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Floor Mats and Insoles: Workplace Considerations for Safe Dynamic Standing

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Abstract

The indiscriminate introduction of mats or insoles for standing employees have unknown effects on standing positions and balance reactions at the workplace. This study investigated the impact on standing with three different density floor mats and insoles ranging from soft (18 to 34 durometers on Shore A scale), mid-firm (30 to 50 durometers), and very firm (50 to 90 durometers). Balance response data measured reaction times, movement velocities, initial excursions, maximum excursions, and directional control using a computerized force plate. Ninety-nine subjects completed randomized order trials of three floor mats and then three weeks later, three different insoles at 100% of their limits of stability. The results indicated statistically significant ($p< 0.05$) improved balance reactions while standing on softer insoles or floor mats (18 to 34 durometers). Most importantly, the comparison of insoles and floor mats revealed softer insoles having a superior improvement ($p< 0.054$) in directional control during dynamic postural changes over the best performing soft floor mat.

Keywords

Balance; Floor Mats; Insoles; Motor Control; Productivity; Safety; Standing

Introduction

Dynamic balance at the workplace is a significant ongoing concern for both productivity and safety. The US Bureau of Labor Statistics [1] ranks slips, trips, and falls as the third leading cause of injury in 1998 with falls being the fourth leading cause of fatal occupational injuries in 1999 [2]. The magnitude of balance issues has not improved, with the US Bureau of Labor Statistics reporting in 2003 that injuries from falls exceed 200,000 per year, accounting for 20% of disabling workplace injuries. Therefore, the importance of gaining a greater understanding of the potential impact from standing on various floor mats and insoles has become paramount for prospective safety policy formation.

The ability to achieve the upright standing balance to work, play, and perform daily functional activities is commonly taken for granted by most people. There is a general acceptance that when standing, the ground will be firm enough to support body weight, and the brain will receive adequate information from the feet and joints to make necessary motor adjustments [3]. Standing on different floor surfaces will necessitate more information from feet/joints for greater adjustments by the trunk and leg muscles. Nasher [4] described “Adaptive sensory interactions are critical to postural stabilization, because some of the information provided by vision, proprioception, and the vestibular system can be inaccurate under some environmental conditions.” If floor surfaces present additional challenges to the proprioceptive system, visual input takes over to confirm or deny balance correction accuracy [5]. This may cause the individuals to take their eyes off a specific task thus potentially impairing work performance and safety [6].

The Boeing Company was concerned about the diversity of floor mats and insoles used within their numerous work settings and worldwide facilities. Safety personnel depended upon subjective input to introduce different floor mats and insoles from multiple vendors without the benefit of any independent or objective information. However, there was no consensus among subjective input as to which floor mat or insole best meets the overall needs of the standing employees throughout their workday. There was no objective data available specifying what influences to balance reactions when placing various soft or hard cushioning materials (floor mats or insoles) between employees’ feet and ground reaction forces.

Boeing commissioned this study to precisely measure balance data from a variety of subjects while standing on soft, mid-firmness, and very firm mats and insoles. The study challenged the subjects on a computerized force plate to stand on various floor mat or insole materials in eight different directions to assess their consequences on dynamic balance. Five critical elements of balance measured the subject's reaction time, movement velocity, initial balance correction, maximum excursion, and directional control. The study data advanced the effect on dynamic standing balance resulting from the various floor mats and insoles to support improved decision-making for cushioning at the workplace. Hou and Shiao [7] and Fernberg [8] highlight the need to alter the current safety approaches for introducing various types of floor mats and insoles that may influence standing work efficiency, safety, and employee performance in those positions.

Methodology

Study design

Ninety-nine randomized control subject trials were completed on a computerized force plate (Balance Master, NeuroCom International, Clackamas, OR 97015) measuring five different dynamic standing balance reactions. Each subject was tested at 100% of his or her Limits of Standing Stability (LOS - very edge of balance loss). All subjects wore standardized shoes and not permitted to wear their own shoes while standing on three different floor mats and insoles. Subjects stood with hands maintained on the hips, at the middle of the force plate watching the projection of an icon, which represented the Center of Pressure (COP) of each individual. For example, the COP icon would move to the right if the subject moved to the right. Eight target areas projected on the wall in a clock-like pattern would represent potential directional balance shifts for the subjects. Once the target area was highlighted with a blue circle, the subject quickly shifted their COP towards the lighted target. All subjects trained two minutes to learn how to shift their balance, maintain hands-on-hips, and monitor the progress of their COP to the target area projected on the wall set at 75% of LOS. The training session also became the screening tool to remove subjects from the study if they were unable to complete the training session.

