Heat Reaction of Heat Acclimatized Tropical Resident in Serial Exposures to Hot Sauna

— A Comparative Study —

Peter George RIWA*, Mitsuo KOSAKA, Masaki YAMAUCHI, Takaaki MATSUMOTO and Nobu OHWATARI

Department of Environmental Physiology, Institute of Tropical Medicine, Nagasaki University, Nagasaki 852, JAPAN

Abstract: The effects of cold season on heat acclimatized tropical resident were studied from his reactions to six consecutive heat exposures in hot dry sauna (temp. 60 ℃) over a period of 3 weeks during summer in Japan. Two young Japanese sportsmen were subjected to similar heat exposures and their reactions were compared with those of the tropical resident. Pulse rate (PR) oral temperature (To), body weight (BW) and pulse pressure (PP) of the 3 subjects were recorded before and at the end of 30 minutes sauna exposures. Functional individuality of responses was apparent. While the tropical resident's post−exposure increase (mean±SE) were lower (PR 16±2.3; BW loss % 0.84±0.12; To 1.42±0.11℃), the Japanese sportsmen had proportionally higher increases. There was no statistically significant difference between the 3 subjects in pulse pressure change percentage. In the time course, the tropical resident had a decline in post−exposure increases of PR, To, Bw loss and PP from the 2nd experiment to the 6 th experiment. One of the Japanese sugjects had a decline in the post−exposure increases markedly from 5th heat exposure. The other sportsman had a decline in the increases of To and PR from the 3rd heat exposure, while his PR and BW losses remained almost constant (r:0.082 and r:0.045 respectively). The results indicate that deacclimatization to heat does not take place after cold exposure to winter or spring. Further the heat acclimation procedure was capable of inducing heat acclimation to the sportsmen. It is thought that regular physical training can contribute to heat adaptation procedures.

Key words: Heat acclimatization, Pulse rate, Pulse pressure, Body weight loss percentage, Physical training, Dry sauna, Tropical resident, Japanese sportsmen

Received for Publication, August 3, 1987.
Contribution No. 1986 from the Institute of Tropical Medicine, Nagasaki University.
*JICA trainee from Occupational Health Unit, Ministry of Labour and Manpower, Dar es Salaam Tanzania

Introduction

More and more people travel abroad nowadays and encounter different climates. The ability to withstand cold stress depends on the body protection against the cold by more insulating clothing. It is evident to many of tropical travellers that they find summer quite uncomfortable after spending winter and spring periods in temperate countries. In order to find out whether the subject has lost ability to withstand the hot humid summer we subjected a tropical resident to high ambient temperatures in sauna. It has previously been reported that artificial acclimation to heat decays after several days to weeks of no heat exposure (Adam *et al.*, 1960). The anthropometric factors associated with ability to achieve a thermal equilibrium in heat stress have been reported (Nunnely *et al.*, 1978; Clark *et al.*, 1983). These have been tested in the experimental model by the choice of a lean subject with smaller body surface area and older age compared to Japanese residents who have served as volunteer subjects in this experiment. These volunteers were regular sportsmen. It has been reported that physical training enhances adaptation to artificial heat acclimation in the temperate climate (Bleichert *et al.*, 1973). Therefore, these factors are compared in the present investigation.

Method

One healthy tropical resident was the subject of this experiment. He had arrived in Japan mid−winter. He has ever been a sedentary worker with no sporting activity. Other subjects were two Japanese sportsmen who served as volunteers. The phycical characteristics of the subjects (all males) are shown in Table 1. The experiments started towards the end of April and ended mid−May. The subjects led normal life without interruption to their daily activities, meals or drinks.

