

ORIGINAL ARTICLE

Ichiro Watanabe · Hiroshi Noro · Yoshinori Ohtsuka
Yukio Mano · Yuko Agishi

Physical effects of negative air ions in a wet sauna

Received: 31 March 1995 / Revised: 25 July 1995 / Accepted: 26 July 1996

Abstract The physical effects of negative air ions on humans were determined in an experimental sauna room equipped with an ionizer. Thirteen healthy persons took a wet sauna bath (dry bulb temperature 42° C, relative humidity 100%, 10 min exposure) with or without negative air ions. The subjects were not told when they were being exposed to negative air ions. There were no differences in the moods of these persons or changes in their blood pressures between the two saunas. The surface temperatures of the foreheads, hands, and legs in the sauna with negative ions were significantly higher than those in the sauna without ions. The pulse rates and sweat produced in the sauna with ions were singificantly higher than those in the sauna without ions. The results suggest that negative ions may amplify the effects on humans of the sauna.

Key words Sauna · Negative ion · Body temperature · Cardiovascular function · Sweat production

Introduction

There are two types of air ions: namely, positive and negative. Numerous positive ions (100–300 ions/ml) may be detected in cities, while numerous negative ions may be found in mountains, forests, and hot-spring areas. Especially in the neighbourhood of a waterfall and after the passage of a typhoon, the number of negative ions increases (300–500 ions/ml), and this is considered to be the cause of the feeling of refreshment that people experience (Hawkins and Barker 1978).

Many research projects have reported that negative ions improved working efficiency (Hawkins and Barker 1978) and the state of mind including emotions (Yates et al. 1986). On the other hand, there has also been the problem of damage to the tissues due to large numbers of negative ions (Yates et al. 1986) and of the generation of activated oxygen (Goldstein et al. 1992). Because of these problems, studies are necessary of the physiological effects of negative ions on the human body.

The recently developed negative ionizer equipment (shinki ionizer; Geochto Ltd., Tokyo, Japan) sprays water through a nozzle and produces a large number of negative ions employing the Lenard’s effect (Duan et al. 1994) due to the breakup of waterdrops. Theoretically this equipment does not produce activated oxygen because it has no electric discharge mechanism. Furthermore, the shinki ionizer equipment has the characteristic of forming fine water droplets having a diameter of 0.3 μm, compared to the diameter of ordinary water particles of about 20 μm or larger. The equipment has already gained recognition (Scheuch et al. 1990; Duan et al. 1994) for its ability to remove dust and bacteria effectively when installed in a sterilized room.

Since early times, sauna bathing has been enjoyed by many people in various forms throughout the world, and also has been used in medical facilities. Taking sauna baths has been shown to have many benefits (Leppaluoto 1988; Vuori 1988), such as accelerating the peripheral circulation to maintain the homeostasis of the organism in the high-temperature environment, stimulating perspiration, and accelerating metabolism. In Japan, saunas of low temperature (40–45° C) with high relative humidity (RH; 90 to 100%) have long been used as steam baths. Such saunas have exhibited temperature and sweating effects comparable to those of high-temperature (90 to 100° C), low RH saunas (Watanabe et al. 1993). In this work we set up a sauna room, which would provide an experimental environment of uniform conditions. In our experiment, healthy persons were made to take sauna baths under identical conditions with the exception that negative ions were present or absent. We examined the differences in physical reaction.

I. Watanabe (✉) · H. Noro · Y. Ohtsuka · Y. Mano · Y. Agishi
Department of Rehabilitation and Physical Medicine,
Hokkaido University School of Medicine, Kita 15, Nishi 7,
Sapporo city 060, Japan

Methods

For the purpose of the experiment, we set up a sauna room (156 cm in width, 180 cm in height, and 104 cm in depth; Fig. 1) which

