EVALUATION METHODS OF NO-SHOES-FLOOR DEFORMATION PROPERTIES CONSIDERING COMFORTABLENESS OF HUMAN ACTIVITIES

Configuration of Psychological Scales and Presentation of an Evaluation Method for Walking

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ABSTRACT

The final goal of our research is the establishment of evaluation methods of floor deformation properties considering comfortableness for various human activities. At the first, we defined the classification into walking and the others by floor deformation properties, based on the result of the sensory tests. At the next, we focused on human walking and examined evaluation methods of comfortableness for walking as the first step of our research. As the result, we defined that performance value compounding 2 factors about hardness and titubation of the floors can evaluate the comfortableness for walking.

1. INTRODUCTION

"No-shoes-floor" refers to floors where a person takes off his/her shoes; such floors are common in general Japanese houses and elderly facilities. A person performs various activities on a no-shoes-floor, e.g., walking, sitting, and lying down, wherein body regions engage in various motions and make numerous contacts with the floor surface. Evaluation methods of floor deformation properties that consider the comfortableness of certain human activities have not yet been developed.

The goal of this research is to establish such evaluation methods. In this paper, we construct psychological scales for measuring the comfortableness of various human activities and examine the relationships between them. As a first step, we examined methods for evaluating the comfortableness of walking.

2. CHOOSING SUBJECT ACTIVITIES

Table 1 summarizes various activities that humans exhibit on a no-shoes-floor. These activities are classified by the body region making contact with the floor; these contacts may be dynamic or static. We studied the following activities:

1) Our previous studies[1)] have found that walking and standing result in similar floor deformation properties. Therefore, in this study, only walking was chosen as a subject activity.
2) Concerning the activities mainly touching the body regions except sole, 9 subjects has been chosen in view of similarity about the body regions during the actions.

Table 1 shows the subject activities.

Table 1 General activities on no-shoes-floor and subjects of this study

	Body regions touching floor	
	only sole	mainly except sle
Dynaminc activitiies	Walking◎	Sitting down◎, Standing up◎, Rolling over◎, Knee walking◎
Static activities	Standing	Sitting (Straight sitting◎, Sitting on floor grasping knees, Long seat, Sitting leds crossed◎) lying (lying◎, Side lying, Lying prone, Lying prone with putting elbow◎), Knee standing

◎ : Subjects of this study

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3. SENSORY TESTS AND CONSTRUCTION OF PSYCHOLOGICAL SCALES

Sensory tests were performed on nine subject activities using 26 floors; these floors were made of various materials via varied construction methods. **Table 2** summarizes the sensory tests. The scales that rank the sensory tests were categorized into dynamic and static activities. Dynamic activities were ranked with the following scales: “good feeling scale,” “easiness of activitiescale” and “aptitude scale.” Static activities were ranked with the following sales: “good feeling scale” and “pain expected in long-term scale.” The “good feeling scale” represents the degree of good feeling during the subject activity. The “easiness of activitiescale” represents the degree of ease for the subject activity. The “aptitude scale” represents the degree of overall comfort combined with those of good feeling and easiness of activity. The “pain expected in long-term scale” represents the degree of pain expected while maintaining the same activity for a long time. The respective judgment categories are shown in **Table 2**.

We performed the sensory tests discussed above. After confirming the significance of the test results, we constructed 23 psychological scales (five dynamic activities × three inspection items = 15 types and four static activities × two inspection items = 8 types)

Table 2 Summary of sensory tests

Method to create scales	Series category method			
psychological scales	Good feeling scale	Easiness of activitiescal	apptitude scale	Pain expected in long-term scale
Question	From a viewpoint of floor hardness and feeling, this floor is…			If you continue to take same attitude for long time, this floor seems…
Categories to reply evaluation	⑦Extremely good feeling ⑥Very good feeling ⑤Slightly good feeling ④Neither good nor ungood ③Slightly ungood feeling ②Very ungood feeling ①Extremely ungood feeling	⑦Extremely easy ⑥Very easy ⑤Slightly easy ④Neither easy nor hard ③Slightly hard ②Very hard ①Extremely hard	⑦Extremely suitable ⑥Very suitable ⑤Slightly suitable ④Neither suitable nor unsuitable ③Slightly unsuitable ②Very unsuitable ①Extremely unsuitable	⑦Not to be painful at all ⑥······· ⑤to be slightly painful ④······· ③to be very painful ②······· ①to be extremely painful
Activities	9 activities shown Table 1			
Sunbject floors	26 various floors			
Examiners	10 adult males (age:21～53, Height:168～184cm, weight:53～99kg)			
Footwear and clothes	Socks and jerseys			

