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The Influence of Oxidation Reduction Potential of Spa Spring Water on the Human Body

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温泉水の酸化還元電位が人体に及ぼす影響について

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抄　録

緒言

温泉水は老化現象を示すことが知られていて、それは温泉水の酸化還元電位が増加し、その治療効果が失われることだと考えられている。しかし温泉水の酸化還元電位が生体に及ぼす影響については良く知られていない。痛風は薬物によってと同様に温泉によって、また鍼治療によって治療されてきた。それ故我々は酸化還元電位と尿酸排泄及び鍼治療と密接な関係にある良導絡との関係を調べた。

方法

各三名、三群の被験者が硫黄泉、炭酸水素塩泉及び水道水の風呂に入浴し、時間毎に尿酸排泄と良導絡を測定した。

結果

尿の尿酸クレアチニン比と良導絡電流は硫黄泉入浴後増加し、水道水浴後減少した。尿の酸化還元電位は尿の尿酸クレアチニン比および尿のpHと負の相関を示した。良導絡電流の変動は尿の酸化還元電位の変動と逆方向を示すことが多かった。

結論

浴水の酸化還元電位は尿の酸化還元電位や尿の尿酸排泄及び良導絡電流に影響を与えた。尿の酸化還元電位は体液の酸化還元電位を反映すると考えられるので、尿酸排泄や良導絡は体液の酸化還元電位によって影響されると考えられた。これらの所見は腎や表皮の細胞に電位依存性のトランスポーターやチャンネルが存在するので、酸化還元電位がそれらの細胞の膜電位に影響を与えたことを示すように思われた。更に尿の酸化還元電位は尿のpHと負の相関を示したので、酸化還元電位は電気的にpHを緩衝しているものと思われた。これらの事実は酸化還元電位を導くネルンストの式を用いて説明できるので、温泉の酸化還元電位は入浴によって生体に電気的な影響を与えるものと思われた。

Key words : oxidation reduction potential, pH, uric acid, ryodoraku, spa spring

Ⅰ OBJECTIVES

Immersion in hot spring water is widely believed to be effective for many diseases and to enhance health. The water at these springs has various chemicals and physical characteristics. Of particular interest is the concept of "aging" of spring water; aerial oxidation causes a gradual increase in oxidation reduction potential (ORP), leading to diminished efficacy of the hot spring[1]. Therefore, maintaining the original ORP of hot spring water is thought to be essential. However, the influence of ORP on the effects of hot spring bathing has not been well elucidated.

Gout is a condition which, like many musculoskeletal diseases, has long been treated not only pharmacologically, but also by spring bathing[2),3)] and acupuncture[4),5)]. We therefore hypothesized that bathing in hot spring water might influence uric acid excretion and the activity of meridians (as conceptualized in oriental medicine). Although the concept of acupuncture meridians is not yet well recognized scientifically, it has been demonstrated that limited epidermal areas corresponding to acupoints along meridians show diminished resistance to low direct voltage. These areas of low electrical resistance were named ryodoten and the lines connecting these ryodoten were termed ryodoraku by Nakatani in 1950. The concept of ryodoraku has been understood to reflect the electrical properties of the meridians[6)]. Accordingly, we examined the relationship between ORP and uric acid excretion, and between ORP and meridian activity as measured by ryodoraku current.

Ⅱ METHODS

Nine volunteers (three men and six women aged 22 to 26 years) were divided into three groups. One group bathed in sulphur-containing spring water, one in bicarbonate and salt containing spring water, and one in tap water. Before the experiment, informed consent was verbally obtained from each participant. Urine specimens were taken six times at intervals of 2 hours from 0600 to 1600 immediately before bathing and immediately before taking meals. Bathing was performed for 10 minutes at 1000 and at 1400, and water temperature was maintained at 40 degrees Celsius. Meals were consumed at 0800 and 1200; all participants consumed the same food during each meal break. We measured ryodoraku current, dermal moisture level, and body impedance using a high frequency alternating current. ORP and pH of urine and spring water were assessed, as were urine concentrations of uric acid and creatinine.

Ryodoraku currents were measured at 24 specified points on the extremities (Fig.1) with a 12-volt load using a Neurosoftar DS603 (Ryodoraku Laboratory, Tokyo, Japan)[6)].

Immediately before the ryodoraku measurements, body impedance was obtained from data recorded by a body fat analyzer (TBF110 Tanita Corporation, Tokyo, Japan).

