Impact of Soft and Hard Insole Density on Postural Stability in Older Adults

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A significant predictor of falls in the elderly population is attributed to postural instability. Thus, it is important to identify and implement practical clinical interventions to enhance postural stability in older adults. Shoe insoles have been identified as a mechanism to enhance postural control, and our study aimed to evaluate the impact of 2 shoe insoles on static standing balance in healthy, older adults compared with standing posture while barefoot. We hypothesized that both hard and soft shoe insoles would decrease postural sway compared with the barefoot condition. Indeed, excursion distances and sway areas were reduced, and sway velocity was decreased when wearing insoles. The hard insole was also effective when visual feedback was removed, suggesting that the more rigid an insole, the greater potential reduction in fall risk. Thus, shoe insoles may be a cost-effective, clinical intervention that is easy to implement to reduce the risk of falling in the elderly population. (*Geriatr Nurs* 2012;33:264-271)

Injuries sustained from falling due to postural instability are a major health problem. Older adults are especially vulnerable to falls, particularly individuals aged older than 60 years.[1] One of the contributing factors to fall episodes with advancing age is a deteriorating proprioceptive system.[2] Elderly adults who experience fall episodes exhibit greater dynamic postural sway during gait compared with older adults who do not fall.[3,4] Consequently, clinical interventions that enhance proprioception and postural control as a strategy to prevent falls in older adults are necessary.

There is evidence to support the role of footwear as a mechanism to enhance postural control. Finlay et al.[5] evaluated gait in 60 healthy older adults and reported that foot function and stability was enhanced when subjects were wearing a prescribed shoe compared with values obtained when subjects wore their own footwear. Enhanced gait parameters included an increase in the ground contact area, lower forefoot loading, and a faster walking speed. Prescribed shoe characteristics were individualized, intended to enhance each subject's current shoe conditions, and described as including wrap-over slippers, extra deep and extra wide shoes, extra wide but normal depth shoes, and odd-sized shoes. The authors concluded that their findings supported the positive benefits of a special program of care including footwear assessment and modification.[5]

Shoe insoles have also been identified as a mechanism to enhance postural control. Priplata et al.[6] evaluated static and dynamic stability in 27 uninjured young and elderly adults both with vibrating, gel-based insoles and without the insoles. The authors reported more pronounced enhancement in postural stability with the vibrating insoles in elderly subjects compared with young subjects. Priplata et al.[6] concluded the insoles enhanced somatosensory function and may be useful in alleviating age-based impairments in balance control. Hard, semirigid, and soft insoles have also been shown to have an impact on lower extremity electromyogram activity in terms of intensity, timing of muscle activity onset, and fatigue during dynamic, functional activities.[7-15] Although changes in muscle activity as a consequence of various insole densities suggest an enhancement of plantar surface sensory input, the previous investigations did not specifically evaluate postural control among a vulnerable population of older adults. A study investigating the effects of age and footwear concluded that shoes with soft, thick soles impair stability by reducing joint position sense.[16] Furthermore, elderly patients often choose to wear slippers because the soft material and flexible structure can comfortably accommodate painful feet and foot deformities.[17]

Unfortunately, soft-soled shoes may threaten an older person's stability, because greater muscular activity is required to maintain such stability when attempting to stop while walking in this type of footwear.[18]

The link between postural stability and falls is well documented, with postural stability deficits being significant predictors of falls in older adults.[19,20] It is therefore imperative to identify and implement practical clinical interventions to enhance postural stability in older adults. To our knowledge, no previous investigations have described the effects of insole density on standing postural stability. Therefore, the purpose of this study was to evaluate the impact of 2 shoe insoles on static standing balance in healthy, older adults compared with standing posture while barefoot. We elected to evaluate postural sway during a barefoot rather than a shoe condition because footwear has been shown to affect sensory feedback, potentially acting as a sensory filter between the feet and the standing surface.[21-23] We hypothesized that both types of shoe insoles would decrease postural sway compared with the barefoot condition.

Methods

Subjects

Twenty-two people participated in the study. Subjects were randomly selected from a group of 128 people already participating in nutritional research studies in various nursing centers throughout Madrid, Spain. Forty-six residents were included in the sample criteria, were asked to participate, and gave consent. From this population, we performed a simple random for 26 subjects (56% of total).[24] Only 22 participants decided to participate in the study.