Table 1. Individual Characteristics of Experimental Subjects (all males)

Subject	Age (yr)	Height (cm)	Weight (kg)	B.S.A. (m^2)	Residence
PG	37	160	54.4	1.56	Tanzania (Sedentary)
SA	20	167	67.0	1.75	Japan (Baseballer)
YA	33	167	70.0	1.78	Japan (Sprinter)
X	30	164.7	64.1	1.69	
SD	7.2	3.3	6.2	0.09	

On the experimental day the subjects entered the environmental control chamber (temperature 28℃, relative humidity 60%) and were instructed to wear sporting shorts and sit quietly in the chamber for 30 minutes to obtain thermal equilibrium. They were free to drink if they so desired. Their body weights were recorded by using human balance (type FW−100K Japan); blood pressure (BP), and pulse rate by using Digital haemodynamometer (UA 535) and oral temperature by using Digital clinical thermometer (Terumo). On entering the sauna box (type Arubi AS−1300SD), at 60℃ which was thermostatically heated by panel radiators, the subjects sat quietly and was instructed not to breath through the mouth or wipe off sweat. They were not allowed to drink during the 30 minutes in sauna. At the end of the 30 minutes in sauna, the subject's BP, pulse rate, and oral temperature were recorded. The subject was instructed to take a bath, dried himself, not to pass out urine and wear similar dry sporting shorts and then was reweighed. This experimental procedure was repeated on Tuesday and Friday from 2−4 pm every week in 3 weeks period for a total of six experiments each.

RESULTS

On examining the results obtained on the time course of pre and post−exposures, individual physiological variables become distinct (Table. 2−5.). Individual reactions are given below−

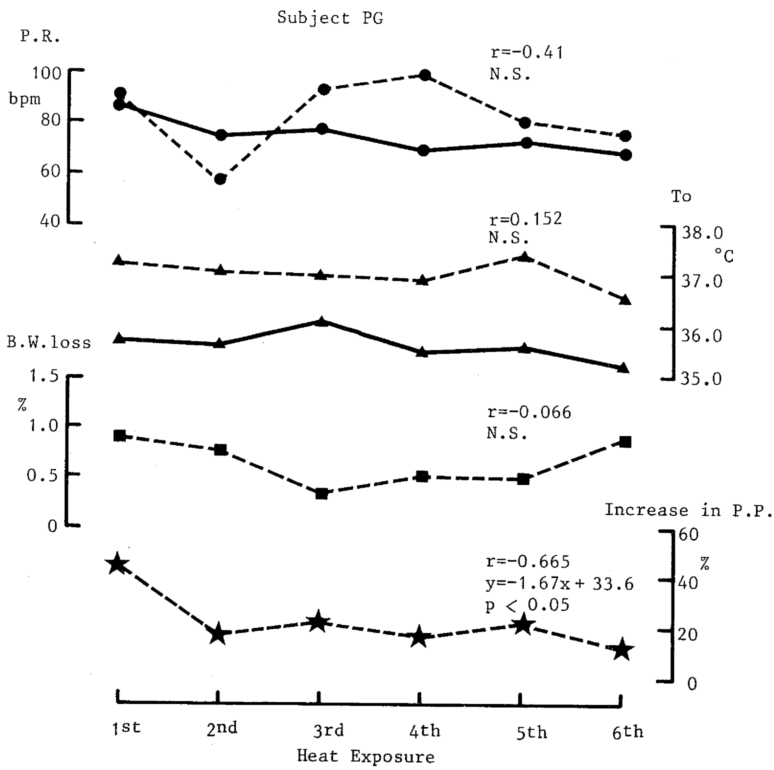

Fig. 1. Individual determinants before (———) and at the end (------) of heat exposure in sauna.
P.R.: Pulse Rate, To: Oral Temperature, B.W.: Body Weight
P.P: Pulse Pressure, r: denotes the regression coefficiency of post exposure values, N.S.: no statistical significance
(Regression lines not shown)

(1) *Changes in Pulse Rate:*

The mean post−exposure pulse rate increased from mean pre−exposure rate by 16 beat per minute (bpm) in subject PG with whom these reactions are compared (Table 2). The Japanese sportsmen had a greater increase (SA: 36.7bpm and YA: 25.7bpm). The time course events in pulse rate in subjects PG and YA were a declining post−exposure pulse rates. However subject SA had almost stable post−exposure pulse rate (Fig. 2.). There was unexplained drop in post−exposure pulse rate after second heat exposure in subject P.G. Also this subject had a pre−exposure pulse rate decrease in the time course as shown in Fig. 1.

