Physiological and Subjective Responses to Low Relative Humidity in Young and Elderly Men

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Abstract In order to compare the physiological and the subjective responses to low relative humidity of elderly and young men, we measured saccharin clearance time (SCT), frequency of blinking, hydration state of the skin, transepidermal water loss (TEWL), sebum level recovery and skin temperatures as physiological responses. We asked subjects to evaluate thermal, dryness and comfort sensations as subjective responses using a rating scale. Eight non-smoking healthy male students (21.7±0.8 yr) and eight non-smoking healthy elderly men (71.1±4.1 yr) were selected. The pre-room conditions were maintained at an air temperature (Ta) of 25°C and a relative humidity (RH) of 50%. The test-room conditions were adjusted to provide 25°C Ta and RH levels of 10%, 30% and 50%.

RH had no effect on the activity of the sebaceous gland or change of mean skin temperature. SCT of the elderly group under 10% RH was significantly longer than that of the young group. In particular, considering the SCT change, the nasal mucous membrane seems to be affected more in the elderly than in the young in low RH. Under 30% RH, the eyes and skin become dry, and under 10% RH the nasal mucous membrane becomes dry as well as the eyes and skin. These findings suggested that to avoid dryness of the eyes and skin, it is necessary to maintain greater than 30% RH, and to avoid dryness of the nasal mucous membrane, it is necessary to maintain greater than 10% RH. On the thermal sensation of the legs, at the lower humidity level, the elderly group felt cooler than the young group. On the dry sensation of the eyes and throat, the young group felt drier than the elderly group at the lower humidity levels. From the above results, the elderly group had difficulty in feeling dryness in the nasal mucous membrane despite being easily affected by low humidity. On the other hand, the young group felt the change of humidity sensitively despite not being severely affected by low humidity. Ocular mucosa and physiology of skin by dryness showed no noticeable differences compared with the result at 120 minutes. J Physiol Anthropol 25(3): 229–238, 2006 http://www.jstage.jst.go.jp/browse/jpa2 [DOI: 10.2114/jpa2.25.229]

Keywords: low relative humidity, saccharin clearance time, frequency of blinking, skin physiology, subjective responses, age difference

Introduction

In the elderly, body temperature regulation and water metabolism are apt to be affected by thermal conditions. The metabolic system and the regulatory system which maintains homeostasis are unstable, and can easily malfunction. In addition, depending on the thermal environment of their residential space, the debilitated elderly can be easily affected by respiratory and cardiovascular complications. The thermal environment of residential space thus seems to be related to the prognosis for disease (Tanaka et al., 1999). Likewise, there have been many studies on the physiological responses of the elderly to thermal environments and the differences between them and younger age groups (Tochihara et al., 1993).

In winter, indoor dryness due to heating causes many health problems. In Japan, the “Law for Maintenance of Sanitation in Buildings” states that the indoor relative humidity (RH) should be kept at more than 40% (Ogawa, 1999), but several surveys reported that it is difficult to maintain this level (Koshimizu et al., 2002). Kitahara (2002) carried out a survey on the thermal and air quality in institutions for the elderly—such as special elderly homes, elderly aid institutions and care homes—and pointed out that in any given room dry air is commonly the first and the most important problem. It is also reported that many elderly people felt their skin was itchy if they used heating equipment that emits warm air in winter (Ohbushi et al., 2001; Hashiguchi et al., 2004). Igarashi et al. (2000) show that dry skin is closely related with itchy skin. Though not
confined to the elderly, the body factors for senile dry skin, which is common in winter, are: decrease in sweat, decrease in sebum, and change of the stratum corneum itself (Yoshikuni et al., 1985). As for the eyes, the contractility of the lens is weakened by age, transparency of the lens is decreased, dilatation of the pupil in the dark becomes difficult and density of rod and cone cells is diminished, all contributing to a decrease in ocular function.

For elderly people who tend to stay in the house for a long time, it is possible that an inappropriate thermal environment caused by the use of heating systems gives rise to not only subjective discomfort but also physical ailments (Hashiguchi et al., 2004). Our previous research (Sunwoo et al., 2006) with young men as subjects clarified that the eye and skin become dry in 30% RH, that the nasal cavity becomes dry as well as the eye and skin in 10% RH, and that the mean skin temperature decreases in 10% RH. But these results are from physiological responses in young people, so it is not certain that they can be applied to the elderly.

