Studies on the Temperature of the Gastrointestinal Tract.

Second Report:

Influence of Bathing on the Intragastric Temperature.

By

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Researches on the changes of the intragastric temperature of the human body by taking a bath are scanty, for which reason we have carried out the present study at the Narugo Spa in Miyagi Prefecture in November 1949.

EXPERIMENTAL.

Methods and Materials.

We made experiments at the following four hot-springs of the Narugo Spa: (1) the earthy sulphate spring (pH 6.6), (2) the alkaline muriated saline sulphur spring (pH 9.2), (3) the sulphuretted acid vitriol spring (pH 1.2), and (4) the sulphuretted simple carbondioxated spring (pH 5.8). A hot bath of tap-water was also used as a control. On the 18 healthy adults (14 men and 4 women) 46 experiments were performed. Continuously before, during and after the bath, we measured the intragastric temperature at 60 cm from the incisor of the upper jaw, in the fasting state at least 4 hours after meals. After bathing, it was measured in the bath room at about 15° C without putting on clothes for more than 30 minutes. In the bath the whole body except the head was submerged. For measurements of the intragastric temperature the thermometer described in the previous paper¹⁾ was used and for the axillary the mercury thermometer.

If among the three factors of the bath, i. e., the kind of spring, temperature and time of the bath, two or one are made constant and the remaining one or two variable, then several combinations of the three are given. By making experiments according to each of the combinations, influences of bathing on the intragastric temperature were studied. Some other experiments were also made. The object of this study was chiefly the hot bath above 40° C.

RESULTS AND DISCUSSION.

1) The combination of the constant temperature and kind of spring, and variable times.

The rises of the intragastric temperatures of 10 individuals who bathed in the sulphate spring for 8 minutes at 44° C are given in Table I and Fig.

TABLE I.
The Rises of the Intragastric Temperature in the
Sulphate Spring at 44°C for 8 Minutes.

No.	Before the bath	During the bath (minutes)							
		1	2	3	4	5	6	7	8
	°C	°C	°C	°C	°C	°C	°C	°C	°C
1	37.1	0	0.1	0.2	0.4	0.5	0.6	0.9	1.1
2	37.4	0	0.1	0.2	0.5	0.7	1.1	1.3	1.7
3	37.8	0	0	0.2	0.4	0.6	0.8	1.2	1.4
4	37.4	0	0.1	0.2	0.4	0.8	0.9	1.1	1.3
5	37.1	0	0	0.2	0.6	0.8	1.1	1.3	1.4
6	37.5	0	0.1	0.3	0.5	0.6	0.6	1.1	1.3
7	37.0	0	0	0	0.1	0.2	0.5	0.6	0.9
8	37.0	0.1	0.2	0.3	0.5	0.7	0.7	0.9	1.1
9	37.6	0	0	0.1	0.2	0.5	0.7	0.9	0.9
10	37.6	0	0	0.2	0.4	0.7	1.0	1.3	1.6
Sum	373.5	0.1	0.6	1.9	4.0	6.1	8.2	10.6	12.7
Mean	37.35	0.01	0.06	0.19	0.40	0.61	0.82	1.06	1.27

Fig. 1. The rises of the intragastric temperature (vertical) in the sulphate spring at 44°C for 8 minutes (horizontal). Three lines indicate respectively the maximum, minimum and mean of the rises.

1. In Fig. 1 the maximums, minimums and means of the rises of every minutes are plotted. In these 10 cases the rise of the intragastric temperature observed from the values before, and 1 and 2 minutes during the bath, was not statistically significant, contrary to the extended time of

2 and 3 minutes which was significant. The rise becomes first significant in the course of more than 2 minutes. As the type of the rise is almost linear obviously in Fig. 1, the relation between the rise and the time during the bath is represented by a straight line. If the rise in t minutes during the bath is $X^{\circ}\text{C}$, X is given according to the empirical formula as follow:

$$X = 0.22 t - 0.47 \quad (t > 2).$$

2) The combination of the constant kind of spring and time, and variable temperatures.

The rises of the intragastric temperatures of the three same men who bathed 4 minutes in the sulphate spring at 40, 44 and 47 $^{\circ}\text{C}$, and of the five same men at 43 and 44 $^{\circ}\text{C}$, are shown in Table II and Fig. 2. The

TABLE II.
The Rises of the Intragastric Temperature
in the Sulphate Spring for 4 Minutes at
40, 43, 44 and 47 $^{\circ}\text{C}$.