The sample consisted of 16 healthy women and 6 men aged 77 to 91 years (age 85 years ± 3; weight 138.89 lb ± 20; height 61.4 inches ± 3.6). Any preexisting foot conditions or deformities were noted and listed in Table 1. All subjects were required to have normal or corrected-to-normal vision and be able to ambulate independently without an assistive device. Exclusion criteria included any current lower-extremity musculoskeletal disorder, uncorrected visual deficiency, neurological disorders, diabetes mellitus, lower extremity amputation and/or prostheses, plantar ulcers, cognitive impairment as determined by a Short Portable Mental Status Questionnaire score <7,[25] and the failure to meet all inclusion criteria.

Table 1.
Preexisting Foot Deformities

Type of Deformity	No. of Patients (%)
Hallux abductus valgus bilateral	16 (72.72)
Hallux abductus valgus unilateral	4 (18.18)
Claw toes/hammer toe	22 (100)
Tailor's bunion	5 (22.72)
Crowded toes (infraductus-supraductus)	7 (31.81)
Metatarsalgia	10 (45.45)
Plantar fat pad atrophy	15 (68.18)
Nail deformity	22 (100)
Flat feet	15 (68.18)
Cavus feet	2 (9.09)

The study protocol conformed to the guidelines set forth in the Declaration of Helsinki. Informed consent was obtained from all subjects before their participation in the study, which was approved by the Ethics Committee of the Universidad Rey Juan Carlos.

Instrumentation

Balance was evaluated using tests of postural sway and coordinated stability using a digital portable force plate (EPS-Platform; Loran Engineering, Castel Maggiore, Bologna, Italy). The platform dimensions were 48 × 48 cm with a thickness of 5 mm and also had a ruler and gridlines that were used as markers to ensure the feet were placed in the same position for all tests. The platform included 2,304 resistive sensors, allowing for accuracy of measurements to be to the nearest 0.01 kPa. Data were recorded at a frequency of 60 Hz, and the platform was linked to a personal computer containing the data-collection software program Foot Checker, version 4.0 for Windows (Loran Engineering, Castel Maggiore, Bologna, Italy).

Procedures

All subjects completed 3 testing sessions in a laboratory setting with a minimum of external distractions. The same testing procedures were repeated during each session, with 1 week between sessions. The gridlines, an important feature of the platform, allowed us to measure the location of the heels, toes, separation of heels, and separation of toes to accurately repeat the foot placement for each patient the following week. Postural sway was assessed as subjects stood on a force platform in a natural standing position with their arms by their side. During the first testing session, postural sway was assessed while subjects were barefoot. In the second testing session, subjects wore a gel soft insole (SoftSock Foot Support, Addison, TX), with a .25-inch solid gel bottom. During third and final testing, subjects wore a hard insole sock (Shore value A50, Algeos Ltd., Liverpool, United Kingdom), with a .25-inch smooth ethylene vinyl acetate surface.

For each condition, 3 trials of 30 seconds' length each were performed, and data were collected as subjects assumed a bilateral stance during each trial. Each task was performed with eyes both open and closed. To control for possible variations in visual field during the eyes-open condition, subjects were asked to focus on a target positioned 2 meters in front of them at eye level. If the person moved or lost his or her balance, the data were discarded, and the trial was repeated until data were obtained with the person remaining still. Aside from these instances, no "practice trials" were permitted.

Data Analysis

For each testing condition, data were managed in the following manner. The first 10 seconds of each trial was discarded.[26,27] The remaining 20 seconds from each of 3 trials were then averaged, and the average was used for subsequent analysis.[26-28] Postural sway was evaluated using a group of measures. Center of pressure (COP; millimeters) was calculated along the medial-lateral and anterior-posterior axes. Sway area (SA; in square millimeters) was calculated using an elliptical area measure generated by the software; distance of the sway area (DSA; millimeters) and the sway velocity (SV) (mm/sc) were also calculated. SV was evaluated along both the anterior-posterior and medial-lateral axes. Limits of stability were based on the maximum excursion (mm) obtained across trials and included anterior excursion (AE), posterior excursion (PE), medial excursion (ME), and lateral excursion (LE). Finally, the Romberg Index was calculated for sway area (RISA), sway velocity (RISV), and the distance of the sway area (RIDSA) using the following equation: (eyes closed/eyes open) * 100. Thus, a value of zero would represent no difference between visual conditions.[29]

