

A Study on the Optimum Thermal Environmental Conditions in loor Heating

바닥난방의 쾌적한 온열환경조건에 관한연구

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Abstract

지금까지 연구해 온 바닥난방이 인체에 미치는 생리적,심리적 영향에 관한 실험결과를 종합하여(건강한 여자를 피험자로 한 경우) 바닥난방의 Optimum Thermal Environmental Conditions 를 검토할때는 다음의 조건을 만족시켜야 한다.

- (1) 저온 화상의 위험성을 고려하여 접촉부위의 피부온도가 40°C를 넘지 않을 것.
 - (2) 생리적 영향으로써 평균 피부온도가 33 - 34°C의 범위일 것.
 - (3) 심리적 영향으로써 온냉감 평가가 열적중성(slightly cool - slightly warm)으로 평가하고,쾌적감 평가가 쾌적한 것으로 평가할 것.
 - (4) 바닥온도에 대한 만족감 평가가 높을 것.
 - (5) 혹구온도는 직접바닥에 앉는 자세에서는 17°C 이상,의자에 앉는 자세에서는 19°C 이상일 것.
- 이상의 조건을 만족시키는 범위가 바닥난방의 Optimum Thermal Environmental Zone (Fig.7) 이라고 생각된다.

1. Introduction

The optimum temperature is said the temperature in which human body feels pleasant with the achievement of an

equilibrium between body heat production and heat emission.¹⁾ In this optimum temperature state, body temperature maintains constant temperature naturally without the thermoregulatory functions of body by means of vessel expansions or contractions or sweat emission or without the external help to

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preserve warmth by relying on clothes. This temperature does not mean a simple temperature but an assessed temperature in which other thermal environmental elements are incorporated and considered. This optimum temperature varies depending on the differences in race, lifestyles, kind and intensity of works, clothing conditions, gender, and age.²⁾ This study attempts to synthesize the already-reported effects of floor heating on skin temperature, thermal sensation vote, and comfort vote³⁾⁴⁾, and thus figure out the ranges of air temperature and floor temperature in floor heating during the winter season, and finally suggest the optimum thermal environmental conditions in floor heating.

2. Summary of the Floor Heating Experiment

(1) Comparison of floor-sitting posture with chair-sitting posture³⁾

The experiment was conducted in the air temperature controlling climate chamber (about 3.5m x 5m, H=2.5m) in the Nara Women's University in Japan in December 1985. The chamber was equipped with insulator of 50mm in thickness on the floor with carbon surface heating material(2m x 3m) to be covered with velveteen or overcarpet. The subjects were exposed to the heat in the sitting-on-the chair posture first and/or sitting-on-the-floor posture next. The subjects were selected with healthy young women (2-4 persons per each experimental condition) clothed with light clothes (which means clothes by which ordinary people feel neither cold nor hot in the 21°C air temperature; about 0.8 clo). The thermal condition was provided with 15°C,

18°C, and 21°C of air temperature, 50 % of relative humidity, and below 0.15 m/s of air velocity. Floor temperature was arranged at several stages within the range between 22 and 37°C. The procedure of the experiment was first to have subjects wear clothes equipped with gauges and other measuring devices in a pre-testroom of 21°C of air temperature and 50 % of relative humidity. In about 30 minutes, subjects were led to the air temperature controlling chamber. Subjects were exposed to the pre-arranged air temperature for 60 minutes per each posture and the responses were observed and recorded by the experimenter.

(2) Comparison of the direct-floor-sitting posture with indirect floor-sitting posture.⁴⁾

This experiment was conducted at the constant air temperature chamber at Home Economics College in the Nara Women's University. The room was equipped with electric floor heating system and insulation materials on the surface of the floor covered with over carpet. Subjects were sat on the carpet and exposed to the air temperature. The thermal environmental conditions were arranged with 15, 18, and 21°C air temperature, 50 % relative humidity, below 0.15 m/s air velocity, and 27, 32 and 37°C floor temperature. The procedure of the experiment was first to have subjects wear clothes equipped with gauges and other measuring devices in a pre-testroom of 21°C of air temperature. After about 30 minute passage, subjects were led to the constant air temperature chamber. Subjects are exposed to the pre-arranged air temperature for 60 minutes per each posture in the direct-floor-sitting posture and indirect-floor-sitting-posture respectively. Subjects were employed with healthy young women clothed with light

clothes (about 1 clo) by which ordinary person would feel neither hot nor cold.