No.	A 40 $^{\circ}\text{C}$	B 44 $^{\circ}\text{C}$	C 47 $^{\circ}\text{C}$	D 43 $^{\circ}\text{C}$	E 44 $^{\circ}\text{C}$
	$^{\circ}\text{C}$	$^{\circ}\text{C}$	$^{\circ}\text{C}$	$^{\circ}\text{C}$	$^{\circ}\text{C}$
1	0.1	0.4	0.9	0.1	0.4
2	0	0.5	0.5	0.2	0.5
6	0	0.5	1.5	0.4	0.5
11				0.1	0.5
12				0.1	0.4
Sum	0.1	1.4	2.9	0.9	2.3
Mean	0.03	0.47	0.97	0.18	0.46

Fig. 2. The rises of the intragastric temperature (vertical) in the sulphate spring for 4 minutes at 40, 43, 44 and 47 $^{\circ}\text{C}$ (horizontal). Three lines indicate respectively the maximum, minimum and mean of the rises.

rise in 4 minutes at 40 $^{\circ}\text{C}$ was not statistically significant, but those at 43 $^{\circ}\text{C}$ and above were all significant. Between the means of the rises at 40 $^{\circ}\text{C}$ (A in Table II) and 44 $^{\circ}\text{C}$ (B), those at 44 $^{\circ}\text{C}$ (B) and 47 $^{\circ}\text{C}$ (C), and those at 43 $^{\circ}\text{C}$ (D) and 44 $^{\circ}\text{C}$ (E), significant differences were seen. It is certain that the rise of the intragastric temperature is directly proportional to the temperature of the bath, and 43 $^{\circ}\text{C}$ is the lower level of the rise in a bath for 4 minutes.

3) The combination of the constant temperature and time, and different kinds of spring.

Fig. 3. The means of the changes of the intragastric temperature (vertical) during and after the bath for 8 minutes (horizontal) at 44°C in the sulphate (—), alkaline sulphur (---) and acid (···) springs and in the tap-water bath (- · - · -).

The means of the rises of the intragastric temperatures of the six same men who bathed 8 minutes at 44°C in the sulphate, alkaline sulphur and acid vitriol springs are given in Fig. 3. The means of 4 individuals of the tap-water bath under the same conditions are shown as a control. The intragastric temperatures rose linear as above mentioned in the course of more than 2 minutes. The types of the rises during the bath and the means of the rises in 8 minutes did not differ significantly by the 4 kinds of spring including also the tap-water bath. The intragastric temperatures continued to rise during the first several minutes after bathing and reached the maximum rises. The mean of the maximum rise in the alkaline sulphur spring was 1.90°C , thus being significantly higher than those in the sulphate (1.40°C) and acid springs (1.45°C). That in the tap-water bath was 1.55°C . The fall of the intragastric temperature thereafter in the alkaline sulphur spring, observed from the values before bathing, of the maximum rise and 30 minutes after bathing, was significantly slower than those at the other three. The mean of the intragastric temperature 30 minutes after bathing in the alkaline sulphur spring was still 0.52°C higher than that before bathing. This difference was significantly greater than those in the sulphate (0.18°C), acid springs (0.18°C) and tap-water bath (0.20°C). These are interesting compared with the fact that at the Narugo Spa, warmth after bathing is said to remain longest in this alkaline sulphur spring.

4) The combination of the constant kind of spring, and variable temperatures and times.

Fig. 4. The means of the changes of the intragastric temperature (vertical) during and after the bath (horizontal) for 15 minutes at 40°C (— · — · —), for 8 at 44°C (---) and for 4 at 47°C (——).

The means of the rises of the intragastric temperatures of the three same men who bathed 15 minutes at 40° C, 8 minutes at 44° C, and 4 minutes at 47° C in the sulphate spring are shown in Fig. 4. The rises were linear as above mentioned. But the types of the rises were obviously different and their direction coefficients were generally proportional to the temperature of the bath. The means of the rises soon after bathing were respectively 1.03, 1.33 and 0.97° C and those of the maximum rises 1.13, 1.53 and 1.53° C. Among them no significant differences were seen. The means of the rises which were observed during the first several minutes after bathing were 0.10, 0.20 and 0.57° C, and the latter was significantly greater than the other two. In this group a stimulation by bathing is so strong that the after-effect is intense. The fall of the intragastric temperature after bathing did not differ by the three groups in these three men. In the group of 15 minutes at 40° C, as obviously seen in Fig. 4, the fall seems to be slower and the intragastric temperature 30 minutes after bathing still remains higher than the other two. This seems to be related to the fact that warmth after bathing remains longer by taking a long bath in a lower temperature.