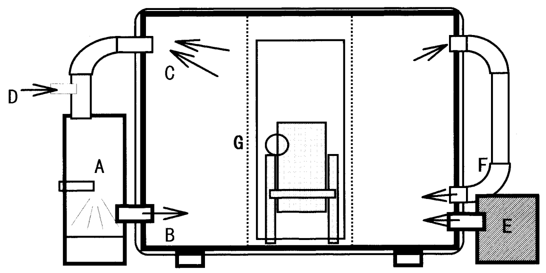

Fig. 1 Arrangement in negative ion sauna room. *A* Shinki ionizer for production of negative ions, *B* duct introducing negative ion air, *C* exhaust air duct, *D* intake of fresh air, *E* wet sauna equipment, *F* duct for circulation of steam sauna, *G* transparent door

could be used either as a sauna room (hereinafter called a shinki sauna) abounding in negative ions or as an ordinary wet sauna. The shinki ionizer equipment (A in Fig. 1; MCN350, Geochto Ltd.) was installed outside the sauna room. Inside the sauna, the air with negative ions was blown into the room from the bottom duct (B in Fig. 1) and circulated to leave the room from the top duct (C in Fig. 1). Upon reaching the exhaust duct, it was mixed with a small amount of fresh air from outside (D in Fig. 1) and recirculated via the shinki ionizer equipment after reloading with negative ions.

In the ordinary wet sauna system, a steamer (E in Fig. 1; Metos electric steamer NS-7E1, Nakayama Sangyo Co. Ltd., Tokyo, Japan) was installed on the opposite side of the sauna to the shinki ionizer equipment. The steamer was equipped with two ducts (F in Fig. 1) for ventilating and circulating the air in the room. Both sauna systems were set for a room temperature of 42° C and a relative humidity of 100%. The sauna room door was made of a transparent synthetic resin so that the subjects could be visually observed. An opening (small circle in Fig. 1) was made in the door to enable the subject to put the right hand out of the room as various measuring instruments were mounted on the hand. A soft synthetic resin was placed around the opening to restrain entry or exit of air when the subject extended the right hand out of the room.

The number of negative ions was measured using an ion tester (KST-900, Kobe Denpa Co. Ltd., Tokyo, Japan). To prevent the erroneous operation of the ion tester due to production of condensation, the sample air taken from the sauna room was cooled, and a line for removing large waterdrops was used before making the measurements.

Subjects

Thirteen healthy subjects (age ranging from 21 to 49 years; 12 male and 1 female, average age, 26.4 years) took a sauna bath once in each of the sauna systems at a 1 week interval and the same time of a day, without being told which sauna system they were taking. Measurements as described below were taken for 5 min before the sauna bathing, during the 10-min sauna bath at 42° C, and during the 20-min following the completion of the sauna bath. The measurements were taken while the subjects were in a

Table 1 Scales of subjective feelings

	Ion sauna				Wet sauna			
	In	5	10	20	In	5	10	20
Subjective temperature scale								
5 very hot					1			
4 hot	4				5			
3 slightly hot	4				3			
2 warm	4	1			3			
1 slightly warm	1		2	3	1			1
0 no feel		5	5	6		2	7	10
–1 slightly cool		3	2			9	6	2
–2 cool		3	3	3				
–3 slightly cold		1	1	1		2		
–4 cold								
–5 very cold								
Subjective pleasantness scale								
3 very good	1							
2 good	2	1					1	1
1 slightly good	3	8	5	3	8	6	5	4
0 no feel	4	4	8	9	3	7	7	8
–1 slightly hard	3			1	2			
–2 hard								
–3 very hard								
Subjective fatigue scale								
3 very tired								
2 tired								
1 slightly tired	8	3	1	1	4	4	3	3
0 no feel	5	10	12	12	9	9	10	10
Subjective sweating scale								
5 very very sweaty	8				6			
4 very sweaty	4	1			5			
3 sweaty		2			1			
2 slightly sweaty	1	1			1			
1 moist			2	1		2	0	1
0 no sweating		9	11	12	11	13	12	

In, Feeling at the end of sauna bath; 5, feeling 5 min after leaving sauna; 10, feeling 10 min after leaving sauna; 20, feeling 20 min after leaving sauna. Each number represents the total number of subjects sitting position in a swimming suit. The experiment was conducted in the summer-time between July 21, 1994 and September 1, 1994. We measured the temperature and moisture in the room where the sauna was set. An averaged environmental temperature during this period was 26.7° C.