The standardized shoes (Slip Grip Safety Shoes) became the control floor mat and insoles for each of the testing phases. Randomized control trials assigned the sequence of floor mat or insole test such that the designation of Mat/Insole A, B, C, D were followed by Mat B, C, D, A for the next subject. After three weeks following the floor mat testing phase, approximately 71% of the original subjects returned to investigate the same balance reactions by standing on three different types of insoles with no floor mats. The remaining 29% were new subjects closely matched in gender and age of those they replaced in the initial floor mat testing. The control variable used in both sections (floor mat and insole) was the same for both phases of balance trials and used the same standardized shoes (control variable Mat A or Insole A).

Subjects

After the American International College Internal Review Board (IRB) gave approval for the study and informed consent forms were signed, ninety-nine human subjects successfully completed the study. There was a combination of employees from local manufacturing companies, college athletes, staff, and faculty. As identified in table 1, Males comprised 46% of the subject population and females comprised 54%. On average, the subjects reported working seven hours per day with approximately six hours spent on their feet either standing or walking. The average distance walked daily was 2.5 miles. Each study subject received $20 for participating in the balance trials. All subjects used the same type of footwear (Slip Grips Safety Shoe) provided by the Boeing Company.

Variables	Mean (SD)	Range
Age	33.98 (14.34)	20-59
Height (cm)	165.18 (3.87)	149-184
Weight (kg)	74.58 (15.9)	44-109
Hours on Feet	6.18 (2.99)	Jan-15

Table 1: Descriptive Statistics for the Subjects (n=55) in the Floor Mat Portion of the Study.

Independent variable - Floor interface materials

Grouped into two sections, the floor mat and insole materials were characterized as representing a range of firmness as measured using the appropriate standardized Shore A or Asker C scale (soft elastomers) and Shore D scale (thermoplastics) to establish ranges of firmness (compression). Table 2 represents the range of durometers for the floor mats, insoles, and control shoes used in the study with mats and insoles sent for independent testing (*). They were categorized according to three different density floor mats, being ¾ inch thick with smooth standing

Shore Scale	A	D	Asker C*	Shore Scale	A	D	Asker C*
Control A (Slip-Grip Shoe)	42	11		Control A (Slip-Grip Shoe)	Heel 42	Heel 11	
Mat B (soft)	18	0	<10	Insole B (mid-firm)	Heel 32	Heel 2	40-44
Mat C (firm)	72	21	75-78	Insole C (firm)	Heel 90	Heel 66	95-98
Mat D (mid-firm)	47	10	45-48	Insole D (soft)	Heel 15	Heel 0	34-36

Table 2: Standardized testing of study floor mats and insoles in the Shore A and D scales.

* indicates results from the Precision Testing Laboratories, Nashville, TN

surfaces. The floor mats were designated as Mat B (soft mat), Mat C (very firm), and Mat D (mid-firmness). Insoles were identified by their surface contour and density. Insole B was flat in contour with mid-range firmness, Insole C aggressively contoured with significant firmness, and Insole D moderately contoured surface with soft firmness. In both sections, Mat A and Insole A were designated as the control variables representing the standardized shoes with the original insoles.

Intervention

All subjects tested wore standard shoes (Slip Grips) while on each of the separate floor material testing conditions, which acted as the control variable. Same standard shoes applied for each insole phase of the balance investigation. After completing the informed consent and intake data forms, two-minute training sessions preceded all subject trials that were part of the inclusion of the study. Foot profile, arch status, or any other foot abnormalities were not considered in the scope of this study. However, if the subject successfully completed the initial training session, they were included in the study.