Table 2. Changes in pulse rate (bpm) due to serial heat exposures in sauna.
*$P<0.005$, **$0.02>P>0.1$: Compared with PG's value.
Mean±SE

Subject	Experiments	Before Sauna	End of Sauna	Increase
PG	6	73.6±2.4	82.2±5.6	16.0±2.3
SA	6	85.0±1.0	120.2±2.2	36.7±2.3*
YA	6	64.2±1.3	89.8±5.0	25.7±4.3**

(2) *Oral Temperature Changes:*

There was a general post−expsure increase in oral temperature in both subjects compared with subject PG having the lowest increase (mean 1.42℃ SE 0.11) and other subject having a higher mean post−exposure oral temperature (Table 3.). The time course oral temperature changes after sauna heat exposure in the two Japanese sportsmen was a decreasing post−exposure oral temperature. The tropical subject had almost a stable post−exposure oral temperatures showing a declining trend except in the 5th sauna heat exposure (Fig. 1.). The increase of post−exosure oral temperature from pre−exposure level was significantly higher with the two Japanese sportsmen ($p<0.05$). Subject PG had a higher and more stable pre−exposure oral temperature (Table 3.).

(3) *Body Weight Loss:*

Body weight loss as an indicator of sweat rate was higher in the two Japanese sportsmen especially in subject YA ($p<0.05$) (Table 4.). Both subjects PG and YA however had decreasing sweat rates over the heat exposure regimen (Fig. 1, Fig. 3.). Subject SA had a fluctuating sweating rate and no decreasing or increasing trend could

Table 3. Oral temperature (in ℃) changes due to serial heat exposures in sauna.
*$P<0.025$, **$0.1>P>0.05$: Compared with PG's value.
Mean±SE

Subject	Experiments	Before Sauna	End of Sauna	Increase
PG	6	36.6 ±0.11	38.00±0.10	1.42±0.11
SA	6	36.15±0.25	38.05±0.25	2.03±0.78*
YA	6	36.55±0.51	38.33±0.15	1.78±0.12**

be observed (Fig 2.). It is interesting to note that the tropical subject had a gradual decrease of sweat rate to the 3rd heat exposure but started to sweat more and more thereafter. The sweat rate however did not exceed the 1st heat exposure rate. The trend was as stated above, a declining sweat rate over the time course regimen although this was not statistically significant (Fig. 1.).

(4) *Changes in Pulse Pressure:*

The pulse pressure in both individual subjects (SA and YA) tended to increase after the heat exposures. But time course trend of the pulse pressure was towards decline from the beginning of the heat exposure regimen to the end. This was statistically significant in both subject PG and SA ($p>0.05$). Subject YA had fluctuations in the post-exposure pulse pressure, but the trend was also a decline in pulse pressure (Fig 3.). There was no statistically significant difference between the 3 subjects in their pulse pressure changes (Table 5.).