Measurements

The systolic, diastolic and mean blood pressure, and pulse rate were recorded every minute using a continuous blood pressure gauge mounted on the left arm. The coefficient of variation for pulse rate (CV-PR) of 100 consecutive beats was calculated using a noninvasive, continuous arterial blood, pressure measuring device (Finapres; Ohmeda Co. Ltd., New York, USA) mounted at the tip of a finger of the right hand.

The amount of sweat produced was determined from the difference between the body masses measured before and after the sauna bath with the subjects wearing no clothing. Surface temperatures of the body were measured every minute by means of an automatic temperature recorder at the forehead, chest, shoulder (blade bone), upper arm, hand (opisthenar), thigh, lower leg, and foot (dorsum pedis), using the following weightings: mean surface temperature=0.07×forehead temperature +0.18×chest temperature, +0.17×back temperature +0.15×upper arm temperature +0.05× hand temperature +0.18×thigh temperature +0.13×lower leg temperature +0.07×foot temperature (Nakayama 1981). For core temperature, the temperature of the rectum was recorded every minute.

After 8 min from the beginning of the sauna bath and after 5, 10, and 20 min from leaving the sauna room, the subjects were questioned about their feelings of temperature (11 levels), pleasantness (7 levels), fatigue (4 levels) and sweating (6 levels, Table 1).

Statistics

Student *t*-tests were conducted using a significance level of 5%. The χ^2 test was also conducted using a significance level of 5%.

Results

Temperature, relative humidity, and number of negative ions in the sauna room

The mean temperatures and relative humidities outside the sauna room were 28.0±0.40° C (mean±SEM) and 77.2±1.9% respectively, during the operation of the shinki sauna; the respective values of 27.4±0.25° C and 78.9±1.2% during the operation of the ordinary wet sauna showed no significant difference between the two types of sauna. In air outside the sauna, the numbers of negative ions varied from 120 to 350 ions/ml. In the shinki sauna during the experiment, the maximum amount of negative ions increased to 20000 ions/ml. In the ordinary wet sauna room, the number of negative ions was <100 ions/ml, in other words less than the number outside the sauna room.

Blood pressure and pulse rate

There were no significant differences in systolic or diastolic blood pressures between shinki sauna and wet sauna. The maximum of systolic blood pressure was 126±3.5 mmHg at the end of bathing in the shinki sauna and 122±3 mmHg in the wet sauna. The maximum of diastolic blood pressusre was 68.5±2.2 mmHg at the end of bathing in the shinki sauna compared with 67.9±2.1 mmHg. In both shinki and wet saunas, the mean pulse rate rose from 75 beats/min to a maximum of 95 beats/min. There was no statistical difference in the change of pulse rate between the two groups (Fig. 2). The pulse rate immediately after the subjects got out of the sauna room was significantly higher after the shinki sauna than after the wet sauna. There was no significant difference in the CV-PR between the two saunas indicating the functioning of the parasympathetic nerve system (Fig. 2).

Sweat production

The absolute sweat production was 234.6±39.0 g in the case of the shinki sauna, showing a significantly higher value (P<0.05) than the wet sauna of 169.2±24.4 g (Fig. 3).