Normal distribution of the data set was evaluated with statistical testing including the Kolmogorov-Smirnov test. A repeated-measure analysis of variance was used to compare sole inserts used over time in the data analysis. Tukey adjustment was applied for the multiple pairwise comparisons between standing conditions: barefoot, soft insole, and hard insole conditions. Interaction between the standing condition and postural stability (eyes open or closed) was also examined. The difference between eyes open and closed was tested with the interaction considered. Statistical significance was established at $P < .05$ using 95% confidence intervals. All data analysis was conducted with commercially available software (SPSS version 14.0; SPSS Science, Chicago, IL).

Results

Kolmogorov-Smirnov tests indicated that all data were normally distributed.

When evaluating postural sway by visual field conditions, there were significant differences as subjects were barefoot for DSA ($P = .022$), SV ($P = .020$), and SA ($P = .026$; Table 2). In each instance, values were greater during the eyes-closed condition compared with eyes open. When subjects wore the gel insole, there were significant differences across visual fields for AE ($P = .044$), DSA ($P = .017$), and SA ($P = .021$; Table 2). In each instance, values were again greater during the eyes-closed condition compared with eyes open. When subjects wore the hard insole, there were significant differences across visual fields for AE ($P = .009$), PE ($P = .018$), ME ($P = .041$), and COP along the y axis ($P = .001$; Table 2). Anterior excursion was greater during the eyes-closed compared to eyes-open condition. Excursion in the posterior and medial planes was greater, however, during the eyes open condition. Finally, COP along the y axis was posteriorly oriented during the eyes-open condition and anteriorly oriented with the eyes closed while wearing the hard insole.

Table 2.
Comparison of Postural Sway with Eyes Open and Closed Across Standing Conditions

	Barefoot			Soft Insole			Hard Insole			
	OE (Mean ± SD)	CE (Mean ± SD)	*P*	OE (Mean ± SD)	CE (Mean ± SD)	*P*	OE (Mean ± SD)	CE (Mean ± SD)	*P*	*P* Value for Interaction
AE (mm)	3.01 ± 2.05	3.05 ± 2.08	.862	2.38 ± 2.06	4.44 ± 5.94	.009	2.55 ± 1.97	4.11 ± 3.39	.048	.197
PE (mm)	4.78 ± 3.83	5.26 ± 4.60	.466	4.65 ± 2.79	3.78 ± 2.52	.191	5.02 ± 2.43	3.68 ± 2.51	.044	.131
ME (mm)	3.80 ± 3.15	3.29 ± 2.46	.546	3.20 ± 1.84	3.77 ± 2.94	.494	5.60 ± 4.75	3.07 ± 2.28	.031	.032
LE (mm)	6.16 ± 6.01	5.54 ± 4.85	.514	5.64 ± 4.50	4.88 ± 3.72	.422	4.94 ± 4.60	5.51 ± 4.70	.546	.550
COP, x axis (mm)	−1.41 ± 4.88	−1.03 ± 2.52	.653	−1.31 ± 2.97	−0.38 ± 2.87	.277	0.36 ± 4.42	−1.14 ± 2.56	.078	.108
COP, y axis (mm)	−0.63 ± 1.85	−1.14 ± 2.29	.314	−1.20 ± 2.29	0.90 ± 1.90	.012	−1.45 ± 2.32	0.42 ± 2.07	.0003	.003
DSA (mm)	69.77 ± 38.21	85.75 ± 54.65	.010	61.80 ± 30.95	75,38 ± 48,22	.013	68.13 ± 28.77	76.35 ± 45.92	.182	.609
SV (mm^2)	2.32 ± 1.27	2.87 ± 1.81	.005	2.08 ± 1.01	2.51 ± 1.60	.027	2.27 ± 0.95	2.54 ± 1.53	.153	.605
SA (mm^2)	7695.30 ± 4199.53	9425.09 ± 5887.00	.038	7012.34 30 ± 4094.30	9275.25 ± 6277.81	.007	7391.65 ± 2861.58	8320.51 ± 4898.16	.261	.515

Statistical significance: $P < .05$.
AE = anterior excursion; CE = closed eyes; COP = center of pressure; DSA = distance of the sway area in millimeters; LE = lateral excursion; OE = open eyes; ME = medial excursion; PE = posterior excursion; SA = sway area; SV = sway velocity.