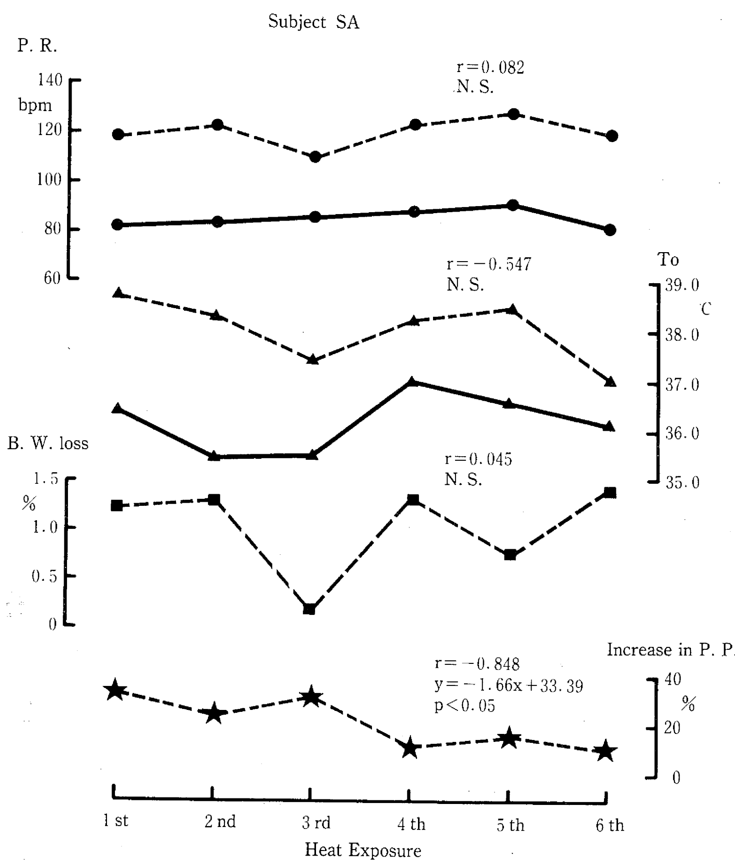

Fig. 2. Individual determinants before (——) and at the end (------) of heat exposure in sauna.
P.R.: Pulse Rate, To: Oral Temperature, B.W.: Body Weight
P.P: Pulse Pressure, r: denotes the regression coefficiency of post exposure values, N.S.: no statistical significance
(Regression lines not shown)

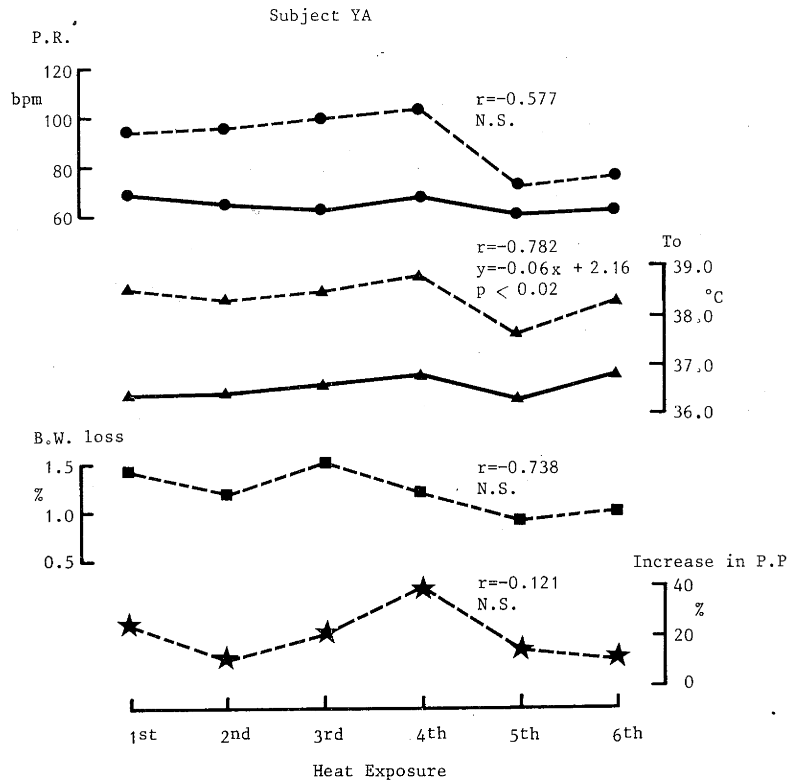

Fig. 3. Individual determinants before (———) and at the end (------) of heat exposure in sauna.
P.R.: Pulse Rate, To: Oral Temperature, B.W.: Body Weight
P.P: Pulse Pressure, r: denotes the regression coefficiency of post exposure values, N.S.: no statistical significance
(Regression lines not shown)

Table 4. Body weight losses due to serial heat exposures in sauna.
*P<0.05 : Compared with PG's value. **Not significant
Mean±SE

Subject	Experiments	Before Sauna	End of Sauna	% Changes in Body Weight
PG	6	55.53±0.10	55.07±0.10	0.84±0.12
SA	6	66.80±0.16	66.10±0.05	1.05±0.18**
YA	6	69.03±0.19	68.20±0.19	1.20±0.08*