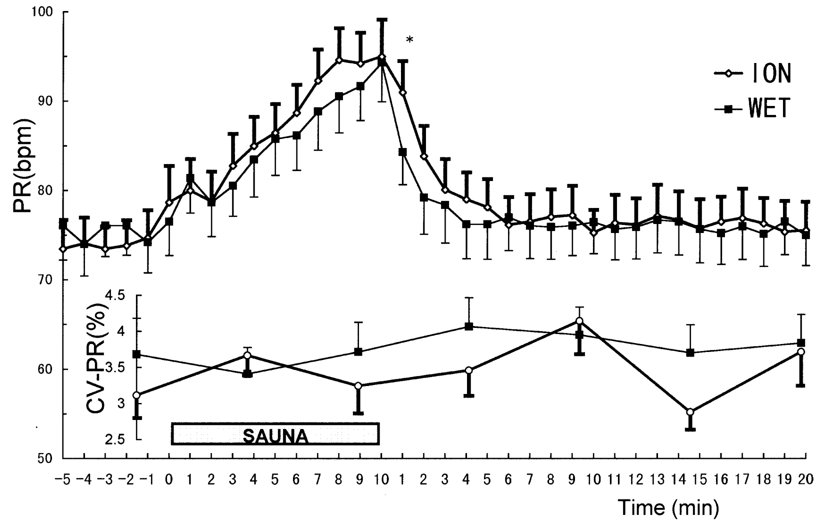

Fig. 2 Change of pulse rate (PR; beats/min) and coefficient of variation of pulse rate (CV-PR) before, during, and after the saunas. *Wet* wet (steam) sauna without negative ions; *ion* sauna with negative ion. Data of mean (SEM), *n*=13; * *P*<0.05

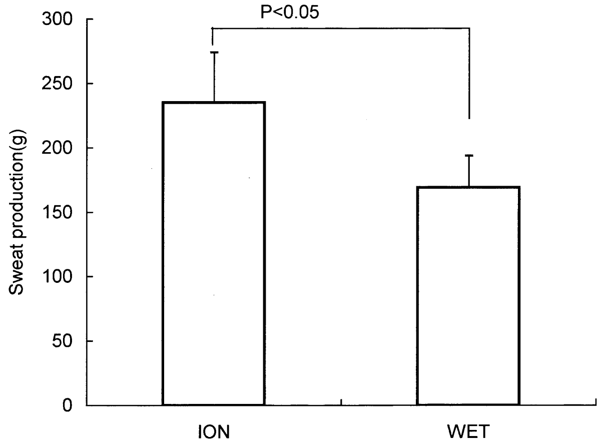

Fig. 3 Sweat production of subjects taking a sauna. The sauna definitions are as given for Fig. 2

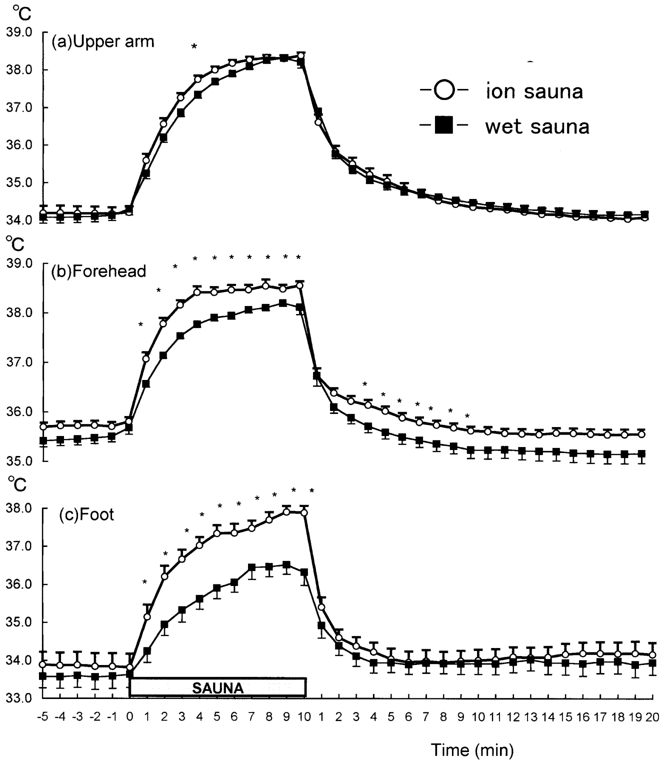

Fig. 4 Temperature of skin at upper arm (**a**), forehead (**b**), and foot (**c**) before, during, and after the saunas. The sauna conditions are as given for Fig. 2. Data are of mean (SEM), n=13; * P<0.05

Body surface temperature

A comparison of body surface temperatures showed no significant differences between the two saunas in the trunk parts, namely, the shoulder and upper arm (Fig. 4a). This indicated that the set temperatures at the height of the shoulder were maintained accurately in both saunas. The temperature of the forehead (Fig. 4b) showed significantly higher levels in the shinki sauna than the wet sauna immediately upon entering the sauna bath, and remained higher in the shinki sauna even after the subjects left the sauna. The temperatures of the hand and thigh similarly to the forehead, showed a significantly higher level in the shinki sauna than in the wet sauna both during the sauna bath and after leaving the room. The temperatures of the lower leg and foot (Fig. 4c) showed higher levels in the shinki sauna than in the wet sauna only during the sauna bath but no differences once the subject left the sauna room.