Training sessions involved standing on the computerized force plate, becoming familiar with the stick figure icon representing their COP and making balance adjustments to targets set at 75% of limits of stability. The COP icon represented the subject's relative Center of Mass (COM) within his or her Base of Support (BOS) between their feet. All subjects had to keep their feet within a marked box on the computerized force plate. An eight foot by eight-foot display projected onto a blank wall fifteen feet away from the subject. Within the display, eight box shaped icons positions projected on the wall in a clock-like pattern at 1.5-hour intervals with the first box positioned at 12 o'clock, next at 1:30, followed by 3:00, 4:30, 6:00, 7:30, 9:00, and 10:30 positions. Standardized movements were in the same eight clockwise positions; Forward (F), Forward Right (RF), Right (R), Backwards to Right (RB), Backwards (B), Backwards to the Left (LB), Left (L), and finally Left Forward (LF).

The starting position for each subject required his or her COP icon maintained in the center box and wait for one of the outer targets to light up with a blue circle. Subject instructions were to get their COP icon into the target as fast and as direct as possible while holding that position for four seconds. If the subject left the center box early, the computer would force a repeat of that trial. During each trial, the subjects had to maintain their hands on their hips to avoid compensating balance responses and to standardize the use of ankle, hip, trunk, and head balance strategies. If any of the subjects removed their hands off their hips or moved their feet during the testing trial, the subject trial would have to repeat the sequence correctly. Each subject completed the same eight clock positions for both floor mat and insole phases of the testing.

Dependent variables

The variables objectively measured by a computerized force plate calculates a set of balance reactions for Reaction Times (RT), Movement Velocities (MVL), Initial Change in Balance (EPE), Maximum Change in Balance (MXE), and Directional Control (DC). Table 3 represents the definitions of terms published in the manual and manufacturer's literature [4]. The description and definition for each of the balance variables measured for each subject in contain in table 4. An example of the resulting compilation of computerized force plate data presentation for each participation is demonstrated in figure 1.

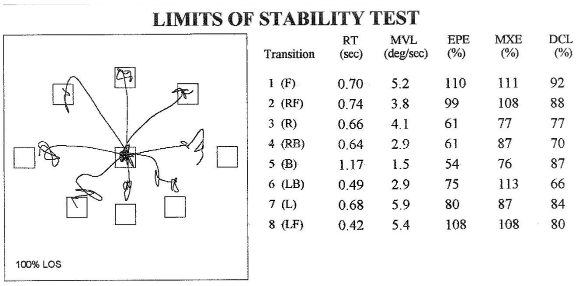
Upon completion of each floor mat and insole trial, the participants offered their subjective responses for each of the three floor mats and three insoles. The participants were requested to rate their perceived preferences, firmness, cushioning, support, and recommendations to friends or co-workers. The post testing survey design was in a Likert scale format with rankings from 1 (poor) to 10 (exceptional) for each of the categories except for recommendations requiring an answer of yes/no and a characterization of the insole arch support (too much/just right/too little). All subjects complied with the posttest survey.

Variables	Mean (SD)	Range
Age	34.36 (14.60)	21-59
Height (cm)	166.98 (4.05)	153-184
Weight (kg)	73.93 (16.14)	44-105
Hours on Feet	6.39 (2.75)	1-13

Table 3: Descriptive statistics for the subjects (n=44) in the Insole portion of the study.

Reaction Time (RT)	Time between command to move and the subject's first movement
Movement Velocity (MVL)	Average speed of COP icon generated by the subject's movement in degrees per second
Endpoint Excursion (EPE)	Distance of the first movement toward the designated target, expressed as a percentage of maximum LOS distance. The endpoint establishes the point where the initial movement towards the target ceases or has been readjusted
Maximum Excursion (MXE)	Maximum distance achieved during a trial as a percentage
Directional Control (DCL)	A comparison of the amount of movement in the intended direction (towards target) to the amount of extraneous movement (away from target)

Table 4: Definitions of each balance response measured by the computerized force plate.



Transition	RT (sec)	MVL (deg/sec)	EPE (%)	MXE (%)	DCL (%)
1 (F)	0.70	5.2	110	111	92
2 (RF)	0.74	3.8	99	108	88
3 (R)	0.66	4.1	61	77	77
4 (RB)	0.64	2.9	61	87	70
5 (B)	1.17	1.5	54	76	87
6 (LB)	0.49	2.9	75	113	66
7 (L)	0.68	5.9	80	87	84
8 (LF)	0.42	5.4	108	108	80

Figure 1: Example of balance data collected from the computerized force plate for each trial.