Immediately after the ryodoraku measurements, dermal moisture level was measured using a mois-

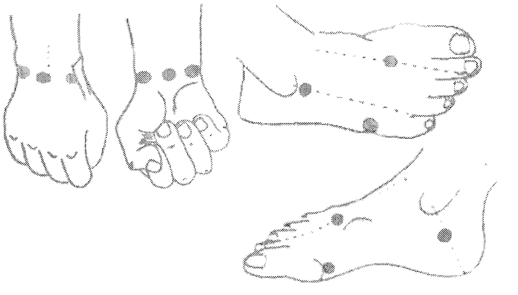


Fig.1 Ryodoraku measurement points (black circles). There are 24 points in total (located on both hands and feet).

ture sensor (MY707S, Scalar Co., Tokyo, Japan), at the 12 ryodoraku measurement points on the hands.

ORP and pH of urine specimens and bath water were simultaneously measured using an M22P instrument (TOA DKK Ltd., Tokyo, Japan). ORP was normalized with reference to the potential of the standard hydrogen electrode.

Measurement of urinary uric acid and creatinine were performed at Miyagi Medical Laboratory Center.

Dr.SPSS8.0J for Windows was used for statistical analysis.

Ⅲ RESULTS

Of the three kinds of bathing water, sulphur-containing spring water had the lowest ORP; urinary ORP decreased in most subjects two hours after bathing in this water. Tap water exhibited the highest ORP; urinary ORP increased in most subjects two hours after bathing in this water. The hydrogen bicarbonate and salt containing spring water had an intermediate ORP and an intermediate effect on urinary ORP. (Table 1, Table 2, Fig.2)

All of the three groups demonstrated a significant negative correlation between urinary ORP and urinary uric acid creatinine ratio: number of samples (n), correlation coefficient (r), and level of significance (p) were as follows. In the sulfur group: $n=18$, $r=-0.6624$, and $p=0.003$; in the bicarbonate group: $n=18$, $r=-0.636$, and $p=0.005$; and in the tap water group: $n=18$, $r=-0.547$, and $p=0.019$. (Fig.3)

Urinary ORP and pH showed a significant negative correlation; among all participants, the results

Table.1 Mean ORP of bath water

Sulfur spring water	145
Bicarbonate salt spring water	407
Tap water	527

ORP=oxidation reduction potential (mV)

Table.2 Difference in urinary ORP before and after each meal or bath

		Sulfur Spa	Bicarbonate Salt Spa	Tap Water
M*	10:00 - 8:00	9.24	-50.77	-19.80
B#	12:00 - 10:00	-48.23	-20.53	-0.51
M*	14:00 - 12:00	34.23	5.16	-25.06
B#	16:00 - 14:00	-13.17	12.29	6.94

Mean value of 3 objects, illustrated on Fig.2, mV

M* indicates urinary ORP measured at 10.00 minus that at 08.00, or urinary ORP measured at 14.00 minus that at 12.00 ; denoting the influence of meals at 8:00 or at 12 : 00.

B# indicates urinary ORP measured at 12.00 minus that at 10.00 or urinary ORP measured at 16.00 minus that at 14.00 ; denoting the influence of bathing at 10:00 or at 14:00.

ORP = oxidation reduction potential

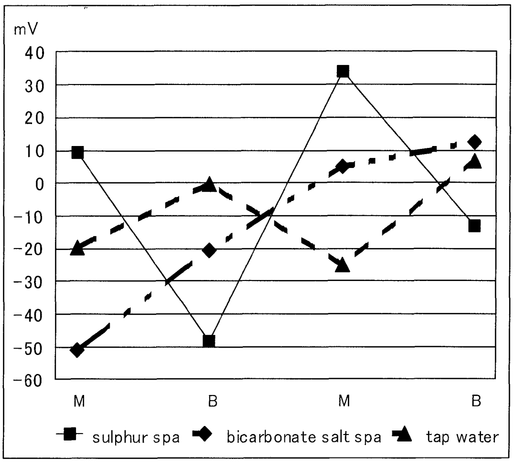


Fig.2 Difference between urinary ORP before and after each meal or bath
M : meal, B: bathing. See the footnote for Table 2 for further details.
Urinary oxidation reduction potential (ORP) increased after tap water bathing but decreased after sulfur spring bathing.

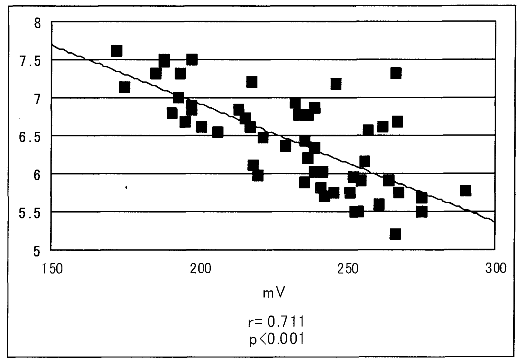


Fig.4 Relationship between urinary pH (Y axis) and ORP (X axis):
Urinary pH was negatively correlated with urinary oxidation reduction potential (ORP).

