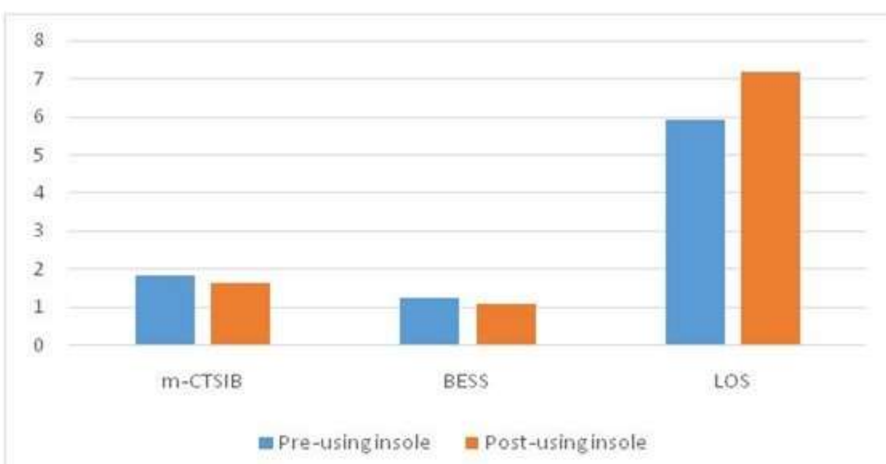

Figure 3: Comparison between pre- and post-usage of insole.

DISCUSSION

The purpose of our study was to investigate the effect of the insole on sensory integration and limit of stability in individuals with flexible flatfeet and how these measures may change abruptly when flatfeet is corrected with the insole. The results showed high and immediate improvement in sensory integration and limit of stability accompanied by correcting the path mechanics of flatfeet.

Postural and motor control comes from somatosensory, vestibular, and visual systems (Kashoo.and Ahmad, 2018). Sensory integration by processing information coming from these systems helps the CNS to balance the external forces affecting the body with internal forces generated by muscles and maintain a healthy posture (Faquin et al. 2018).

Flatfoot disrupts the neural signals transmitted from the plantar surface to the CNS which in turn affects the optimal performance of the somatosensory system. Therefore, restoring the normal foot arch reduces this distortion and enhances the better perception of signals transmitted from the plantar surface to the CNS resulting in optimizing the somatosensory system performance (Hatton al. 2011).

The relationship between flatfoot and postural stability was studied by Harrison who found a reduction in postural stability in participants with absent normal foot arch with an average age of 18 years (Harrison and Littlewood, 2010). Accordingly, Gross et al. (2012) reported immediate improvement of postural stability and balance after using foot orthoses.

In this respect, the present study is in line with the results of Steinberg et al. (2015); Palluel et al (2008). Whose researchers believed that textured insole is beneficial in improving the perception of the foot posture in young people with flatfoot. Also, Aruin and colleagues found improvement in gait parameters in young subjects who used textured insoles (Aruin and Kanekar, 2013). Palluel also, proposed that spike insole had the ability to stimulate the proprioceptors. Thus, using insoles could improve balance parameters in younger people (Palluel et al. 2008) Waddington found that using textured insole could improve the perception of the ankle position in athletes and improve balance (Waddington, 2003).

The proprioception and sense of touch are improved with the proper combination of a shoe and an orthosis, thus enhancing balance and reducing the risk of falls and sprains. These variations will also positively influence the normal posture of the lower extremities (Percy and Menz, 2001). The center of body mass tends to displace internally in individuals who suffered from flexible flatfoot because of medial longitudinal arch falling. Orthoses are beneficial in returning normal foot posture and maintaining normal arch; therefore, they will return the body's center of mass to its normal location. (Payehdar et al. 2016)

Finally, further studies are needed to assess the effect of flat feet on balance and postural control with these sequences. Also, how medical Insole eliminates these deficits in the long term.

CONCLUSIONS

Wearing the insole in cases of flexible flatfeet improves balance and postural control according to our results by improving sensory integration and the limit of stability of balance.

Supplementary materials

The supplementary material / supporting for this article can be found online and downloaded at: https://www.isisn.org/article/

Author contributions

Authors Alaaeldin Khaireldin, and Bishoy S. Lobbos made substantial contributions to the conception or the design of the manuscript. All authors contributed to the acquisition, analysis, and interpretation of the data and have participated in drafting the manuscript and revised it critically. All authors read and approved the final version of the manuscript

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Institutional Review Board Statement

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Informed Consent Statement

Not applicable.

Data Availability Statement

All of the data is included in the article/Supplementary Material.

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Conflict of interest

The authors declared that present study was performed in absence of any conflict of interest.
OR The authors declare no conflict of interest.

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