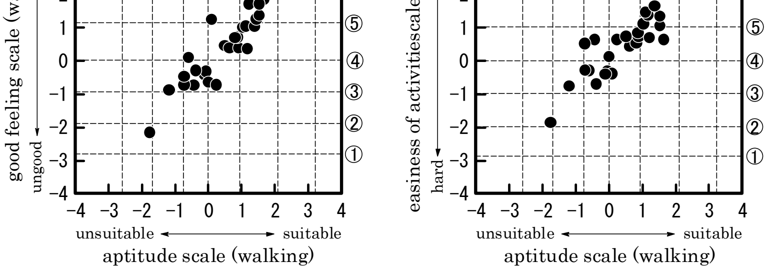
4. CONSIDERATION OF RELATIONSHIPS OF MUTUAL PSYCHOLOGICAL SCALES

4.1 Consideration of Same Activities with Each Other

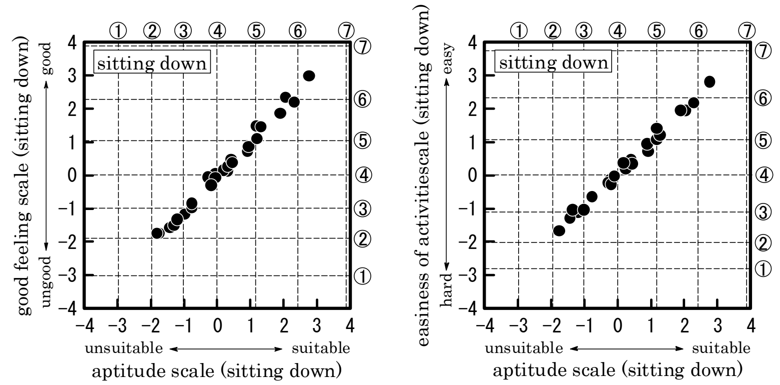
Figure 1 shows examples of relationships of mutual psychological scales for each activity. In this figure, **(1)** is walking, **(2)** is sitting down, **(3)** is straight sitting, and **(4)** is lying down. The broken lines of ①～⑦ in this figure show the position of each judgment category (cf. **Table 2**).

In **(1)** of **Figure 1**, there was a poorer correspondence between both scales than in **(2)**～**(4)**. Similar results were obtained with walking. From these results, we determined different performance values for each scale in walking.

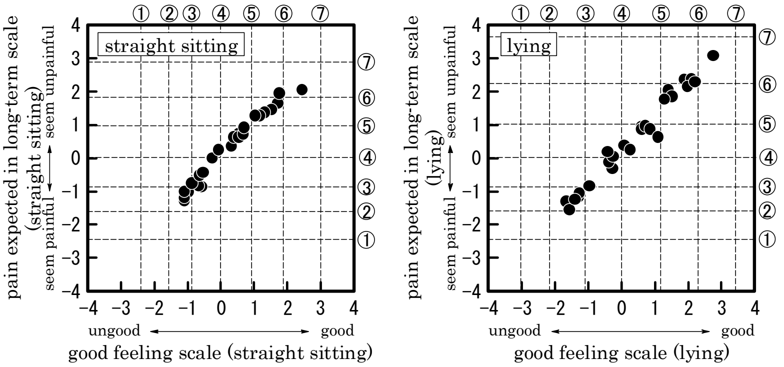
On the other hand, there was a good correspondence between both scales in **(2)**～**(4)** of **Figure 1**. Similar results were obtained in other activities. From these results, it was determined that one performance value corresponding to one scale can correspond to the other scales as well.