Statistical analysis

A one-way ANOVA repeated measures design was the method for analyzing the data. The factors included comparison within the floor mat group, within the insole group, and of the combined floor mats and insoles. An alpha level of $P < 0.5$ was considered statistically significant. If assumption of compound symmetry was violated ($P < .05$) the Greenhouse Geisser adjustment was used. If the ANOVA was significant, a Bonferroni adjustment was made for multiple comparisons.

Results

Overall, statistical results of the ANOVAs among the three floor mats tested revealed a statistically significant positive difference for Mat B (soft) for the most important components of balance and upright positions. Directional control, initial, and maximum excursions were better on the soft Mat B in comparison to the control, very firm Mat C (p=0.084), and semi-firm Mat D (p=0.023) for initial changes in balance efforts (Table 5). Mat B exhibited a statistically significant difference in maximum balance efforts when compared to Mat C (p=0.034) and Mat D (p=0.032). There was a statistically significant difference for Mat B in directional control when compared to the control - Mat A (p=0.007). Better performance was noted on soft Mat B in the left and backwards balance challenges compared to others within the floor mat group.

Variable	F	P	Mat A (control)	Mat B (soft)	Mat C (firm)	Mat D (mid-firm)
RT	1.11[a]	0.34	.73 (.21)	.75 (.22)	.90 (1.1)	.74 (.21)
MVL	2.54	0.06	5.69 (1.65)	5.37 (1.44)	5.53 (1.51)	5.43 (1.48)
EPE[b]	3.74	0.01	80.83 (13.46)	82.21 (12.49)	78.74 (10.87)	77.85 (9.75)
MXE[c]	5.03[a]	0.01	96.74 (10.43)	99.51 (13.25)	94.89 (9.16)	94.40 (11.97)
DCL	1.39[a]	0.25	75.90 (9.67)	77.83 (8.77)	75.63 (11.68)	76.11 (10.07)

Table 5: Mean comparisons for Mats A, B, C and D with the dependent variables (N = 55).

Reported in Means (Standard Deviation)
[a] indicated Greenhouse Geisser adjustment was used
[b] Mat B was significantly larger than both Mats C and D. c Mat A was significantly larger than Mat D
[c] Mat B was significant larger than Mat C

The statistical analysis of the tested insoles provided only one statistically significant difference between each of the insoles. The End Point Excursion (EPE) changes in balance was significant for Insole D (p=0.051). The data did provide a clear trend demonstrating better dynamic standing balance performance in many balance components with Insole D (soft density with a slightly contoured insole). Insole B (semi-soft but flat with no contours) was also beneficial compared to Insole C (hard density with aggressive contours) and Insole A, which was the control. The lack of statistical difference on a broad range of balance components among the insoles was not surprising given the proximity of the insoles to the surface of the subjects' feet. The positive trend did establish Insole B and D as affording better dynamic standing balance reactions.

ANOVA results in the above table compare Insole B, Insole D, and MAT B with all the dependent variables. Directional control was in close proximity to statistical significance (p=0.054) when comparing Insole D to the best performing mat, Mat B. The data offers a concise comparison between the best floor mat (Table 5) and best insoles (Table 6) indicating a positive trend towards better balance reactions and upright dynamic postural responses when cushioning is placed closest to the foot surface. In the context of dynamic standing and upright positions in employees performing work tasks, the data analysis did not demonstrate any significance for the role of gender, body weight, height, or age as a factor. The average age of the subjects was 35 years with an average body weight of 165 pounds. The study results indicated Insole D followed by Insole B and Mat B as having a better interface between ground and employee for better dynamic balance reactions regardless of gender, body weight, or height.

Data comparisons from each of the eight clockwise directional challenges are represented in figures 2 and 3. Subjects were tested at 100% of Limits of Stability (LOS) with recorded tracking of movements in eight clockwise positions; Forward (F), Forward Right (RF), Right (R), Backwards to the Right (RB), Backwards (B), Backwards to the Left (LB), Left (L), and Left Forward (LF). These particular balance components represent statistically significant differences within each of the testing phases for floor mats and insoles. Data results indicated better balance reactions when standing on Insole D (soft) and floor mat B (soft) for initial and maximum excursions towards the target.