In addition, because the duration of exposure to a low relative humidity environment was 120 minutes in our previous study, we lack knowledge about the effect of exposure to a low relative humidity environment longer than 120 minutes. Therefore, the present study aims to compare the influence of low RH caused by heating in winter between elderly and young men by measuring mucociliary activity as well as the functions of the eyes and skin and the thermal, dryness and comfort sensations under RH of 50%, 30% and 10% at the same temperature (25°C) for a longer duration (180 min.).

Methods

Subjects

Eight non-smoking healthy male students and eight non-smoking healthy elderly men were selected. The means and standard variations of their age, height, body weight, and body mass index (BMI) are shown in Table 1. The elderly group subjects had never suffered from hypertension, heart disease, or cerebral apoplexy, etc. Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol.

Procedures

This study was conducted from February to March, at the Research Center for Human Environmental Adaptation, Kyushu University, which has 9 chambers controlling air pressure, air temperature, air humidity, air velocity, illumination and water pressure. Two climatic chambers (No. 4 and No. 3) were used. The pre-room (No. 4) conditions were maintained at an air temperature (Ta) of 25±0.1°C and a relative humidity (RH) of 50±1%. The test-room (No. 3) conditions were adjusted to provide 25±0.1°C Ta and RH levels of 10±1%, 30±1% and 50±1%. The subjects wore short pants, a long-sleeved sweat shirt and trousers (0.8 clo) in the pre-room. After waiting for 50 minutes in a sitting position in the pre-room, the subjects moved to the test-room and sat on a chair for 180 minutes.

Measurements

Saccharin clearance time (SCT), frequency of blinking, hydration state of skin, transepidermal water loss (TEWL), sebum level recovery and skin temperatures were measured as physiological responses. Also, we asked the subjects to evaluate the thermal, dryness and comfort sensations with subjective responses using a rating scale. Mucociliary transport was measured by SCT. A saccharin tablet (2.5 mm×0.5 mm) was placed just behind the anterior end of the nasal septum on the level of the anterior end of the middle nasal concha. The subjects were asked to sit quietly with their heads forward and not to sniff or sneeze. The time was measured beginning at the first perception of the sweet taste. Frequency of blinking was measured while the subjects counted white spots flickering randomly in the center of a monitor for two minutes (each white spot was illuminated for one sec., and the interval between the illumination of the spots was 0.2–1.4 sec.). Both SCT and frequency of blinking were measured in the pre-room, and at 90 minutes and 180 minutes after entering the test-room.

The hydration state of the skin was obtained using the CORNEOMETER®CM825 (Courage+Khazaka Electronic GmbH, GERMANY), and TEWL was obtained using the VapoMeter (Keystone Scientific, JAPAN). Both hydration state and TEWL were measured in the pre-room and in the test-room on the right side of the cheek and the back of the right hand three times every 30 minutes. The sebum level recovery was obtained using the SEBUMETER®SM 810 (Courage+Khazaka Electronic GmbH, GERMANY). It was measured in the pre-room after the removal of sebum using an alcohol sponge and in the test-room every 60 minutes on the left side of the cheek and the back of the left hand. Skin temperatures at eight local body sites (i.e., the forehead, chest, shoulder, forearm, abdomen, hip, thigh, foot) were measured with thermistors every minute. Mean skin temperature was calculated by applying Fukuda’s method (Watanabe, 1976), i.e. \[ T_{sk} = \frac{\text{forehead} \times 9.8 + \text{chest} \times 8.3 + \text{shoulder} \times 8.3 + \text{forearm} \times 19.6 + \text{abdomen} \times 8.1 + \text{hip} \times 8.1 + \text{thigh} \times 30.6 + \text{foot} \times 7.2}{100} \] Body weight loss was obtained by deducting the weight before the experiment from the weight at the end of the experiment.

Thermal, dryness and comfort sensations were evaluated once in the pre-room, once upon entering the test-room, and

<table>
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<th>Table 1 Physical characteristics of subjects</th>
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<tr>
<td>Age**</td>
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<tr>
<td>-------</td>
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<tr>
<td>Elderly (n=8)</td>
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<td>Young (n=8)</td>
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Values are means±S.D. **p<0.01 indicates significant difference between young and elderly subjects.
then every 30 minutes thereafter. Subjects evaluated the thermal sensation for the head, trunk, legs and the whole body, and they evaluated the sensation of dryness for the nose, throat, eyes, face and hands. Table 2 shows the scales used for the subjective judgments.