(1) Walking



(2) Sitting down



(3) Staraight sitting (4) Lying

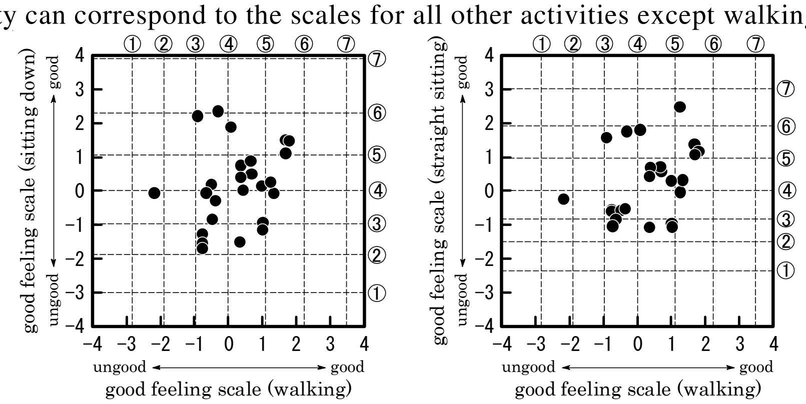
Figure 1 Relationships of mutual psychological scales for the same activities

4.2 Consideration of Same Scales with Each Other

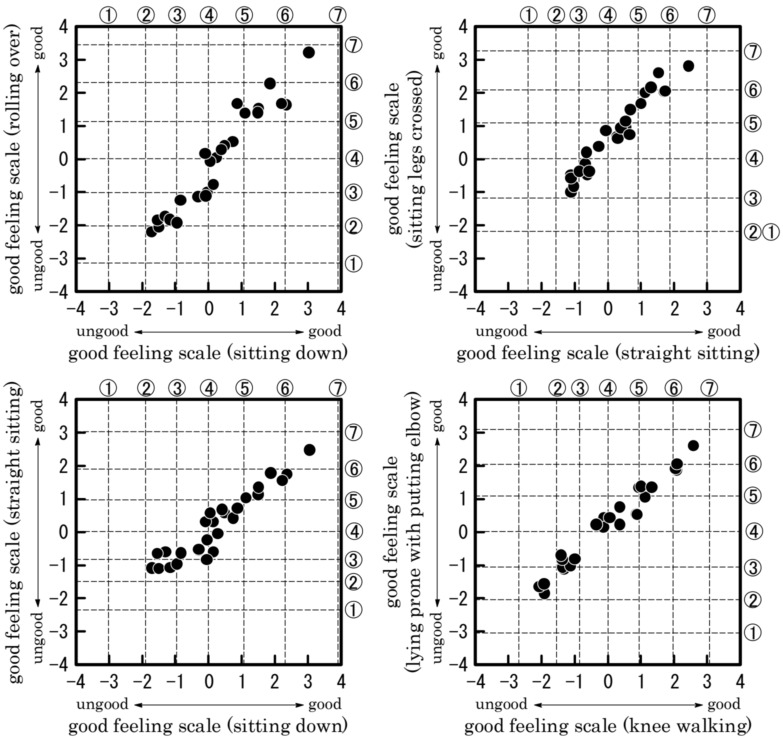
Figure 2 shows examples of the relationships between activities in the same scales. In this figure, **(1)** represents relationships between walking and the other activities and **(2)** represents relationships between all activities except walking.

In **(1)** of **Figure 2**, there was a poor correspondence between walking and the other activities; this may be because soles routinely support the body weight and have a very different feeling compared with other body regions. Based on this result, different performance values were set for walking and the other activities.

On the other hand, there was a better correspondence in **(2)** than **(1)** of **Figure 2**. Similar results were obtained in other relationships; this may be because all non-sole body regions have a similar feeling. Based on these results, it was concluded that one performance value corresponding to one scale of an activity can correspond to the scales for all other activities except walking.



(1) Realationships between walking and the other activities



(2) Realationships between activities except walking

Figure 2 Relationships between activities in same scales

5. MEASURING FLOOR DYNAMIC ACTIVITY AND EXAMINATION ABOUT APPLICABILITY OF PREVIOUS RESEARCH SUBJECT

We measured floor dynamic activity on 26 floors using Ono's measuring device and an improved discrimination device.