3. Comparison and Analysis of the Experiment Results

(1) The Effect on Skin Temperature

When exposed to the 15 and 18°C air temperature, skin temperature in general declines except on buttocks in both the direct-floor-sitting and indirect-floor-sitting postures, while skin temperature tends to decline except on the soles in the sitting-on-the-chair posture. Skin temperature on the buttocks increases abruptly in the direct-floor-sitting posture. Thus skin temperature on the buttocks reaches up to 40°C or higher when floor temperature is 37°C, making subjects move and change their sitting posture with discomfort. Considering of the report that protein in the human cells makes chemical transformation, causing the risk of being burned at lower temperature when the skin temperature reaches higher than about 40°C, the subject's reaction is understood as a

response to remove the danger of being burned. Skin temperature on the sole increases with the increase of the floor temperature when the contacting skin temperature is lower than 40°C.

(2) The Effect on Mean Skin Temperature⁵⁾

Fig. 1 shows the relationships between air temperature and mean skin temperature in each posture. In the case of 15°C air temperature and 27-37°C floor temperature, mean skin temperature ranges between 31.9 and 33.0°C in the direct-floor-sitting posture, between 31.5 and 32.5°C in the indirect-floor-sitting posture, and between 29.5 and 32.3°C in the sitting-on-the-chair posture. Therefore, the effect of heating by means of floor heating is the greatest in the direct-floor-sitting posture, and the second in the indirect-floor-sitting posture, and the third in the sitting-on-the-chair posture. In the case of 18°C air temperature, the range moves higher by 1°C. When comfort votes are voted, the mean skin temperature is higher than 32.7°C in the direct-floor-sitting posture, and 33.2°C in the indirect-floor-sitting posture. The

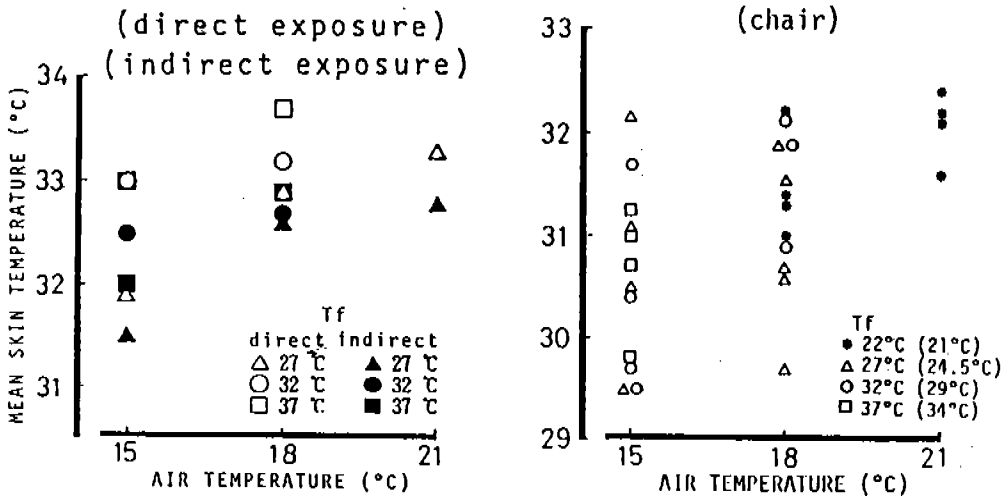


Fig. 1. Relationship between air temperature and mean skin temperature.

results lead us to conclude that the optimum temperature is when the mean skin temperature is between 33. and 34°C.

(3) The Relationship between Globe Temperature and Comfort Vote

Fig. 2 shows the relationships between globe temperature and comfort vote. While comfort

vote is obtained when globe temperature is around 16°C in the direct-floor-sitting-posture, it is obtained when globe temperature is around 19°C both in the indirect-floor-sitting-posture and sitting-on-the-chair posture.