**Statistical analysis**

Data for comparing the pre-room with the test-room were analyzed by the paired t-test. Results of the physiological and subjective data were analyzed by repeated-measure analysis of variance (ANOVA) using Visual State for Windows Release 4.5J Software (Stat Soft, Inc.). The factors were age, conditions and time. A multiple comparison was performed using Scheffe’s test. Differences at $p<0.05$ were significant for all statistical analyses.

**Results**

**Physiological responses**

Figure 1 shows SCT in the pre-room, and at 90 minutes and 180 minutes after entering the test-room. SCT showed significant ($p<0.05$) differences between groups. Moreover, it was significantly ($p<0.001$) affected by the interaction of humidity and time. SCT of the elderly group in 10% RH increased significantly ($p<0.05$) in comparison with SCT in the pre-room, whereas the SCT values in 30% RH and 50% RH showed no significant differences. There was no significant difference in SCT of the young group under all three conditions.

Figure 2 shows the frequency of blinking in the pre-room, and at 90 minutes and 180 minutes after entering the test-room. Frequency of blinking showed significant ($p<0.001$) differences at each time-point. Moreover, it was significantly ($p<0.001$) affected by the interaction of humidity and time. Significant ($p<0.05$) changes were observed in 30% RH and 10% RH in both the elderly and the young groups in comparison with the pre-room level. But there was no

<table>
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<tr>
<th>Thermal sensation</th>
<th>Sensation of dryness</th>
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<tr>
<td>3 hot</td>
<td>extremely dry</td>
<td>very comfortable</td>
</tr>
<tr>
<td>2 warm</td>
<td>dry</td>
<td>comfortable</td>
</tr>
<tr>
<td>1 slightly warm</td>
<td>slightly dry</td>
<td>slightly comfortable</td>
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<tr>
<td>0 neutral</td>
<td>neutral</td>
<td>neutral</td>
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<tr>
<td>−1 slightly cool</td>
<td>slightly humid</td>
<td>slightly uncomfortable</td>
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<tr>
<td>−2 cool</td>
<td>humid</td>
<td>uncomfortable</td>
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<tr>
<td>−3 cold</td>
<td>wet</td>
<td>very uncomfortable</td>
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Table 2  Scale of subjective judgments

**Fig. 1**  Saccharin clearance time in the pre-room, and at 90 minutes and 180 minutes after entering the test-room. Values are means±S.D. for each of the 8 subjects in both groups. *$p<0.05$ indicates significant differences between pre-room and 90 minutes, and between pre-room and 180 minutes after entering the test-room values. A significant main effect (Age) and significant interaction (RH×Time) were determined by ANOVA.

**Fig. 2**  Frequency of blinking in the pre-room, and at 90 minutes and 180 minutes after entering the test-room. Values are means±S.D. for each of the 8 subjects in both groups. *$p<0.05$ indicates significant differences between pre-room and 90 minutes, and between pre-room and 180 minutes after entering the test-room values. A significant main effect (Time) and significant interaction (RH×Time) were determined by ANOVA.
significant difference between the elderly and the young groups, nor between the result at 120 minutes and 180 minutes.

Figure 3 shows the hydration state of the skin. The hydration state of the face showed significant \( p<0.001 \) differences among humidity levels and significant \( p<0.001 \) differences at each time-point in both groups. Moreover, it was significantly \( p<0.001 \) affected by the interaction of humidity and time. Under RH levels of 10% and 30%, the hydration state of the face decreased in both groups. The hydration state of the hand showed significant \( p<0.05 \) differences among humidity levels and significant \( p<0.001 \) differences at each time-point in both groups. Under 10% RH, the hydration state of the hand decreased in both groups. However, at 60, 90, 120, 150 and 180 minutes after entering the test-room, the hydration state did not decrease any further and was stabilized in both measurement sites.

Figure 4 shows the TEWL of the skin. The TEWL of the face showed significant \( p<0.001 \) differences among humidity levels and significant \( p<0.001 \) differences at each time-point in both groups. Moreover, it was significantly \( p<0.001 \) affected by the interaction of humidity and time. TEWL of the face increased under 10% RH compared with under RH levels of 30% and 50% in both groups. However, at 60, 90, 120, 150 and 180 minutes after entering the test-room, the hydration state did not decrease any further and was stabilized in both measurement sites.