When evaluating the Romberg Index, sway area was not significantly different when comparing the barefoot and hard insole conditions ($P = .321$) but was significant when comparing the gel and hard insole conditions ($P = .022$; Table 3). In both instances, indices were lower when subjects wore the hard insole (Table 3). There was no significant difference in the Romberg Index for sway area when comparing the barefoot and gel insole conditions (Table 3). There were also no differences for the Romberg Index for sway velocity or the distance of the sway area when comparing barefoot, gel, and hard insole conditions (Table 3).

When comparing postural control across standing conditions with the eyes open, there were significant differences in ME ($P = .016$) when comparing the gel and hard insole conditions (Table 4). In each instance, values were greater when the hard insole was worn compared with the gel insole condition. There were also differences approaching significance in COP along the x axis when comparing the barefoot and gel insole standing conditions ($P = .059$), because there was greater posterior excursion while subjects were barefoot. There were no other significant differences across standing conditions with the eyes open (Table 4).

When comparing postural control across standing conditions with the eyes closed, there were significant differences in PE ($P = .044$), COP along the y axis ($P = .041$), and approaching significance in SV ($P = 0.054$) when comparing the barefoot and gel insole conditions (Table 5). In each instance, values were higher in the barefoot compared with gel insole condition. There were also significant differences in AE ($P = .028$), PE ($P = .029$), and COP along the y axis ($P = .007$) when comparing the barefoot and hard insole standing conditions (Table 5). Excursion was greater anteriorly when the hard insole was worn and greater posteriorly during the barefoot condition. Center of pressure along the y axis was greater and oriented posteriorly during the barefoot condition compared with a smaller, anterior orientation during the hard insole condition. There were no significant differences in postural control with the eyes closed when comparing the gel and hard insole conditions (Table 5).

Discussion

The maintenance of postural stability is dependent on a range of somatosensory inputs. Tactile sensitivity within the foot has a strong influence on maintenance of postural stability, as evidenced when this sensory input is lost in diabetic neuropathy.[30,31] Furthermore, vision has a definitive role in postural control.[31,32] Elderly persons are often unable to take advantage of the reinsertion of proprioception when vision is not available. Reintegration of proprioception under a no-vision scenario yielded a faster COP speed for elderly persons compared with young adults.[29] Shoe insoles can increase plantar foot surface contact and potentially increase somatosensory input. Therefore, this investigation evaluated the impact of soft and hard shoe insoles on postural control in the elderly during static standing posture during both eyes open and eyes closed conditions. We hypothesized that both insoles would result in a more stable standing posture compared with standing barefoot. The results from this study confirmed this hypothesis, because excursion distances and sway areas were smaller and sway velocity was slower when wearing insoles compared with barefoot standing. These changes in postural stability promoted positioning of the center of mass and displacement within the base of support. Thus, shoe insoles may be a cost-effective, easy-to-implement clinical intervention to reduce fall risk in a vulnerable population.

Removing visual sensory input places a greater demand on tactile feedback to maintain postural stability. It was therefore not surprising to detect pronounced changes in postural sway when subjects stood with their eyes closed compared with standing with their eyes open. Standing with eyes closed in both the barefoot and soft insole conditions resulted in a more unstable standing posture, as values for sway area, distance of sway area, and sway velocity were all greater than in the eyes open condition. Additionally, excursions along the anterior axis were also greater when subjects stood on the soft insole with their eyes closed compared with standing with their eyes open. Although standing on the hard insole with the eyes closed also yielded greater anterior excursion compared with eyes open, posterior excursion, medial excursion, and center of pressure translation along the y axis were all lower. Although the mechanism underlying improvements with the eyes closed is not clear, we do believe these results are supportive of using a hard insole as an effective means to enhance postural stability in a challenging environment.