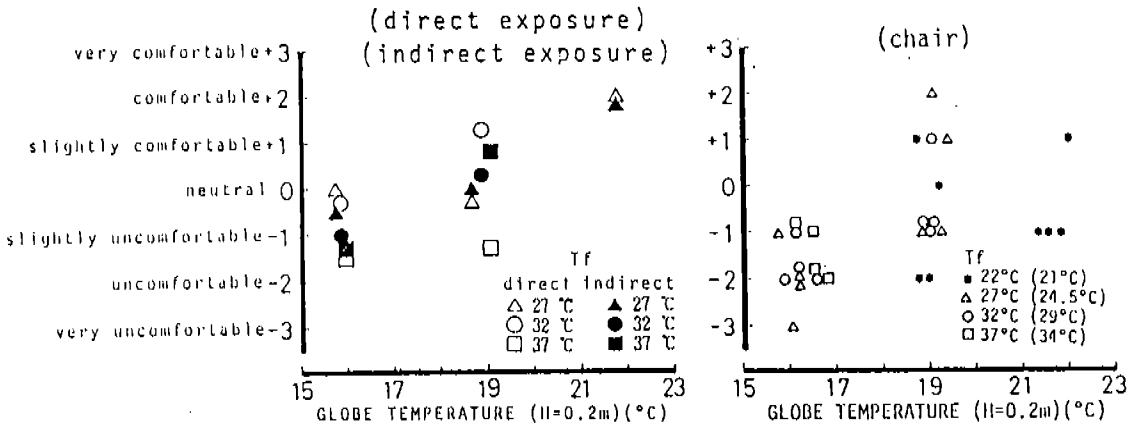


Fig. 2 Relationship between globe temperature and comfort vote

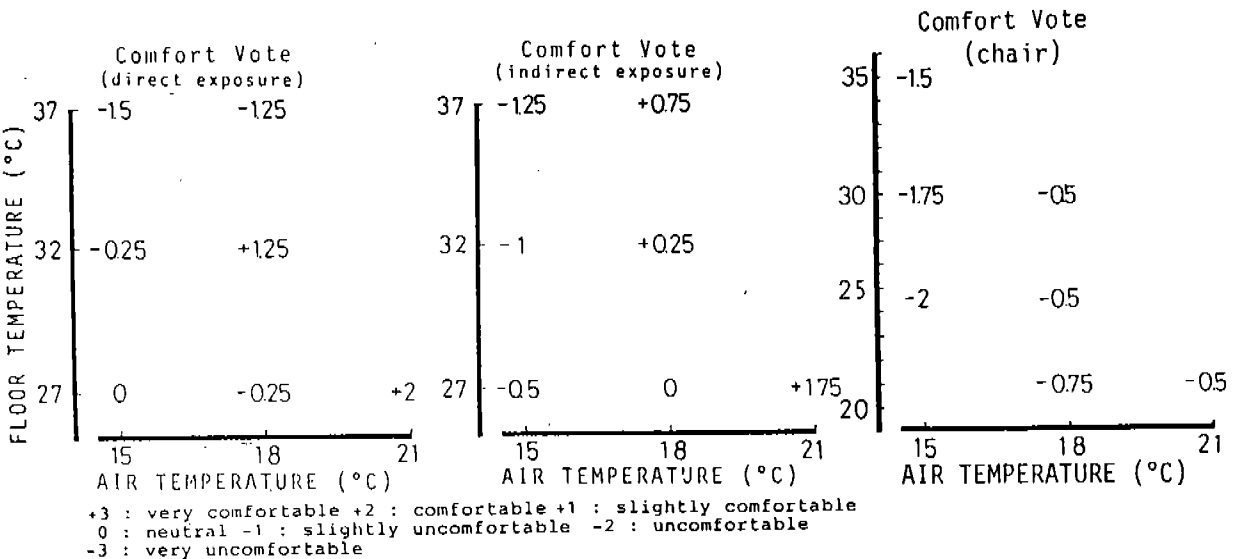


Fig. 3 Comfort vote for each sitting posture in combined conditions of air temperature and floor temperature

(4) Comfort Vote for each Sitting Posture in Combined Conditions of Air Temperature and Floor Temperature

Fig. 3 shows comfort vote in combined conditions of air temperature and floor temperature respectively. Comfort vote is voted at 18°C of air temperature and 32°C floor temperature and 21°C air temperature and 27°C floor temperature respectively in the direct-floor-sitting posture. In the indirect-floor-sitting posture, comfort vote is voted at 18°C or higher air temperature. In overall comparison, comfort vote is less reported in the direct-floor-sitting-posture than in the indirect-floor-sitting posture. This is because of the temperature difference between low air temperature in one hand and high floor temperature on the other hand. Comfort vote is least voted in the sitting-on-the-chair posture.

(5) Thermal Sensation Vote for each Sitting Posture in Combined Conditions of Air Temperature and Floor Temperature

Fig. 4 shows the relationships between air temperature and floor temperature and

thermal sensation vote. In the direct-floor-sitting-posture, warm vote is voted at 18°C air temperature and 32°C or higher floor temperature. In the indirect-floor-sitting-posture, however, warm vote is not voted except at 21°C air temperature and 27°C floor temperature. In the sitting-on-the-chair posture, warm vote is not voted in all temperature levels.