Variable	F	P	Insole A (control)	Insole B (mid-firm)	Insole C (firm)	Insole D (soft)
RT	0.64	0.6	0.77 (0.22)	0.78 (0.24)	0.77 (0.21)	0.80 (.23)
MVL[b]	2.97	0.03	5.69 (1.81)	5.32 (1.80)	5.59 (1.72)	5.68 (1.64)
EPE	1.16[a]	0.33	82.18 (13.27)	82.39 (12.54)	81.94 (10.23)	84.12 (9.50)
MXE	0.08[a]	0.97	95.90 (9.34)	95.84 (13.98)	95.51 (7.72)	96.23 (8.90)
DCL	1.27[a]	0.28	79.62 (10.00)	78.94 (7.22)	80.05 (6.04)	81.35 (4.14)

Table 6: Mean comparisons for Insoles A, B, and C with the dependent variables (N = 44).

Reported in Means (Standard Deviation)
[a] indicated Greenhouse Geisser adjustment was used
[b] Insole A was greater than Insole B (P = .70).
No significant post hoc comparisons are found with the Bonferroni adjustment

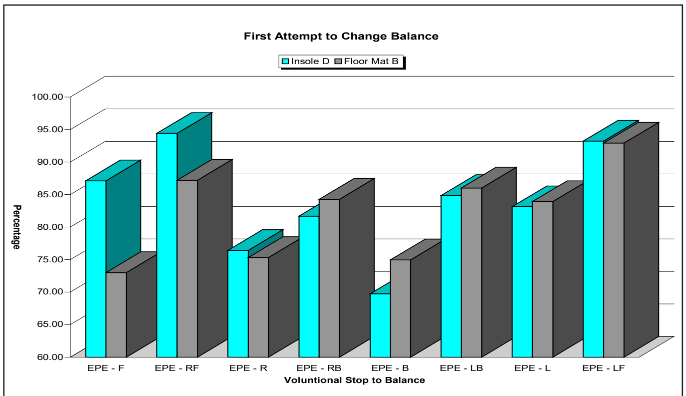


Figure 2: Initial efforts of subjects' comparison of Insole D and Floor Mat B.

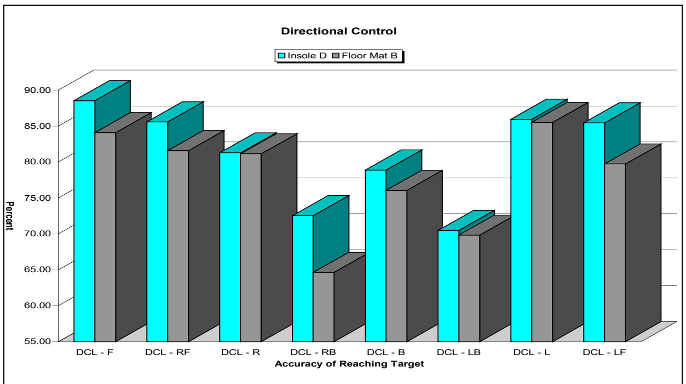


Figure 3: Dynamic standing balance accuracy (DC) comparison of Insole D and Floor Mat B.

Subjective survey responses

Subjective survey results were not statistically significant for any one particular floor mat or insole. However, while there was no statistical relevance, the trend of subjective responses noted in figures 4-6 do appear to parallel the statistically significant objective balance reaction data as highlighted in the summary of responses provides a balance with the objective data completing the results section. A consistent preference of the subjects becomes apparent in the following figures.

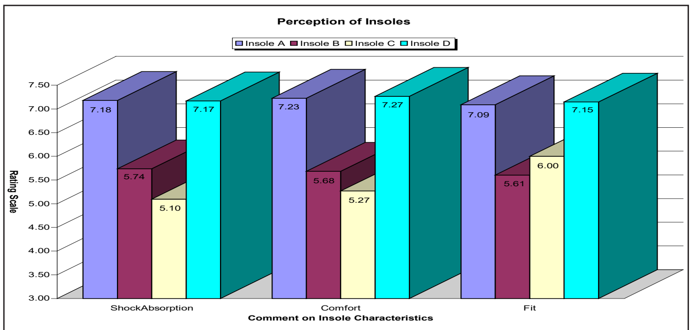


Figure 4: Perceived insole ratings for shock absorption, comfort, and overall fit.