As in the case of the above cited 3), the axillary temperatures after bathing were measured, the results are briefly described and compared with those of the intragastric. The means of the maximum rise of the axillary temperature in the alkaline sulphur spring (3.10° C) was significantly higher than those in the acid spring (2.40° C) and in the tap-water bath (2.50° C). That in the sulphate spring was 2.78° C. The mean of the rise still remained 30 minutes after bathing in the alkaline sulphur spring was 0.43° C; this was significantly higher than those in the sulphate (0° C) and acid springs (0.08° C) and in the tap-water bath (0° C). Accordingly

the fall in the alkaline sulphur spring was significantly slower than those in the sulphate and acid springs. These differences in the axillary temperature were all seen in the intragastric; the former is compared with the latter. The maximum rise of the axillary temperature is significantly higher than that of the intragastric in the 4 springs including the tap-water bath. There is no significant difference between the two in the remaining rise 30 minutes after bathing. Accordingly the falls of the axillary temperature are steeper than those of the intragastric in the sulphate, alkaline sulphur and acid springs.

The rises of the intragastric temperatures of the two same men who bathed their whole body or only their legs under the same conditions in the sulphate spring, are given in Table III. The statistically significant

TABLE III.

The Rises of the Intragastric Temperature of the Whole Body and the Partial Bath of the Legs in the Sulphate Spring.

No.		The whole body bath	The partial bath of the legs
1	The Bath of	°C	°C
	8 minutes at 44°C	1.9	0.4
2	15 minutes at 43°C	1.8	1.0
Sum		3.7	1.4
Mean		1.85	0.70

difference between the rise by the two methods of the bath was not seen in these two men. However, if more men are measured, it is certain that the rise by the whole body bath will be significantly higher than that by the partial bath of only their legs. Concerning this problem it is necessary to study the influence of local warming or cooling of various parts of the body upon the intragastric temperature.

We analyzed the type for the fall of the intragastric temperature after bathing, as an example, in the 10 cases in the sulphate spring. In the semi-logarithmic table, Fig. 5, the mean of the remaining rise of the intragastric temperature is given in logarithmic scale as ordinate and the time after bathing as abscissa. Obviously in Fig. 5 two straight lines are obtained before and after the coordinate of 15 minutes. Accordingly the fall of the intragastric temperature is expressed by the two exponential functions except the first several minutes after bathing. The empirical formulas are as follows:

$$X = 1.84 e^{-0.109t} \quad (3 \leq t \leq 14), \text{ and } X = 1.12 e^{-0.074t} \quad (15 \leq t \leq 30),$$

in which $X^{\circ}\text{C}$ is the difference of the intragastric temperature between before and t minutes after bathing. In the other springs the empirical

Fig. 5. The means of the falls of the intragastric temperature after bathing in the sulphate spring for 8 minutes at 44°C . The intragastric temperature still remained above the one before bathing (vertical) within 30 minutes after bathing (horizontal). The two lines represent the empirical formulas.

Fig. 6. The changes of the intragastric temperature (vertical) in the carbon-dioxated spring at 37°C for 50 minutes (horizontal). Three lines indicate respectively the maximum, minimum and mean of the changes.

formulas are represented by more than 2 exponential functions, according to the temperature of the bath and the room temperature after bathing.

The means of the intragastric temperatures of 4 men who bathed 50 minutes at 37°C in the carbondioxated spring, are shown in Fig. 6. The intragastric temperature at first fell and reached the minimum of 0.28°C after 10 minutes. Thereafter it slowly rose and reached after 40 minutes the level before bathing and after 50 minutes it became 0.10°C higher. Both the fall and rise are significant and both augment linear with the time of the bath.

SUMMARY.

The changes of the intragastric temperature of the human body by taking a bath were studied at the four hot-springs of the Narugo Spa. The

results of the baths above 40° C were given and the following facts were confirmed.

1. The intragastric temperature during the bath rises linear with the time.

2. The rise of the intragastric temperature is high and its direction coefficient is generally proportional to the temperature of the bath.

3. The type of the rise of the intragastric temperature does not significantly differ according to the kind of spring.

4. In the alkaline sulphur spring, the maximum rise was highest and the fall after bathing was slowest.

5. There were no significant differences among the maximum rises of the baths of 15 minutes at 40° C, of 8 at 44° C and of 4 at 47° C, in the sulphate spring. The after-effect of the bath remained proportionally to the temperature of the bath.

6. The changes of the axillary temperature have the same tendency as those of the intragastric. The maximum rise was about 1.0° C higher and the fall was steeper in the former than in the latter.

7. The rise of the intragastric temperature by the whole body bath is higher than that by the partial bath of legs.

8. The fall of the intragastric temperature after bathing is expressed by more than 2 exponential functions.

In the bath of 37° C in the carbondioxated spring the intragastric temperature at first fell and then rose slowly.

References.

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