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THE EFFECTS OF FLOOR TYPES ON STANDING TOLERANCE IN INDUSTRY

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by

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It is recognized by the studies in many industries that standing tolerance is affected by the type of floor used. This study investigated the effects of different flooring conditions on workers required to stand for long periods of time using a psycho-physical approach. Nine different flooring conditions were used including concrete, seven types of mats, and a viscoelastic shoe insert. Questionnaires administered at the end of the workday were used to monitor the perceived fatigue and pain associated with the various floors. The results of the study showed that there was a significant difference between the ratings of the floor for perceived hardness, overall body fatigue, and leg fatigue. Specific discomfort areas of the body were also rated by the workers with the results showing a significant difference between the flooring conditions on the different areas of the body. In evaluating the results, the study showed that workers who are required to stand for prolonged periods of time experience significant levels of fatigue and discomfort in different areas of the body. It appears that the effectiveness of a floor in relieving this fatigue is a function of its hardness and it's depth before bottoming out as well as flooring dynamic properties.

In many industries, workers are required to work while standing, walking, and/or carrying loads. The problems associated with this are great. Slipping and tripping problems are the best documented and account for about 18 percent of all industrial accidents (Pater, 1985). Another problem which is well known but much less documented is lower extremity discomfort and fatigue from forced long term standing and walking. In a survey of a typical assembly plant, leg pain and fatigue was found to be prevalent, however it is generally not reported, Of the reported injuries in the plant, it was found that 15 percent of reported injuries were chronic lower extremity problems. While these reports of injuries are not all directly caused by long term standing and walking, it is believed that most of them are directly or indirectly related. It is also believed that long term standing may have an effect on chronic low back pain in some workers, Magora (1972) showed that the incidence of low back pain was highest in those workers who stood regularly every working day for periods of more than four hours. It is difficult to define the problem of standing and walking tolerance because the cause and effect relationship is so elusive.

1. Introduction

In many industries, workers are required to work while standing, walking, and/or carrying loads. Lower extremity discomfort and fatigue from forced long term standing and walking is a problem often identified, but seldom documented. In 1983, it was reported by the American Podiatric Association that 83 percent of the industrial work force in the United States had foot or lower leg problems such as discomfort, pain or orthopedic deformities. Bousseman, et al. [1] showed in the laboratory that long term standing is a direct cause of pain and discomfort. Morgora [2] showed that the incidence of low back pain was highest in those workers who stood regularly every working day for periods of more than four hours.

It is difficult to define the problem of standing and walking tolerance because the cause and effect relationship is so elusive. There are no models or methods to directly measure the effects of long term standing and walking. It is interesting and insightful to note the attempts of the workers to alleviate the problem. It is common to see a worker put cardboard, a mat, or a piece of rubber on the floor to try to reduce the perceived stress and tiredness in his/her legs. Flooring and show manufacturers are also beginning to become sensitive to this problem. Flooring companies now sell various mats and floor coverings that they claim help to alleviate tiredness and fatigue in the legs due to prolonged standing and walking.

2. Objective

The purpose of this research project was to investigate the effects of different flooring conditions on workers that are required to stand while performing their job. Questionnaires were used at the end of the workday to monitor the perceived fatigue and pain experienced by the workers when on various floors.

3. Methods

This study involved 14 workers, all of whom stand throughout their shift. The subjects were chosen from various areas of the plant. The major criterion used in choosing the subjects was that their jobs require they stand throughout the entire shift. A total of nine flooring conditions were used including concrete, seven types of mats and a viscoelastic shoe insert. Table 1 describes these conditions. Hardness of the floor conditions were measured by a stress-deformation analysis using an Instron machine.

Table 1: Flooring conditions used in the flooring study.

1) thin – 1/16" rubber mat
2) medium – _" rubber mat
3) thick – 3/8" rubber mat
4) Tri – hard mat with Tri-laminate padding underneath
5) Notri – hard mat without any padding
6) Concrete – bar concrete floor
7) A – viscoelastic mat
8) Insert 0 viscoelastic shoe inserts
9) Uneven – soft, uneven surface mat

The first three floors (1, 2 and 3) are mats made of the same material but of varying thickness, with the thicker ones creating more "give" under the feet of the workers. The material used, a rubber material, is fairly stiff. Figure 1 shows the stress - deformation relationship of this material. The slope of these curves show the elastic modulus of the material which is a measure of it's firmness. As the stress level increases, further compression of the material becomes very difficult. This relates to the level at which the mats "bottom out" under the weight of the worker. The stress under the foot of a worker can vary greatly depending on what activity he/she is performing. It can range from as little as 1 Kg/cm^2 when standing perfectly still to 30 Kg/cm^2 during heel strike of the walking cycle.