There were improvements in postural sway for both insole conditions compared with barefoot standing. These differences were modest for the soft insole and only evident when visual feedback was removed; posterior excursion and the distance of the sway area were both lower during the soft insole standing condition. Significant enhancement in postural sway was evident during the hard insole standing condition compared with barefoot standing. These differences included a lower Romberg Index for sway area, small center of pressure values along the x axis with the eyes open and smaller anterior-posterior excursions and center of pressure values along the y axis with the eyes closed. When comparing insoles, the hard insole yielded a lower Romberg Index for sway area, whereas the soft insole yielded lower values for medial excursion and the distance of the sway area when the eyes were open. There were no differences in postural sway between the insoles when the eyes were closed.

Because the hard insole was effective in promoting postural sway when visual feedback was removed and when compared with the barefoot standing condition, we suggest a more rigid insole

Table 3.
Romberg Index

	Barefoot (Mean ± SD)	Soft Insole (Mean ± SD)	Hard Insole (Mean ± SD)	Barefoot/Soft Insole *P* Value	Barefoot/Hard Insole *P* Value	Soft/Hard Insole *P* Value
RISA	1.14 ± 0.67	1.45 ± 1.29	0.87 ± 0.14	.396	.321	.022
RISV	0.94 ± 0.09	0.94 ± 0.09	0.91 ± 0.09	.964	.567	.415
RIDSA	1.23 ± 0.35	1.19 ± 0.30	1.11 ± 0.33	.839	.128	.339

Statistical significance: $P < .05$.
RIDSA = Romberg Index Distance of the Sway Area; RISA = Romberg Index Sway Area; RISV = Romberg Index Sway Velocity.

Table 4.
Postural Control Across Standing Conditions with Eyes Open

	Barefoot (Mean ± SD)	Soft Insole (Mean ± SD)	Hard Insole (Mean ± SD)	Barefoot/Soft Insole *P* Value	Barefoot/Hard Insole *P* Value	Soft/Hard Insole *P* Value
AE (mm)	3.01 ± 2.05	2.38 ± 2.06	2.55 ± 1.97	.506	.731	.929
PE (mm)	4.78 ± 3.83	4.65 ± 2.79	5.02 ± 2.43	.976	.923	.825
ME (mm)	3.80 ± 3.15	3.20 ± 1.84	5.60 ± 4.75	.748	.088	.016
LE (mm)	6.16 ± 6.01	5.64 ± 4.50	4.94 ± 4.60	.811	.321	.680
COP, x axis (mm)	−1.41 ± 4.88	−1.31 ± 2.97	0.36 ± 4.42	.992	.059	.115
COP, y axis (mm)	−0.63 ± 1.85	−1.20 ± 2.29	−1.45 ± 2.32	.546	.287	.883
DSA (mm)	69.77 ± 38.21	61.80 ± 30.95	68.13 ± 28.77	.183	.927	.336
SV (mm/sg)	2.32 ± 1.27	2.08 ± 1.01	2.27 ± 0.95	.245	.926	.429
SA (mm^2)	7695.30 ± 4199.53	7012.34 30 ± 4094.30	7391.65 ± 2861.58	.548	.887	.829

Statistical significance: P < .05.
AE = anterior excursion; COP = center of pressure; DSA = distance of sway area; ME = medial excursion; OE = open eyes; PE = posterior excursion; LE = lateral excursion; SA = sway area; SV = sway velocity.