(6) Assessment on the Effect of Floor Temperature: Satisfaction Vote

Fig. 5 shows the relationships between floor temperature and satisfaction from floor temperature. In the 15 and 18°C air temperature, satisfaction vote is voted at 27 and 32°C floor temperature in the direct-floor-sitting-posture, whereas dissatisfaction vote is voted at 37°C floor temperature. This leads us to believe that floor temperature may be too high to obtain satisfaction voted on this occasion. In the indirect-floor-sitting-posture, satisfaction vote is voted at 37°C floor temperature. On the contrary, dissatisfaction vote is voted even at 15°C of air temperature

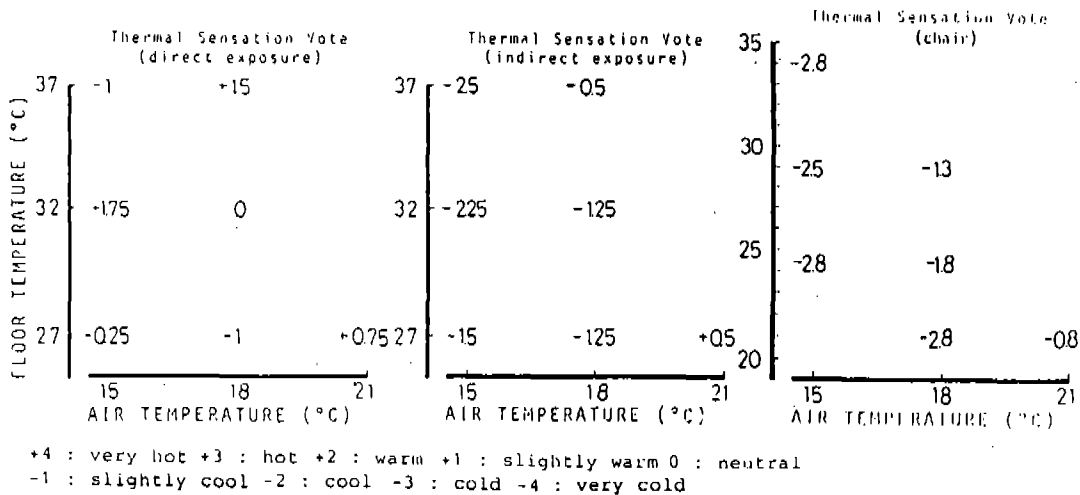


Fig. 4 Thermal sensation vote for each sitting posture in combined conditions of air temperature and floor temperature

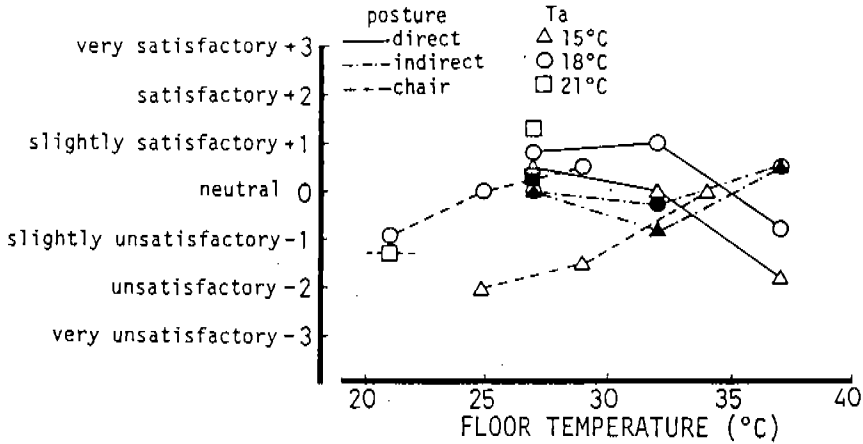


Fig. 5 Relationship between floor temperature and satisfaction from the floor temperature for each sitting posture

in the sitting-on-the-chair posture, while at 18°C air temperature slightly-satisfaction vote is voted in 32 and 37°C of floor temperature respectively.

(7) The Optimum Thermal Environmental Conditions in floor heating

Based on the discussed knowledge regarding the effect of floor heating on human body, we may list the following conditions which need to be satisfied in order to obtain the optimum temperature in the floor heating system. The optimum temperature was obtained after an experiment conducted with young woman subjects in stable mental condition wearing winter clothes in each sitting posture in the floor heating system.

- Contacting skin temperature should not be higher than 40°C considering the danger of being burned at a lower temperature.
- As a physiological influence, the range of mean skin temperature should be within 33 and 34°C.
- As a psychological influence, thermal

sensation vote should be voted as thermal neutral (slightly cool-slightly warm) and comfort vote should be voted as comfort.