The next three floors (4, 5 and 6) were the controls. The hard mats with and without the tri-laminate padding, a soft foam rubber, (4 and 5) are a standard in the surveyed plant. Most of the workers who stand throughout the day put these mats down instead of standing on concrete. The stress deformation curves for these floors are shown in Figure 2. The trilaminate mat allows some "give" in the floor is lower than the thick and medium rubber mats. Note also that the "bottoming out" level of the trilaminate floor is lower than the thick and medium rubber mats. The hard mat without trilaminate (5) is not used in the plant to reduce leg fatigue, but rather to reduce the slipperiness of the floor surface. Therefore this is a hard mat with a very high elastic modulus as shown in Figure 2. The concrete floor(6) is an industrial standard for most extended standing jobs.

The final three floors (7, 8 and 9) are other commercial methods of attempting to reduce leg fatigue. The viscoelastic floor (7) is an experimental mat supplied by a company that produces primarily vibration reduction materials. This material reduces the high frequency components of impact forces, and thereby reduces the shock when the foot hits the ground during walking. The mat is fairly hard elastically as shown in Figure 3. The insert (8) is a viscoelastic shoe insert made of a similar material as the mat (7) but made to fit inside the shoe. The same principal is involved regarding shock absorption. It is also claimed by the manufacturer to reduce low back pain by reducing shock. The last floor, the uneven surface (9), is a new commercial mat designed to reduce fatigue. The theory behind it (as put forth by Brantingham (1978) is that the uneven surface allows slight movement of the ankles thereby improving circulation is the muscles of the lower legs. The mat is also soft relative to the others. This can be seen in the stress - deformation curve in Figure 3.

Figure 1
Stress - displacement curves for the rubber mats (1,2 and 3) used in the study

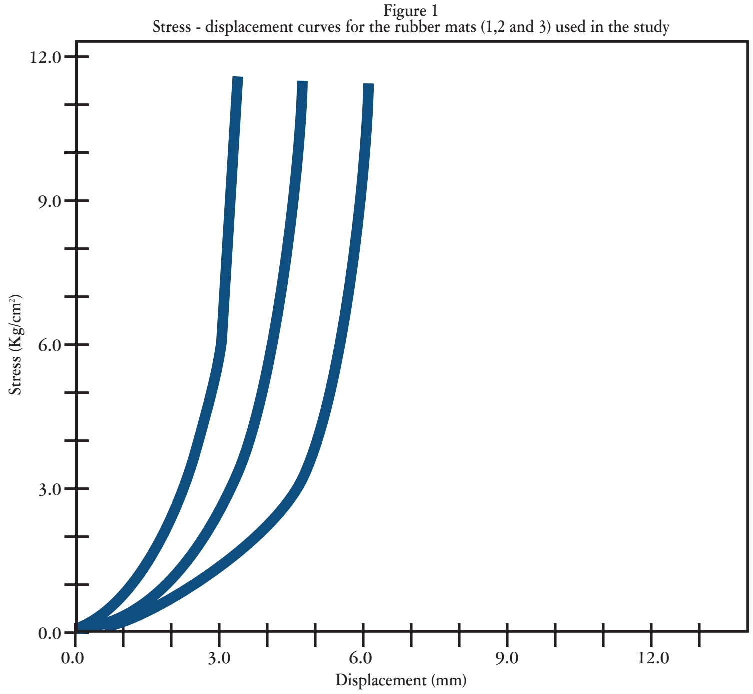


Figure 2
Stress - displacement curves for the hard mats (5) and without (4) Trilaminate material