Mean surface temperature and core temperature

The mean skin temperature, as obtained by calculation, exhibited a significantly higher value in the shinki sauna than the wet sauna during the sauna bathing (Fig. 5). The rectal temperature (Fig. 5) showed no significant differences between the two groups. However, rectal temperature of the subjects in the wet sauna declined immediately after the beginning of the sauna bath although it subsequently rose gradually, while the temperature in the case of the shinki sauna rose slightly and remained elevated from the beginning of the sauna bath.

Subjective symptoms and side-effects

There were no cases of low blood pressure (including shock) in either the shinki sauna or the wet sauna. There were also no differences in the sensation of temperature (Table 1). Regarding the feelings of pleasantness, many subjects expressed pleasantness 5 min after leaving the shinki sauna (shinki sauna; 8 subjects feeling slightly good, 1 subject feeling good, wet sauna; 6 subjects feeling slightly good). Concerning the feelings of fatigue during the sauna bath, 8 subjects in the shinki sauna expressed feelings of fatigue at the end of the sauna bath, while only 4 subjects in the wet sauna expressed feelings of fatigue. There were no significant differences in the scores of subjective ratings between the two saunas.

Discussion

Although there were no differences in subjective symptoms, it was found that in the presence of negative ions, the sauna bath had a greater effect on the subject's rise in body temperature and sweat volume. The method did not produce harmful activated oxygen, which accompanies the conventional corona discharge method of producing negative ions. Furthermore, the negative ions from the shinki equipment were theoretically closely related to humidity, and accordingly the experimental conditions were set in a sauna room at 100% relative humidity. The measurement of the negative ions in the air in an ordinary wet sauna system, which was used as the control, indicated that the number of negative ions in the ordinary wet sauna system was significantly smaller compared with the shinki sauna.

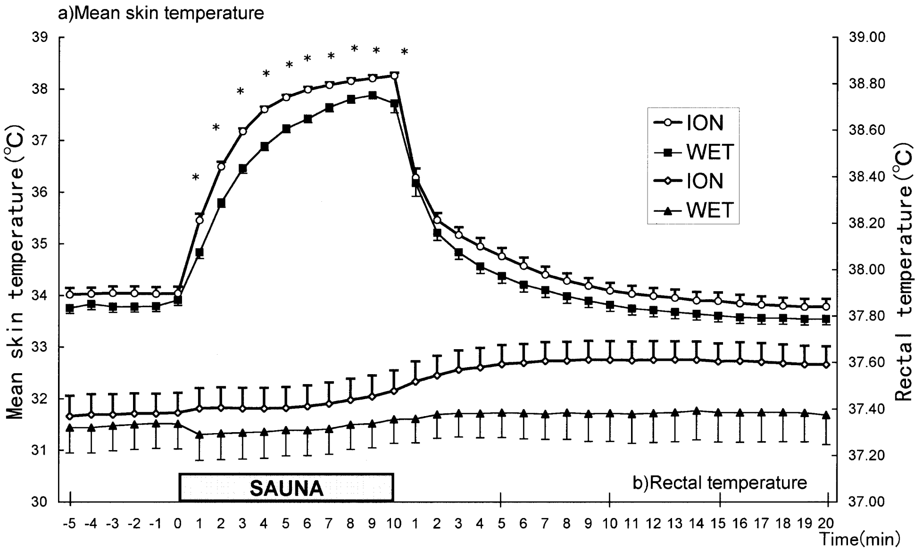

Fig. 5 Mean skin temperature and rectal temperature before, during, and after the saunas. The sauna definitions are as given for Fig. 2. Data are of mean (SEM), n=13; * P<0.05. Mean skin temperature was calited by the ratio of skin area (Nakayama 1981)

The temperature gradients in the sauna room posed a problem, namely, the temperatures were higher in the upper than in the lower part of the room due to the circulation of air, in other words, the temperature was higher at the level of the head than that at the level of the foot. The significant rises observed during the experiment in body temperatures at both forehead and foot under the high-temperature environment cannot be attributed to any unsatisfactory experiment condition. Thus, it may be considered that the negative ions brought a strong temperature raising effect to parts of the body other than the trunk. If negative ions have a direct effect on the skin, there should be no difference between the trunk and more distant parts. Duan et al. (1994) reported that negative ion air reaches the depths of the lungs. The possibility was considered that the inhaled negative ions caused any vital reaction via any automatic nerve function, which in turn had the effect of raising the temperature of the distant body parts.