Figure 3 illustrates an overview of Ono's measuring device[2]. This device measures the activity of the floor around a loading plate; the landing dynamic load is similar to the landing load in walking. The load is reproduced by dropping a 40 kg weight on the well-buffering rubber spring. **Figure 4** shows an example of measurement with the device wherein the following data is produced: a deformation-time curve, a load-time curve, and a load-time curve from the start of landing to the maximum point.

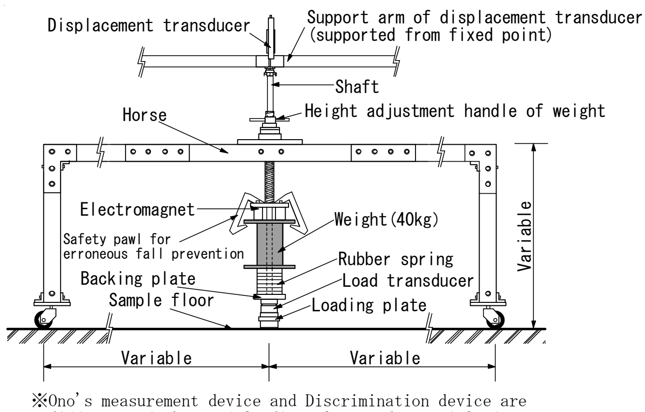


Figure 3 Ono's measuring device and discrimination device

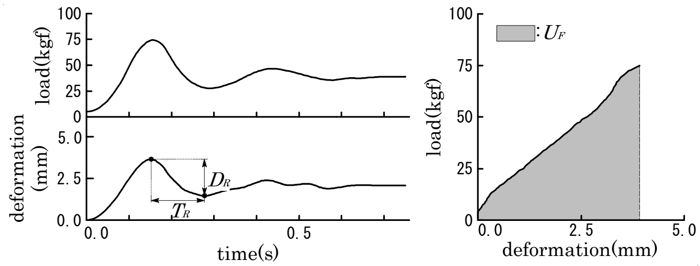


Figure 4 Example measured using Ono's measuring device

From the results of this measurement, we determined the performance value to evaluate the hardness of floors to human sense to be the following: $T = \log(U_F - 8 \cdot D_R \cdot D_R / T_R)$.

The discrimination device[3)] is an improvement over Ono's measuring device wherein the weight of some parts of the device was reduced and the load was changed from flat bottom to curved. When using the discrimination device, we measured the floor's dynamic activity in dropping weight around the load plate using parallax got with two high-speed cameras as shown in **Figure 5**. **Figure 6** illustrates a measurement made with the discrimination device. The figure shows deformations at two timings: on the center of the load plate and at the measuring line (**Figure 5**). $Dmax$ refers to when the deformation is at the maximum, and D_R refers to when recovery reaches the maximum. At $Dmax$, the deformation $Dmax$ was extracted at the center of the load plate. At D_R, the deformations D_R40 and D_R50 were extracted at 40 mm and 50 mm distances, respectively, from the center of the load plate. With these values, we calculated $(D_R40– D_R50)/10$ and $Dmax-D_R40$.