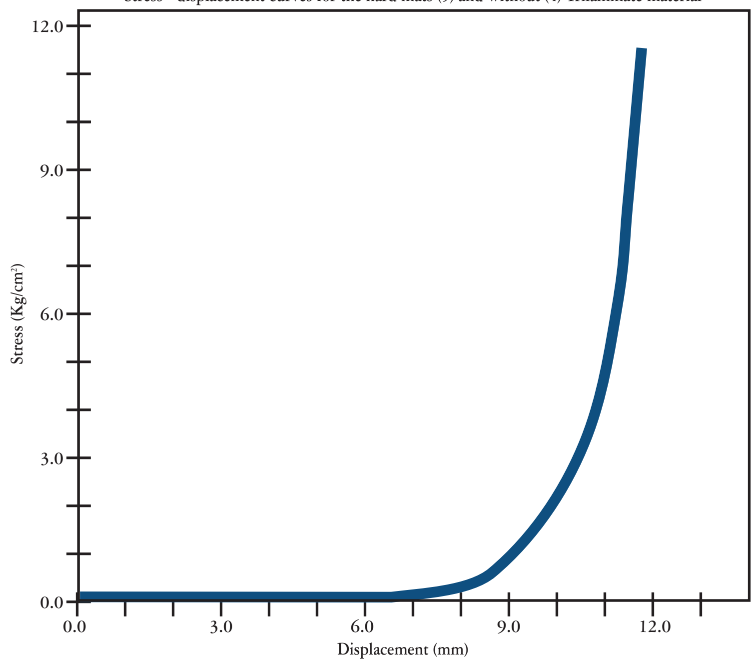
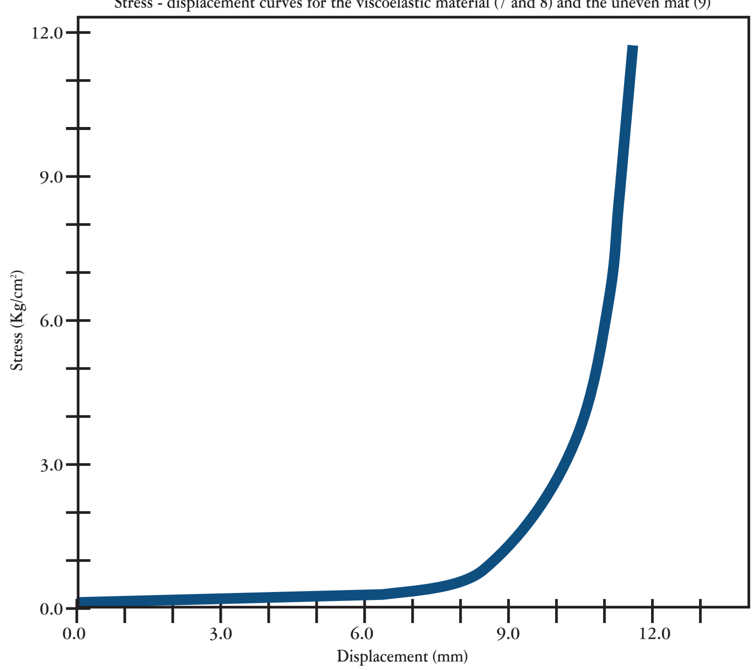


Figure 3
Stress - displacement curves for the viscoelastic material (7 and 8) and the uneven mat (9)



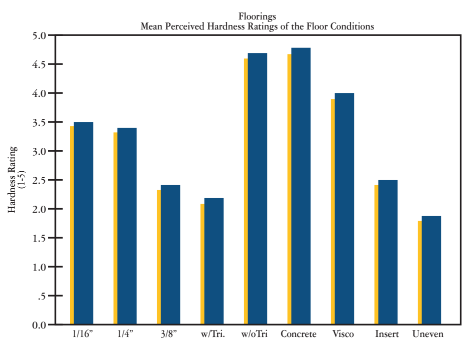
Questionnaires were used to monitor the perceived fatigue and pain associated with the various floors. Fourteen workers, all of whom stand throughout their shift, were asked to complete the questionnaire to evaluate the particular floor he/she was using. The floors were rotated between subjects every two weeks until every subject had evaluated every floor condition. The hardness and elastic properties of the floors were measured using an Instron compression tester to get an objective measure of these parameters to compare to results of the questionnaire.

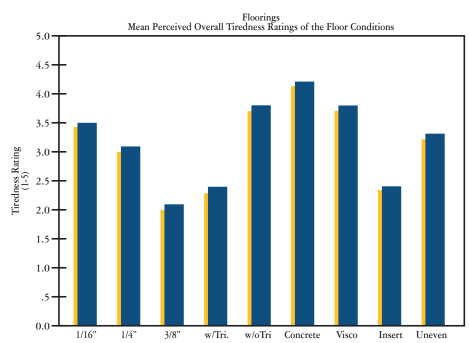
4. Results

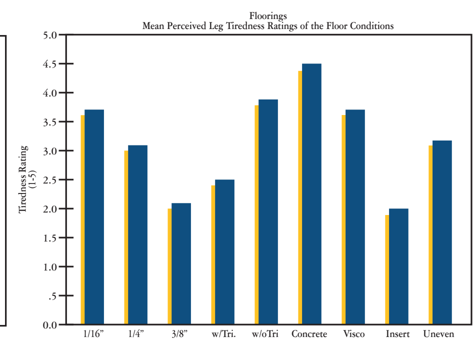
The first three questions on the questionnaire asked the workers to rate the floors according to: 1) perceived hardness of the floor, 2) overall tiredness of the body at the end of the day, and 3) tiredness in the legs at the end of the day. Table 2 is a summary of the results of this section.