Table 5. Pulse pressure changes due to serial heat exposures in Sauna. No statistical significant difference between the individual pulse pressure change percentage.
Mean±SE

Subject	Experiments	Before Sauna	End of Sauna	Pulse Pressure Changes %
PG	6	47.3±4.1	44.5±4.4	20.7±4.4
SA	6	58.3±3.6	53.0±3.7	21.5±3.6
YA	6	51.7±5.3	58.0±2.6	20.1±4.2

Discussion

The findings reveal that hot dry heat exposures in sauna can modify the thermoregulatory response in both heat acclimatized and non−heat acclimated individuals. Although the tropical resident acquired heat acclimation by the heat exposures, there seem to be less diversified responses in the non−heat acclimatized Japanese residents. They took, however, more times of heat exposure to adapt to the heat stress and even so not to all physiological parameters of heat acclimatization namely cardiac frequency, sweat rate, lower rise in body temperature and cardiac output.

Subject SA did not develop as much thermal adaptation as the other subjects and that is why his oral temperature remained higher and this being the same case as with his pulse rate.

It is known that heat deacclimatization occurs after a period of weeks of no exposure to heat (Adam *et al.*, 1960) but in this case subject PG responded very promptly to the thermal stress and was well adapted only after the second heat exposure dispite of the winter stay in Japan. Normally such high temperatures as was the sauna heat are uncommon in many parts of the tropics. The bodily constitution of the subject was such that his lean body possibly facilitated heat transfer in his body with greater efficiency. The delay to adapt to the thermal signals of the sauna by the two sportsmen is arbitrary because we already know that training and physical fitness improves the response to thermal stress (Bleichert *et al.*, 1973). It is difficult also to stipulate that the effects of sitting in the sauna during thermal stress would affect the sportsmen's response of their cardiovascular mechanism (Harrison *et al.*, 1985). Further the dry heat of the sauna progressively changed its humidity because of subject's sweat. As the air change in the sauna was almost negligible, dripping of sweat occasioned a higher body temperature rise. This phenomenon could be an attribute in the reaction of the two Japanese subjects. It has been cited elsewhere that skin wettedness is associated with impairment of heat loss mechanism in hot bath (Fujishima and Kosaka, 1971).

We are not able to attribute the fluctuations in the weight losses of subjects SA because the temperature of the sauna was constant throughout the experiments. It suggested by some authors that acclimation to more severe heat effects cardiovascular adjustments and greater sweat rates (Shapiro *et al.*, 1981). We concluded that reaction to thermal stress in an individual may meet varying alterations in his or her cardiovascular physiology. The core temperature was not recorded. We found that there is no absolute index of core temperature and the oral temperature was a convenient approximation in this experimental model (Von Euler, 1961).

As far higher pre−exposure oral temperatures, the tropical resident had a higher resting core temperature. This is consistent with other authors (Wyndham *et al.*, 1964). The three subjects responded very well in their circulatory mechanism especially in cardiac output which is a function of pulse rate and pulse pressure. Both tended to stabilize at a lower pulse pressure from the first experiment onwards except for subject YA on the 4th exposure. This rise couldn't be explained by the experimental model except for his peculiar reaction on that particular day. It is known that exposure to sauna temperature rises the cardiac output and pulse pressure (Eisalo, 1956) but we were not able to explain the proportional increase by this experimental model.

Further the age difference in the subjects was a modifying factor. And together with body size we found the association to heat exchange to be also complex (Turner *et at.*, 1985; Clark *et al.*, 1983). Ohwatari et al. (1983) did studies on heat adaptation to a tropical resident and found out that the subject did not lose his heat acclimatization states after staying in Japan in Autumn. Further Fan et al. (1984) in studying heat adaptation found out that anthropometric characteristics of tropical residents have an added advantage in their homeostatic capacity in hot climates. In conclusion, short term exposures to dry heat in sauna is capable of inducing heat adaptation in non–heat acclimatized athletic subjects but the physiological reactions are not necessarily similar to all sportsmen. More works need to be done in determination of short term heat acclimation and seasonal adaptation, and cross adaptation between physical training and acclimatization to hot humid summer.