- Satisfaction vote on floor temperature should be higher.
- Globe temperature is to be 17°C or higher in the direct-floor-sitting-posture and 19°C or higher in-the-sitting-on-the-chair posture.

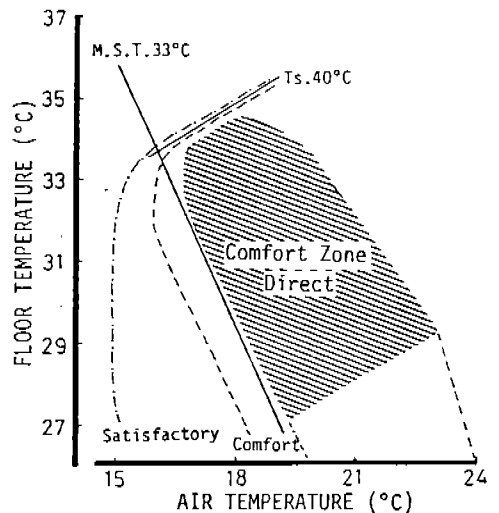


Fig. 6 Comfort zone in combined conditions of air temperature and floor temperature

The above conditions were applied to healthy female subject to check the range of optimum temperature, which is the combination of air temperature and floor temperature, in order to find out the optimal thermal environment in the floor heating system. The range indicated in Fig. 6 satisfies all the conditions listed above and it is thus reasonably believed that the temperature range is the optimum thermal environmental temperature zone. Fig. 7 shows the optimum temperature zone in the direct-floor-sitting posture, the indirect-floor-sitting posture, and sitting-on-the-chair posture respectively.

4. Conclusion

Thus far we have attempted to figure out the effect of floor heating on human body and on physiological and psychological responses in each different posture; in the direct-floor-sitting posture, in the indirect-floor-sitting posture, and in the sitting-on-the-chair posture. The attempt was to find out the optimum thermal environmental conditions in the floor heating system. Results of the experiment are summarized as follows:

(1) Skin temperature abruptly increase on the buttocks and soles, which have direct contact with the floor, in all sitting posture; in the direct-floor-sitting posture, in the indirect-floor-sitting posture, and in the sitting-on-the-chair posture.

(2) The order of mean skin temperature at 15°C air temperature and between 27 and 37°C floor temperature is the direct-floor-sitting posture first, the indirect-floor-sitting posture second, and sitting-on-the-chair posture the third.

(3) Comfort votes are voted when globe

temperature is higher than 17°C in the direct-floor-sitting posture or when globe temperature is higher than 19°C both in the indirect-floor-sitting posture and sitting-on-the-chair posture.

(4) Comfort vote is voted when the air temperature and floor temperature are higher than 18°C and 32°C respectively in the direct-floor-sitting posture, whereas comfort votes are voted when the air temperature is higher than 18°C in the indirect-floor-sitting posture. Comfort votes are seldom voted in the sitting-on-the-chair posture.

(5) While satisfaction votes are voted at 15 and 18°C air temperature with 27 and 32°C or higher floor temperature in the direct-floor-sitting posture, satisfaction votes are voted at 15 and 18°C air temperature with 37°C floor temperature in the indirect-floor-sitting posture. In the sitting-on-the-chair posture, a little bit of satisfaction votes are voted at 18°C air temperature with 32 and 37°C floor temperature.

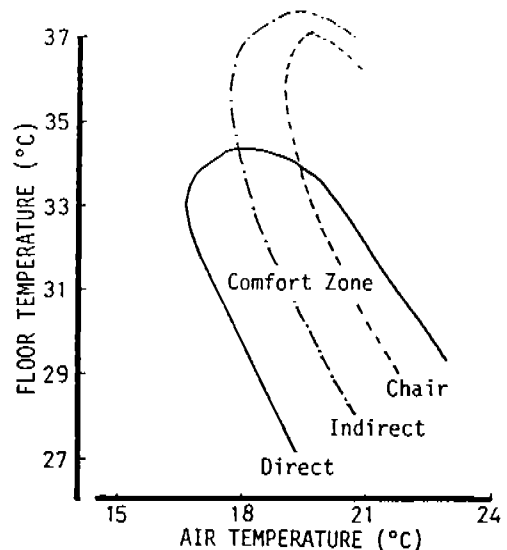


Fig. 7 Comfort zone for each sitting posture in combined conditions of air temperature and floor temperature

(6) The standard guides for optimum thermal environmental condition are that contacting skin temperature is to be lower than 40 °C, comfort and satisfaction level should be high, and mean skin temperature should be between the 33 and 34°C range.

(7) Taking the above standards into consideration, we can find the optimum thermal environmental conditions showed in.

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