Table 2: Mean and Standard Deviations of ratings for the perceived hardness of the floor surfaces.

	Perceived Hardness		Overall Tiredness		Leg Tiredness	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
1) 1/16" (thin)	3.5	1.4	3.5	0.7	3.7	0.8
2) 1/4 " (med)	3.4	1.2	3.1	1.0	3.1	1.0
3) 3/8" (thick)	2.4	1.2	2.1	1.2	2.1	1.2
4) Hard mat w/ Tri-lam.	2.2	1.2	2.4	1.3	2.5	1.2
5) Hard mat w/o Tri-lam.	4.7	0.5	3.8	0.8	3.9	0.9
Concrete	4.8	0.4	4.2	1.0	4.5	0.8
Viscoelastic mat	4.0	0.7	3.8	0.7	3.7	0.7
Viscoelastic shoe insert	2.5	1.4	2.4	1.1	2.0	1.1
Uneven mat	1.9	1.0	3.3	0.9	3.2	1.0







The results of the study showed that there was a significant difference between the ratings of the floors for perceived hardness, overall body fatigue, and leg fatigue. When the data were stratified by each floor type, the correlations between the three indices ranged from .60 for the concrete floor to .97 for the thick rubber mat. In general, the ratings of perceived hardness correlated very well with the measured hardness of the floors with the one exception of the uneven mat (9) which was perceived as the softest mat. The general correlations between perceived hardness and either leg tiredness or body tiredness were both about .50. A major difference seen between the perceived hardness ratings and these general tiredness ratings was that the uneven mat (9) was rated as the softest floor; however the tiredness rating was 3.3 which were fifth in rank and just below the think rubber mat (1). The uneven mat also was fifth in the rank for the leg tiredness ratings.

Specific discomfort areas of the body were also rated by the workers. These areas were divided as follows: Feet, Ankles, Shank, Knee, Thigh, Hips, Lower Back, and Upper Back. The results showed a significant difference between the flooring conditions on the different areas of the body. The concrete floor (6) and the hard mat (4) consistently had the highest discomfort ratings, while the lowest ratings were shared by the thick rubber mat (3), the tri-laminate mat (5) and the shoe insert (8). F-tests between the mean discomfort ratings for each floor showed that they were significantly different ($p<.05$) for the foot, ankle, shank, knee, upper back and lower back. The others, the leg and hip, were not significantly different ($p<.05$) between floor types.

When looking at the ratings for the different parts of the body, the feet had the highest discomfort rating followed by the ankle. In fact, the general discomfort ratings involved in standing tend to decrease as the distance from the floor is increased. For example, the feet ratings are higher than the ankle, the shank are higher than the ankle, and so on.

5. Discussion

In evaluating the results, the study showed that workers who are required to stand for prolonged periods of time experience significant levels of fatigue and discomfort in different areas of the body. Also, the floor surfaces on which they stand during their shift affects the workers' perceptions of this tiredness and discomfort. It appears that the effectiveness of a floor in relieving this fatigue is a function of its hardness and it's depth before bottoming out. A floor can be too soft, however. This is evidenced by the fact that the uneven mat (9) was relatively soft and had low perceived hardness levels, but had relatively high tiredness ratings. The dynamic properties of the floor may also be important. These properties reflect how the floors absorb and transmit forces to the body when the foot hits the ground. The non-linear dynamic properties such as in the viscoelastic material also have some effect.

Another observation from this study is the high correlation between leg tiredness and general tiredness. This indicates that the flooring is not only affecting the legs, but the entire body in some way. The discomfort ratings showed that the lower legs were most affected by the type of floor used. It seems that the body segments closer to the floor had the high ratings. In other words, the discomfort diminishes as the distance away from the floor.

6. Conclusions

This research has shown that workers who are required to stand for prolonged periods of time experience significant levels of fatigue and discomfort in different areas of the body. Also, the floor surfaces on which they stand during their shift affect the workers' perceptions of this tiredness and discomfort. It appears that the effectiveness of a floor in relieving this fatigue is a function of its hardness and it's depth before bottoming out. Further research needs to be done to determine the effect of flooring on the human body. Investigations into both the physiologic and biomechanical influences should be undertaken. Better methods to identify and quantify the effects of long term standing are also necessary to continue this work.

Acknowledgements

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