When the whole body is exposed to high temperatures such as high-temperature water immersion or sauna, a change is observed of the rectal temperature. It is characterized a pattern in which the temperature slowly rises, after falling for 1 to 2 min, due to the stress caused by an abrupt change in the environment immediately after the whole body is exposed to such high temperature. In the shinki sauna, however, the change of the rectal temperature showed a different pattern in which the fall of temperature was not observed but the temperature continued to rise slowly. The reason for this is considered to be that the shinki sauna diminished thermal stress to the body but instead allowed a gradual change in the temperature. However, it was also found that the increase in the rectal temperature was higher in the shinki sauna than the wet sauna and that negative ions exerted a strong temperature raising effedt on the body.

The differences in the body temperatures as described above account for the significant increase in the sweat volume produced in the shinki sauna. The pulse rate also showed a significant increase. Watanabe et al. (1993) have shown that a high-temperature water immersion or a high-temperature/low-humidity sauna causes the pulse rate to rise to a dangerous level of 150 beats/min but to lead to only a small increase in sweat production (Watanabe et al. 1993). The negative ions in the air have been supposed to accelerate the increase in sweat production compared with the increase in pulse rate. Thus a negative ion sauna has been considered a thermal therapy which is useful from the viewpoint of safety as well as other aspects.

There have been many studies in the past reporting that negative ions contribute to subjective feelings of pleasantness and an improvement in work efficiency. In the present study, we have found that negative ions helped to raise the body temperature and increased sweat production, but failed to make any difference to subjective symptoms. The reason why no difference was found in the subjective symptoms may be that the exposure time (10 min) was short compared with the times reported in past studies (several hours); also that the subjects could not recognize any differences because of the strong stress caused by the sauna bath itself. Conversely, the reason why the subjects were not aware of a rise in body temperature, which is a strain on the body, and of the increase in the sweating volume, which causes feelings of a sticky skin or unpleasantness, may be that the negative ions reduced such unpleasantness.

In conclusion, we have investigated the effects of negative ions on the human body in a shinki sauna. We found that while there was no difference in subjective symptoms, negative ions had the effects of increasing the body temperature, sweat production, and pulse rate to a significant degree as well as enhancing the effects of the sauna bath. There are many unknown factors about the mechanism of development of the effects of negative ions, and we feel that more detailed study is needed.

References

Duan HJ, Gao F, Oguchi K, Nagata T (1994) Light and electron microscopic radioautographic study on the incorporation of ^{3}H-thymidine into the lung by means of a new nebulizer. Arzneim Forsch 44:880–883

Goldstein NI, Goldstein RN, Merzlyak N (1992) Negative air ions as a source of superoxide. Int J Biometeol 36:118–122

Hawkins LH, Barker T (1978) Air ions and human performance. Ergonomic 21:273–278

Leppaluoto J (1988) Human thermoregulation in sauna. Ann Clin Res 20:240–243

Nakayama A (1981) Thermological physiology, Rikogakusya, Japan, pp 1–32

Scheuch G, Gebhart J, Roth C (1990) Uptake of electrical charges in the human respiratory tract during exposure to air loaded with negative ions. J Aerosol Sci 21:439–442

Vuori I (1988) Sauna bather's circulation. Ann Clin Res 20:249–256

Watanabe I, Agishi Y, Noro H, Yabunaka N, Koizumi H, Tyosa H (1993) Comparison of thermoregulatory reactions between dry and steam sauna bathing. Biomed Thermol 13:146–150

Yates A, Grey FB, Misiaszek JI (1986) Air ions: past problems and future directions. Environ Int 12:99–108