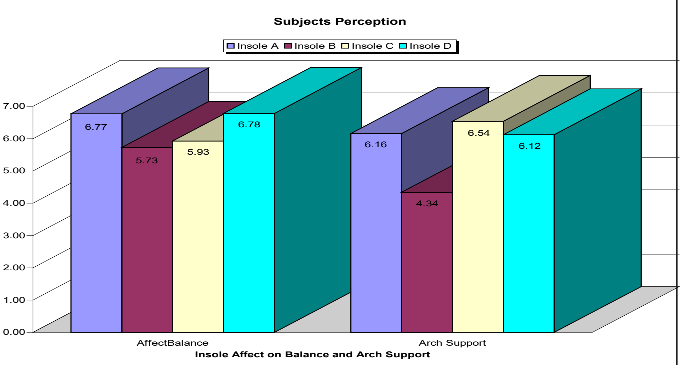


Figure 5: Subjective perception ratings of insoles on balance and arch support.

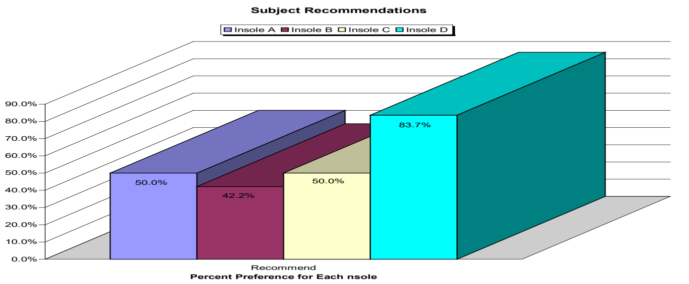


Figure 6: Percent of subjects recommending each insole to co-workers, friends, and family.

Discussion

A statistically significant improvement in dynamic balance reactions occurred when subjects stood on materials of a Shore a durometer range of 18 to 34 when compared with medium and firm materials. This was consistent for the composition of both floor matting material and insole materials. However, when comparing that same durometer between floor mats and insoles, softer materials placed closer to the surface of the feet rather than under the surface of worker's footwear improved the balance variable outcome. Placing the cushioning close to the surface of the feet was surprisingly better for balance reactions, particularly for directional control. It is important to note that while not statistically different at $p = 0.05$, the difference between the soft insole and the soft mat was considerably noteworthy at $p = 0.054$, a value that could be easily argued as being significant for the workplace scenario.

Directional control is one component of balance that relates most appropriately to work performance in standing positions. The effort to alter upright positions for purposeful work requires the most efficient ability to adjust muscular exertion for directional control in various tasks expected in the workplace but it can be affected by a worker's age [9]. Typical work tasks can range from manufacturing computer chips, hospital procedures, building airplanes, or a variety of complex procedures of work processes requiring accurate postural control for work productivity.

The most impressive findings of this study confirmed the consistency of a specific range of material density as measured in durometers that are beneficial for balance reactions. Prior applications and practice of placing various materials between the employee and the ground has been predominately based on subjective input or unrelated material colors or shapes expressed by the manufacturers of floor mats and insoles. Although it seems somewhat intuitive to consider the effects on worker balance and upright postural control as it relates more to the potential impact on workplace productivity and safety, there was little objective data to substantiate guidance in this critical safety domain.

While there were no statistical differences between each of the insoles, there was a clear positive trend in many of the dynamic standing balance components with Insole D (soft density with a slightly contoured insole) followed by Insole B (semi-soft but flat with no contours). Both Insole D and B were remarkably advantageous over Insole C (hard density with aggressive contours) and Insole A, the control. Insole A was actually the standard insole that came with the safety shoe tested in the study. The lack of any statistical difference among the insoles was not surprising, given the proximity of the insoles to the surface of the subject's feet.

The interaction between dynamic standing and the requisite motor control performing productive work tasks while in the upright position reflected in figure 7. There is a constant feedback loop between the feet sensory input that is influenced by the firmness of the material the subject is standing on at the time. It was interesting to note the data's positive trend in dynamic standing balance reactions for Insole B and D developing across the EPE, MXE, and DCL balance reaction variables. Soft insoles with a slight or subtle contour exhibited the best conditions for efficient balance interactions for a variety of work standing tasks. While there were no statistical differences among insoles, except for EPE using Insole B (Table 6), the data from the softer Insole B and D did present a positive trend for dynamic standing balance reactions. A potential benefit of softer cushioning would permit greater surface contact and sensory feedback from more efficient muscle use during standing whereas floor mats would be under the footwear surface not in contact with the actual foot itself.