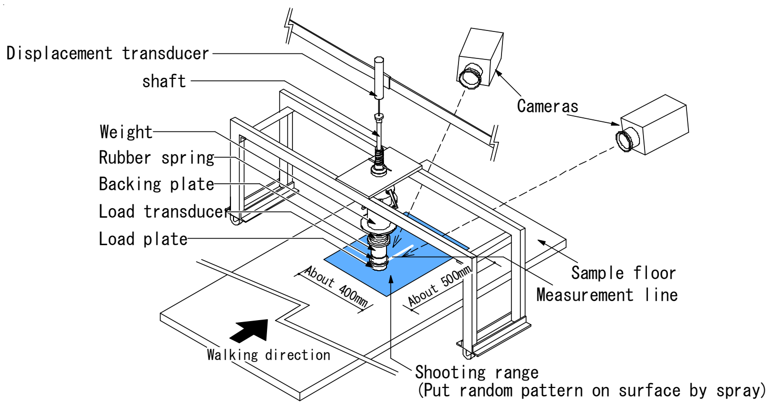


Figure 5 Measuring circumstance using discrimination device

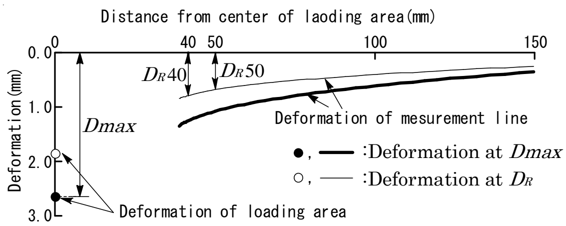


Figure 6 Example measurement using discrimination device

Figure 7 shows the relationship between $(D_R40– D_R50)/10$ and $Dmax-D_R40$. The following relationships[3)] were found: the floors that produced results that were higher than the broken line did not degrade by feelings; the floors that produced results that were between the broken and chain lines degraded by approximately one category; and the floors that produced results below the chain line degraded by approximately two categories.

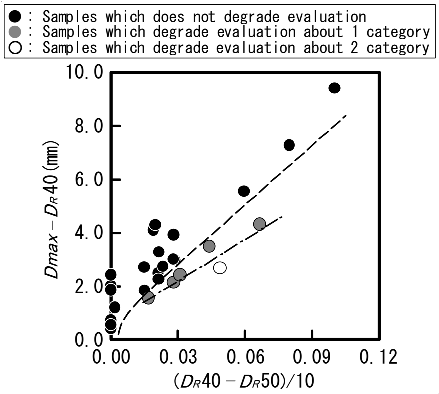


Figure 7 Relationship between $(D_R40- D_R50)/10$ and $Dmax-D_R40$

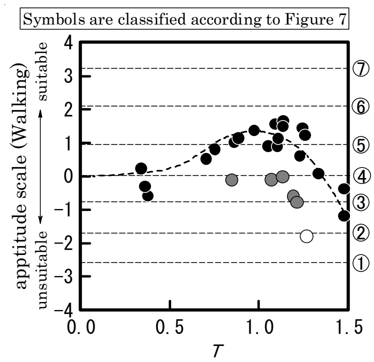


Figure 8 Relationship between aptitude scales for walking and T

Figure 8 shows relationships between T and the aptitude scale for walking as mentioned in the previous report (No. 2). In **Figure 8**, ●, ●, and ○ represent the degree of degradation by feeling as shown in **Figure 7**.

In **Figure 8**, ● represents the convex upward correspondence, and its central corresponding curve is get as the dotted line. ● degrades about one category, and ○ degrades about two categories from the curve. This indicates the applicability of previous studies[2) and 3)].

6. EXAMINATION OF EVALUATION METHOD FOR WALKING

At first, we examined the alternative method of T for evaluating floor hardness using measurement results obtained from the discrimination device. We tried to calculate $T' = \log(U_F' - 8 \cdot D_R' \cdot D_R'/T_R')$, which is equivalent to T because the discrimination device had similar load properties to Ono's measurement device. **Figure 9** shows relationships between T and T'. From this figure, there is a good correspondence between them; therefore, T is an alternative to T'.

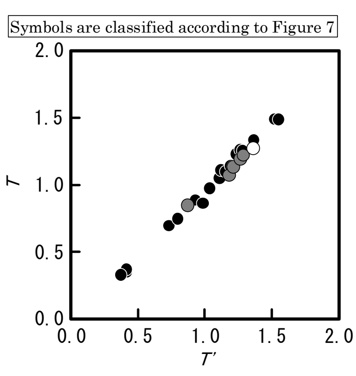


Figure 9 Relationship between T and T'

On the other hand, we calculated the degree of bad foot touching by $(D_R40- D_R50)/10$ and $Dmax-D_R40$ because of the consistency of the discrimination method. As shown in Figure 5, there is a tendency that floors that have large (D_R40– D_R50)/10 and small $Dmax-D_R40$ are much degrade of evaluation. Further, we examined D shown in the following formula as a performance value of the degree of evaluation by bad foot touching.

$$D=\{((D_R40-D_R50)/10)/(Dmax-D_R40)\}-0.011$$

However, $D=0$ in the case of $D<0$.