Figure 5 shows the sebum level recovery. The sebum level recovery for the face showed significant \( p<0.001 \) differences at each time-point in both groups. The sebum level recovery for the hand showed a significant \( p<0.001 \) difference between groups and significant \( p<0.001 \) differences at each time-point. Moreover, it was significantly \( p<0.001 \) affected by the interaction of age and time. The amount of sebum level recovery on the hand in the elderly group was much more than in the young group. The sebum level recovery increased as time passed in both measurement sites.

Figure 6 shows the change in mean skin temperature. The degree of decrease in mean skin temperature under 10% RH was greater than under 50% RH, but there were no significant differences among humidity levels or between groups.

Figure 7 shows body weight loss. There were significant \( p<0.05 \) differences among humidity levels showing a greater loss of body weight under 10% RH than under 50% RH in both groups.

Subjective responses

Figure 8 shows the thermal sensation for each measurement site and for the whole body on entering the test-room, and at 90 minutes and 180 minutes after entering the test-room. For the thermal sensation observed just after moving to the test-room, there were significant \( p<0.001 \) differences among humidity levels at the tested body sites except the head, showing that subjects felt cooler as the humidity decreased. There were no significant differences, however, among humidity levels for thermal sensation after 90 minutes and 180 minutes after entering the test-room. There were significant...
(p<0.001) differences between the two groups for thermal sensation of the trunk and the whole-body under 10% RH observed just after moving to the test-room, showing that the young group felt cooler than the elderly group. There were also significant (p<0.001) differences between the two groups for thermal sensation of the legs under 30% RH and 10% RH observed after 180 minutes, showing that the elderly group felt cooler than the young group.

Figure 9 shows the sensation of dryness for each measurement site on entering the test-room, and at 90 minutes and 180 minutes after entering the test-room. Regarding the sensation of dryness after 90 minutes, there was a significant
difference between the two groups only in the eyes, showing that the young group felt greater dryness than the elderly group. After 180 minutes, there was a significant ($p<0.05$) difference between groups only in the throat, showing that the young group felt greater dryness than the elderly group. Also, there were significant ($p<0.05$) differences among humidity levels in the throat after 180 minutes, showing that subjects felt greater dryness under 10% RH than under 50% RH.

### Discussion

Mucociliary clearance of the airway is an important self-defence mechanism, and it plays an important role in the removal of foreign bodies. When this mechanism is impaired, the possibility of respiratory infections is increased. The saccharin method used in this experiment is widely used to assess the function of mucociliary clearance (Lale et al., 1998). An increase in SCT suggests a decrease in the activity of the mucociliary function. In this study, SCT of the older age group increased significantly in the 10% RH environment, suggesting that hypofunction of nasal mucociliary activity increases with age (Fig. 1). Salah et al. (1988) reported an increase in SCT because of the loss of moisture in the nasal mucous membrane by breathing dry air in an experiment with 11 healthy nonsmokers. In the present experiment, only SCT in the elderly group was increased in 10% RH. However, in our previous experiment with 16 young male subjects (Sunwoo et al., 2006), SCT in young men increased significantly in 10% RH. From these results, it is thought that the nasal mucous membrane of the elderly is more likely to be affected by low relative humidity, rather than that of young men. In a
20.5–24°C environment with 50% RH and above, the survival rate of the influenza virus is only 3–5% after 6 hours (Harper, 1961). However, the survival rate increases to 66% under a 20% RH environment. Harper (1963) reports that although the airborne influenza virus loses its infectivity in an environment at and above 50% RH, the virus survival time is extended in environments below 50%. There is also a seasonal factor in the rate of influenza infection (Satsuta et al., 1985), namely that respiratory infections are especially prevalent in winter. Thus it is clear that the organism has a long survival rate in low humidity environments in winter. Inflammation, caused by cold air inhalation, of the nasal and pharyngolaryngeal mucosa makes it easier for these mucosa to be infiltrated by the organism. Therefore, according to the present study, it would be fairly easy to catch a respiratory infection caused by an influenza virus in the air in an environment with RH below 10%, owing to the fact that dryness of the nasal mucocilia compromises the defense mechanism. Because the elderly have a high risk of death when infected with influenza viruses, maintaining adequate humidity seems to be absolutely necessary.