Table 5.
Postural Control Across Standing Conditions with Eyes Closed

	Barefoot (Mean ± SD)	Soft Insole (Mean ± SD)	Hard Insole (Mean ± SD)	Barefoot/Soft Insole *P* Value	Barefoot/Hard Insole *P* Value	Soft/Hard Insole *P* Value
AE (mm)	3.05 ± 2.08	4.44 ± 5.94	4.11 ± 3.39	.337	.526	.940
PE (mm)	5.26 ± 4.60	3.78 ± 2.52	3.68 ± 2.51	.044	.029	.982
ME (mm)	3.29 ± 2.46	3.77 ± 2.94	3.07 ± 2.28	.760	.941	.555
LE (mm)	5.54 ± 4.85	4.88 ± 3.72	5.51 ± 4.70	.678	.999	.705
COP, x axis (mm)	−1.03 ± 2.52	−0.38 ± 2.87	−1.14 ± 2.56	.520	.979	.407
COP, y axis (mm)	−1.14 ± 2.29	0.90 ± 1.90	0.42 ± 2.07	.041	.007	.779
DSA (mm)	85.75 ± 54.65	75.38 ± 48,22	76.35 ± 45.92	.338	.272	.989
SV (mm/sg)	2.87 ± 1.81	2.51 ± 1.60	2.54 ± 1.53	.054	.141	.977
SA (mm^2)	9425.09 ± 5887.00	9275.25 ± 6277.81	8320.51 ± 4898.16	.983	.402	.504

Statistical significance: P < .05.
AE = anterior excursion; COP = center of pressure; DSA = distance of sway area; ME = medial excursion; OE = open eyes; PE = posterior excursion; LE = lateral excursion; SA = sway area; SV = sway velocity.

may be a more effective orthotic intervention than a soft orthosis as a strategy to reduce fall risk. This finding is consistent with previous investigations in which it was determined that soft-soled shoes may threaten an older person's stability, because greater muscular activity is required to maintain stability during a stopping motion while wearing this type of footwear.[18] One of the proposed mechanisms underlying the effectiveness of orthotics and insoles in the enhancement of postural stability is an improvement in kinesthetic awareness.[33] An orthotic cradles the foot and can promote a more neutral alignment of the talocrural joint. This can facilitate efficiency in muscle contractile performance, thereby potentially improving muscular contributions to ankle joint stability.[33] Placing the foot in a more neutral position as a mechanism underlying improved postural stability is also supported by a study reporting lower frontal-plane center of pressure length and velocity measures in 15 healthy subjects when an orthotic medial rearfoot post was used.[34] The improvement in stability was hypothesized to be a consequence of limiting the range of foot pronation. A hard insole is more likely to be corrective and promote a neutral foot position, because a soft insole is designed to accommodate foot posture. Thus, we suggest that the hard insole may be a more effective intervention than a soft insole for reducing fall risk in the elderly.

Findings from this study are consistent with previous reports that foot orthosis intervention improves postural stability. Ochendorf et al.[33] evaluated the influence of ankle muscle fatigue and custom-made, semirigid orthotic use on postural sway in healthy male subjects. The authors reported that after fatigue, the nonorthotic condition yielded greater sway values than orthotic condition. Rome and Brown[35] balance was improved in 20 healthy male subjects with excessively pronated feet when they used a rigid foot orthosis compared with a group that had no orthotic intervention. Olmstead and Hertel[36] evaluated postural in 30 individuals with different foot types. They reported improvements with semirigid orthotic use among individuals with a cavus foot structure. Our study differed from previous reports in using a soft insole and evaluating an older population. Although the mechanisms contributing to improved postural stability across investigations may not be consistent, collectively the findings support the use of insoles and orthotics to improve postural control.

One limitation of this study was the use of the same testing order, which could introduce bias into the study. Further research is needed with regard to the order of testing to potentially better counterbalance across conditions. We evaluated a spectrum of postural sway variables. We did note improvements in stability in some, but not all, of these variables. At this time, we are not aware of which parameters may be predictive of fall risk. Furthermore, although improvements in postural sway were noted with the use of insoles, it is not clear whether they will actually decrease the risk of falling. Prospective, longitudinal studies will be necessary to determine which postural stability variables are useful in predicting fall risk and if the use of shoe insoles are an effective intervention for fall prevention. Finally, we did not collect direct measures of sensory and motor function. Thus, this study cannot provide direct insight to the mechanisms underlying improvements in postural stability as a consequence of the insole intervention.

Conclusion

There were significant improvements in postural sway when subjects stood on both soft and hard insoles compared with standing barefoot, with more pronounced improvements when a hard insole was used. Providing increased sensory inputs with hard insoles may be an inexpensive and effective way to reduce fall risk in older adults.

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