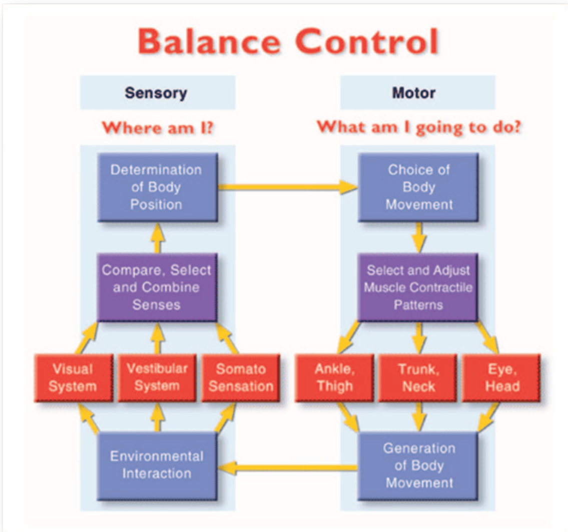


Figure 7: Interaction of sensory input and muscle control for maintaining competent standing balance.

In comparison to floor mats, there was a statistically significant difference between the positive impacts of Mat B, the softer mat, in three major standing balance components. As noted prior in a statistical comparison between the best responding floor mat (Mat B) and insoles (B or D), the application of softer materials is best applied to the surface of the feet rather than under the worker's footwear. This approach to effective cushioning would support the sensory and motor relationship for efficient trunk and leg muscle postural controls, as observed in figure 8. The data in table 7 indicates the overall standing balance benefits when using soft insoles with a durometers range of 18 to 34 durometers in comparison with the use of harder insoles and firmer floor mats, especially those with higher durometers of firmness. The study data indicates the potential to improve work-standing positions and balance reactions with application of encouraging safer work performance.

Variable	F	P	Mat B (N = 55)	Insole B (N = 44)	Insole D (N = 44)
RT	0.51	0.6	0.75 (0.22)	0.78 (0.24)	0.79 (0.23)
MVL	0.65	0.52	5.37 (1.44)	5.31 (1.80)	5.68 (1.64)
EPE	0.38	0.69	82.21 (12.49)	82.39 (12.54)	84.12 (9.50)
MXE	1.36	0.26	99.51 (13.25)	95.84 (13.92)	96.21 (8.90)
DCL[a]	3.04[b]	0.05	77.83 (8.77)	78.94 (7.22)	81.35 (4.13)

Table 7: Mean comparisons for Mat B, Insole B, and Insole D.

Reported in Means (Standard Deviation)
[a] indicates that the Assumption of Homogeneity of Variance was violated. No adjustment was made.
[b] Insole D is larger than Mat B (P = .054)

Analysis of the data reveals a statistically significant difference utilizing the softer mat (Mat B) in comparison to the other firmer mats, (Mat C and Mat D) as may benefit an employee's balance reactions. For example, Mat B demonstrated a confidence interval of 95% level ($p<0.05$) for better standing balance response outcomes. The difference centered on the balance reaction components of Initial Efforts (EPE), the Maximum Efforts (MXE), and Directional Control (DCL) of a subject's ability to modify and efficiently change his or her standing balance positions. These improvements would benefit many contemporary sectors of the economy spanning from healthcare, technology, manufacturing, transportation, hospitality, and many others. Overall, the study data points to the fact that, overall, subjects performed better with softer cushioning between the feet and ground. Most importantly , the balance reaction components benefitting from softer materials were observed regardless of gender, age, weight, and height.

The subjective input from the study participants offered unique insight into the preferences and perceptions executing dynamic balance responses at 100% of their limits of stability. The softer insole with a slight contoured surface was rated subjectively higher than either the insole with no contour or the aggressive firm contour. Carley & Swanson [10] observed in an earlier study at the workplace, subjects generally indicated a preference for more cushioning added to the medial arch area of the insole. This is evident in figure 5 where subjects rated the insole with cushioning and soft arch support with better balance higher than the insole with no contour or firm arch support. Interestingly, overall preference for a soft contoured insole did show a positive relationship with the objective findings of this study. King [11] noted similar subjective findings in a workplace study with softer insoles.