In the present experiment, frequency of blinking was measured to determine the effect of humidity on the mucous membrane of the eye. The frequency of blinking seemed to reflect the state of dryness of the eyes, because blinking acts to supply moisture to the eyes. We observed that the frequency of blinking increased significantly under environments of 10% RH and 30% RH (Fig. 2), suggesting that a low RH environment influences the activity of the mucous membrane of the eye. But because there was no significant difference between the two groups, there seemed to be little change in the ocular mucous membrane with age. It has been reported that many contact lens wearers in low RH environments complain about dry eyes and discomfort, and low humidity seemed to be the most significant factor contributing to discomfort for lens wearers (Nilsson et al., 1986; Eng et al., 1982). There were no contact lens wearers in this experiment, and no subjects had any disorder such as dry eye. In both groups, frequency of blinking increased significantly at 10% RH and at 30% RH, and this result is the same as that obtained for contact lens wearers in the above studies. As long as there is no dry eye, corneal disorder or lacrimal hyposecretion, blinking seems to prevent eye dryness in a low RH by increasing tear secretion, regardless of age. Tsubota et al. (1989) measured the humidity above the cornea of subjects wearing spectacle frames only, spectacles, and spectacles with side panels, in both normal subjects and patients with a moderate degree of dry eye. The result showed that the cornea humidity in subjects wearing spectacles with or without side panels maintained a higher level than ambient humidity. Consequently, they reported that, in patients with dry eye, wearing spectacles or spectacles with side panels could improve the discomfort of eye dryness in a low humidity environment. Although they removed their spectacles before the test in this experiment, the members of the elderly group who ordinarily wore spectacles for presbyopia seemed to be less affected by low RH in daily life than young people who wear contact lenses.

In the present study, a marked decrease in the hydration state of the face was observed under 10% RH and 30% RH (Fig. 3). TEWL of the face also increased significantly under 10% RH (Fig. 4). But there was no significant difference between the elderly group and the young group. Generally it is known that the proportion of oily skin decreases while that of dry skin increases in the elderly. But an obvious change of hydration

![Fig. 9](image-url) Sensation of dryness at each site on entering the test-room, and at 90 minutes and 180 minutes after entering the test-room. Values are means for each of the 8 subjects in both groups. *p<0.05 indicates a significant difference between young and elderly men. *p<0.05 indicates a significant difference between 10% RH and 50% RH.
state measured by skin conductance as age increases has not been ascertained. Kumagai et al. (1989) measured skin conductance in Japanese women and found that it was lowest in winter among women in their twenties and below, and presents a constantly stable value after the twenties. There were few differences between women in their twenties and older women. Decrease in the hydration state as age increases has been reported (Akazaki et al., 1993) but there has been no report to present a significant decrease in hydration state with increases in age. Wilhelm et al. (1991) used the same measuring device as ours to measure the skin conductance at 11 sites (i.e., forehead, upper arm, volar forearm, dorsal forearm, postauricular, palm, abdomen, upper part of back, lower part of back, thigh, ankle) in an elderly group and a young group. The results showed significantly lower skin conductance in the palm for the elderly group, while for other measurement sites there were no significant differences between the two groups. In addition, in a study on hygroscopicity and the water-holding capacity of the stratum corneum (Tagami et al., 1982), there was a tendency for hygroscopicity and water-holding capacity to decrease in the elderly, but there were no significant differences between groups of elderly and young subjects. As for TEWL, there has been a report (Wilhelm et al., 1991) indicating a decrease in TEWL with age. Alternatively, reduction of TEWL in the elderly group might not reflect improvement of the barrier function against water, but might result from epidermal atrophy and a resulting smaller water reservoir associated with the aging process (Wilhelm et al., 1991). The decrease in TEWL by increasing age is due to hypertrophy of the stratum corneum, and the skin barrier function against dryness cannot be said to be better in the elderly group than in the young group. In our experiment both groups showed similar values in hydration state and TEWL in the pre-room, suggesting no age related differences in skin water content in ordinary life. In addition, there were no significant differences in the change of hydration state and TEWL between the two groups under each RH. Thus there appears to be no change in skin water content with age in healthy males. As for TEWL by passage of time, the two groups showed significantly higher TEWL in 10% RH than in the pre-room, but in 30% RH they showed a tendency to gradually recover from 120 minutes after entering the test room.