Figure 10 shows D of each floor on a number line. From this figure, it is likely that D can correspond to the degree of evaluation because ●, ●, and ○ are explicitly distinguished.

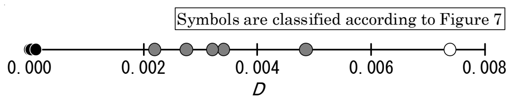


Figure 10 Relationship between degree of evaluation and D

Multiple regression analysis was performed using the following regression formula wherein T'^2, T', and D are explanatory variables and the psychological scale is the objective variable.

$$Y=A_1+A_2\cdot T'^2+A_3\cdot T'+A_4\cdot D.$$

Y : objective variable $A_1 \sim A_4$: coefficients.

Table 3 shows the results of the multiple regression analysis for the good feeling scale, easiness of activitiescale, and aptitude scale. The coefficients are different depending on the psychological scales. The optimum value of T' and contribution ratio of D are different for each evaluation. This result is consistent with the considerations in **Chapter 4**.

Table 3 Results of multiple regression analysis

Psychological scale	Performance values	A_1	A_2	A_3	A_4
Good feeling scale	Y_1	-3.951	-4.694	9.720	-358.9
Easiness of activitiescale	Y_2	-1.459	-3.719	6.343	-289.3
Apptitude scale	Y_3	-3.583	-5.298	10.143	-322.5

Figure 11 shows relationships between psychological scales and $Y_1 \sim Y_3$, which are calculated from the regression formula. From this figure, it was clarified that $Y_1 \sim Y_3$ are sufficiently effective performance values of floor deformation properties for walking.

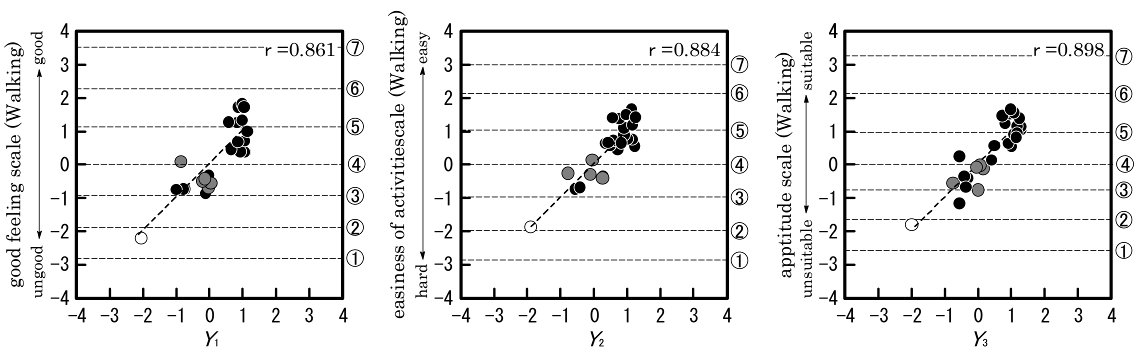


Figure 11 Relationships between psychological scales and Y for walking

7. CONCLUSIONS

The conclusions of this paper are as follows:

1) The studied subject activities can be classified into walking and non-sole activities on the basis of evaluations performed on the comfortableness of floor deformation properties.
2) The methods to collate $Y_1 \sim Y_3$ calculated from results obtained with a discrimination device with **Figure 11** are presented as methods for evaluating deformation properties of a no-shoes-floor from a viewpoint of comfortableness for walking.

We plan to examine activities other than walking.

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2. Hidenori Ono and Yutaka Yokoyama, "Study on Hardness of Building Floors and Its Evaluation from A Viewpoint of Comfortableness : (Part 2) Design and Development of A Hardness Tester and Presentation of The Evaluating Method of Hardness of Building Floors", Architectural Institute of Japan, Journal of Structural and Construction Engineering, 373, (1987)
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