Studies in the past have indicated that there is more muscle activity on the softer mat surfaces with no elaboration of the value and functional relevance of actual work performance and balance activities [12-15]. The study results indicated that softer floor mats and insoles can possibly afford the employee with a predictable time delay through greater shock or force absorption. In addition, the softer cushioning may offer more time for efficient muscle recruitment, resulting in greater accuracy for making balance adjustments as observed in this study. The potential for time-delayed muscle recruitment would suggest a more efficient or functional use of lower extremity muscle activity, as evidenced by the statistically significant benefit of more accurate adjustments to standing balance.

It would be difficult to suggest the relationship of standing on softer materials unequivocally causes sufficient muscle fatigue to the point of work performance reduction. Chiang & Ge [16] reported that standing while on a foam (soft) surface "would affect the inputs to both joint receptors and cutaneous mechanoreceptors in the foot, but not the muscle receptors in the early phase of the platform movement." The study continued with an observation that the "medium and long latency responses in the leg muscles appeared to be delayed significantly when standing on foam, while the short latency response in the gastrocnemius muscle was unchanged." Nigg et al., (1997) observed the changing consistency of footwear on the affects of altering gait patterns.

The above observation provides a better understanding of a study exploring the EMG influence of footwear, athletic shoes, and standing positions that signifies an "increased activity in the triceps surae complex and in other muscles that support the changes in postural requirements caused by the anterior shift in center of pressure" [17]. If work tasks involve the timely upright repositioning of a worker for precision reaching and fine motor control of the hands, then it could be argued that more efficient EMG activity could translate to improved work performance throughout the day and not necessarily fatigue. Popa et al., [18] recorded alternative standing balance strategies with subjects experiencing chronic low back pain. Alexander et al., [19] noted individuals with chronic unilateral low back pain, when "compared with control subjects, [those] with low back pain demonstrated greater anterior-posterior center of gravity excursion." While the low back study did not test with cushioning material, a future study measuring the impact of softer floor mats or insoles on this group could be important.

Blood flow indicators, girth measurements, and electromyography have been tools used in the past to assess the impact of floor mats and insoles at the workplace. While these additional modalities are helpful in understanding various physiological responses to upright positions throughout the workday, the consideration for dynamic standing responses and challenges imposed by floor mats and insoles necessitates further study to comprehend the full long-term impact of standing at the workplace. The use of the NeuroCom's Balance Master, a Computerized Dynamic Posturography (CDP), as a sophisticated assessment technique is extremely effective at objectively quantifying and differentiating among the variety of complex systems involved in balance, including sensory, motor, and central adaptive balance behaviors. The CDP is sensitive enough to identify and differentiate the impairments associated with balance problems in the clinical arena designed to localize and categorize medically related balance disorders.

Limitations

Some limitations to the study included not controlling for diet, medications, daily exercise, or caffeine intake of the subjects. Time of day for all testing sessions was not controlled.

Conclusion

This study concludes that the indiscriminate placement of materials, such as floor mats and insoles, between the worker and the ground is a practice that warrants scrutiny. The balance interactions between the employee and the ground emerged as a more responsive and sensitive interface than formerly considered before this study. Although the data results were initially surprising, softer materials closer to the surface of the foot offer more subjective cushioning, they also appear to provide an important time-sensitive input for sensory and joint proprioception that improves balance reactions through the efficient recruitment of trunk and leg muscles.

The balance reactions of subjects who used hard floor mats and very firm insoles did not perform well in comparison to softer mats and insoles (Asker C Scale durometer range of 18 to 34). The softer materials were significantly better for directional control, the most important aspect of balance in relation to work performance. This study affords an increased understanding of the impact of placing various mats and insoles under workers' feet. Employers and safety personnel should require suppliers of floor mats and insoles to present a standard durometer rating of their respective products for realistic comparisons.

This study provides the manufacturing, transportation, healthcare, and many other sectors of the economy with an unambiguous direction for the safer management of cushioning of work floor surfaces. Future studies combining electromyography with dynamic force plate analysis of balance reactions would be noteworthy and would augment critical information in exploring the efficiency of muscle use and upright balance corrections with floor mats and insoles during the workday. Further longitudinal studies need to challenge the ubiquitous use of the term "anti-fatigue" for floor mats and insoles. The expectations should be directed towards more practical, cost-effective, and realistic safety assessments of those required to stand at the workplace.

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