The sebum level recovery was not affected by humidity in either group, but the sebum level on the back of the hand was different according to age. The sebum level recovery was thus much higher in the elderly than in the young group (Fig. 5). Secretion of sebum by females reaches a peak in the twenties and declines thereafter; for males, it reaches a peak later than for females—between the twenties and the fifties—and gradually declines thereafter (Yamamoto, 1991). The results in the present experiment were not coincident with previous reports about generally known changes with age. The reason for this difference is not apparent. However, sebum secretion is also affected by skin temperature: the higher the skin temperature, the higher the secretory activity of the sebaceous gland. In our experiment, mean skin temperature in the elderly group was slightly higher than the young group, though not significantly so. This probably affected sebum secretion of the back of the hand. It may be necessary to evaluate the relationship between skin temperature and sebum secretion more precisely.

Concerning the change of mean skin temperature, there was no significant difference among humidity levels or between the two groups, but as the humidity became lower, the mean skin temperature also declined (Fig. 6). Body weight was reduced significantly in both groups in 10% RH (Fig. 7). The reason for this decrease in mean skin temperature and body weight is thought to be due to the loss of moisture from the skin.

Collins (1979), after measuring the finger temperature discrimination ability in the young and the elderly, reported that this ability was duller but not significantly different in the elderly, and the comfort temperature of the elderly was not different from that of the young. Collins (1981) also reported that sensitivity to changes in air temperature declines with age. Furthermore, Tochihara et al. (1993) indicated that elderly people did not feel as cold as young people immediately after cold exposure, and that their sensitivity to cold is less intense compared to that of the young. In our experiment, there was no difference among humidity levels and between the two groups with respect to comfort sensation. In the case of thermal sensation, the whole-body felt significantly different by humidity just after entering the test-room from the pre-room. In both groups, subjects felt cooler in 10% RH compared with 30% RH or 50% RH. Thermal sensation in the trunk showed a significant difference among humidity levels just after entering the test-room from the pre-room. Subjects felt cooler in 10% RH compared with 50% RH. Also, at 180 minutes after entering the test-room, there was a significant difference between the two groups in the legs. Thus the elderly group felt cooler than the young group (Fig. 8). Hashiguchi et al. (2004) reported similar results: in a group of elderly subjects, significant relationships were indicated between thermal comfort and peripheral skin temperature, and the relationship between thermal comfort and thermal sensation of the legs was also significant. According to Hashiguchi et al. (2004), for the elderly, ensuring the warmth of peripheral parts rather than that of the corporeal body is important to obtain thermal comfort.

In terms of dryness of the eyes, there was a significant difference between the two groups 90 minutes after entering the test-room, with the young group feeling drier than the elderly group. In terms of the throat, there was a significant difference among humidity levels 180 minutes after entering the test-room, and subjects felt drier in 10% RH than in 50% RH. There was also a significant difference between the two groups, with the young feeling drier than the elderly. But for the whole body, face, hands and nose, there was no significant difference among humidity levels and between the two groups (Fig. 9). From these results, it seems that perception of dryness is duller than perception of temperature in the elderly. In fact,
even during moisture loss, it is difficult, and takes a long time, for the elderly to feel dryness, and thus a great deal of moisture must be removed in low RH before the elderly begin to perceive dryness. According to Ohbuchi et al. (2001), 70% of heating control is performed by elderly people themselves, and 72% percent of elderly people used their own feelings as the standard for heat control. This shows that subjective mood in the elderly is the key to heat control. Elderly people cannot maintain an optimum thermal environment through their own perceptions because of the age-related decrease in perception of thermal change and humidity change, delayed response to coldness, and decrease in discrimination of temperature, all of which lead to dullness of thermal sense in the elderly.

In conclusion, humidity had no effect on sebum secretion, or on change of mean skin temperature. But SCT increased, and the ocular mucosa and the stratum corneum of the skin became dry as a result of low RH. In particular, considering the SCT change, the nasal mucous membrane seems to be affected more in the elderly than in the young in low humidity. In the effect of longer exposure (180 min.) to low RH, only TEWL showed a slight decrease after 120 minutes in 30% RH, and all the measured results showed no noticeable differences compared with the result at 120 minutes.

Specifically, the eyes and skin become dry in 30% RH, whereas the nasal cavity becomes dry as well as the eyes and skin in 10% RH. These findings suggested that to avoid dryness of the eyes and skin, higher than 30% RH must be maintained, and to avoid dryness of the nasal mucous membrane, higher than 10% RH must be maintained. Because it is difficult for elderly people to sense the degree of dryness by themselves, especially the debilitated elderly, not only the temperature but also the humidity should be checked by a thermo-hygrometer in heated indoor areas in the winter season. It seems particularly important to pay careful attention to temperature and humidity in hospitals or facilities for the elderly.

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