ACKNOWLEDGEMENT

The authors greatly acknowledge the assistance provided by Marutaka Co. Ltd., Tokyo for providing the Sauna Box which was used in this experiment.

REFERENCES

1) Adam, J. M., Fox, R. H., Grimby, G., Kidd, D. J. & Wolff, H. S. (1960): Acclimatization to heat and its rate of decay in man. J. Physiol. (London), 152, 26–27.
2) Bleichert, A., Behling, K., Scarperi, M. & Scarperi, S. (1973): Thermoregulatory behaviour of man during rest and excercise. Pflügers Arch., 338, 303–312.
3) Clark, G. W. & Lipton, J. M. (1983): Brain and pituitaray peptides in thermoregulation. Pharmac. Ther., 22, 249–297.
4) Eisalo, A., (1956): Effects of Finnish sauna on circulation. Annales medicine experimentalis et biologiae fenniae, 34(suppl. 4), 7–94.
5) Fan, Y. J., Ohwatari, N. & Kosaka, M. (1984): Studies on heat adaptation (Report II) –Sweating responses of tropical inhabitant.– Trop. Med., 26(4), 191–195.
6) Fujishima, K. & Kosaka, M. (1971): Sweating on the immersed human skin in hot bath. Nagoya Med. J., 17(1・2), 25–31.
7) Harrison, M. H. (1985): Effects of thermal stress and exercise on blood volume in humans. Physiol Review, 65(1), 149–209.
8) Nunnely S. A. (1978): Physiological responses of women to thermal stress. A Review Medicine Science in Sports, 10(4), 250–255.
9) Ohwatari, N., Fujiwara, M., Iwamoto, J., Fan, Y. J., Tsuchiya, K. & Kosaka, M. (1983): Measurement of the sweating reaction of a tropical inhabitant. Trop. Med., 25(4), 235–241.

10) Shapiro, Y., Pandolf, K. B., Avelline, B. A., Pigemtal, N. A. & Goldman R. F. (1981): Physiological responses of men and women to humid and dry heat. J. Appl. Physiol., 50(4), 791－798.

11) Turner, J. S. & Trancy, C. R. (1985): Body size and the control of heat exchange in alligators. J. Therm. Biol., 10(19), 9－11.

12) Von Euler, C. (1961): Physiology and pharmacology of temperature regulation. Pharmac. Reviews, 13, 361－398.

13) Wyndham, C. H., Strydom, N. B., Munro, A., Mac Pherson, R. K., Metz, B., Schaff, G. & Schieber, J. (1964): Heat reactions of caucasians in temperate, in hot dry and in humid climates. J. Appl. Physiol., 19(4), 604－612.

高温・低湿サウナの反復負荷による対暑反応
—熱帯地人と日本人スポーツマンの比較研究—

Peter G. Riwa, 小坂光男, 山内正毅, 松本孝朗, 大渡　伸
(長崎大学熱帯医学研究所疫学部門・環境生理)

暑熱順化・熱帯地非スポーツマン（1名）と日本人スポーツマン（2名）を60℃の高温低湿サウナに週2回（1回：30分），3週間反復負荷させて対暑反応を比較検討した．対暑反応指標として発汗量（体重減少比），口腔温，脈圧，心拍数等をサウナ負荷前後で測定し次の結果を得た．

（1）対暑反応の順化発現時間が日本人スポーツマンで延長を認める以外熱帯地人との間に有意の差を認めなかった．

（2）すなわち，熱帯地人はサウナ負荷第1回目から対暑反応に順化が獲得されたが，日本人スポーツマンでは5回の負荷を要した．

（3）両者間に核温（口腔温）の上昇率や心拍，脈圧に軽度温度適応変化を認めたが，この結果は運動トレーニングが生体反応の季節変動の調整や暑熱順化の形成過程に大きな役割を果たしていることを示す。

以上の結果から熱帯地人の寒冷地在住後の脱順化についても検討を加えた．

熱帯医学　第29巻　第3号　165－173頁，1987年9月