(1) sulfur spring. (2) bicarbonate salt spring. (3) tap water.

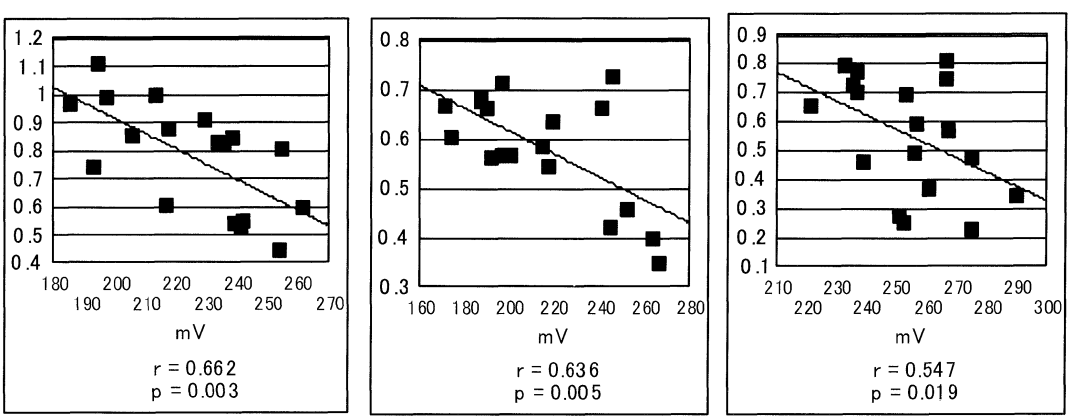
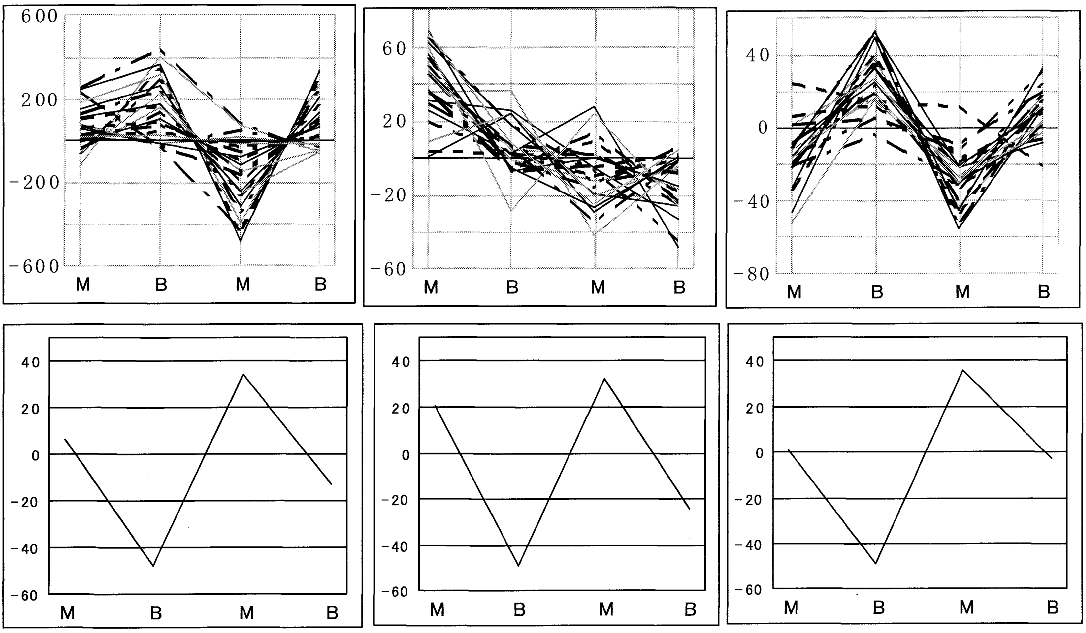


Fig.3 Relationship between urinary uric acid/creatinine ratio (Y axis) and ORP (X axis) :
Urinary oxidation reduction potential (ORP) was similarly negatively correlated with urinary uric acid/creatinine ratio for the three different kinds of bath.

were as follows; n=54, r=−0.711, and p<0.001. (Fig.4)

In many cases, ryodoraku current increased after two hours of sulphur spring bathing and decreased after two hours of tap water bathing. In all three groups, ryodoraku currents tended to fluctuate in an opposite manner to changes of ORP. When fluctuations of ryodoraku currents at 10.00, 12.00, 14.00 and 16.00 were compared to those of ORP, these changes were in the opposite direc-

(a) Sulfur spring group.



(b) Tap water group.

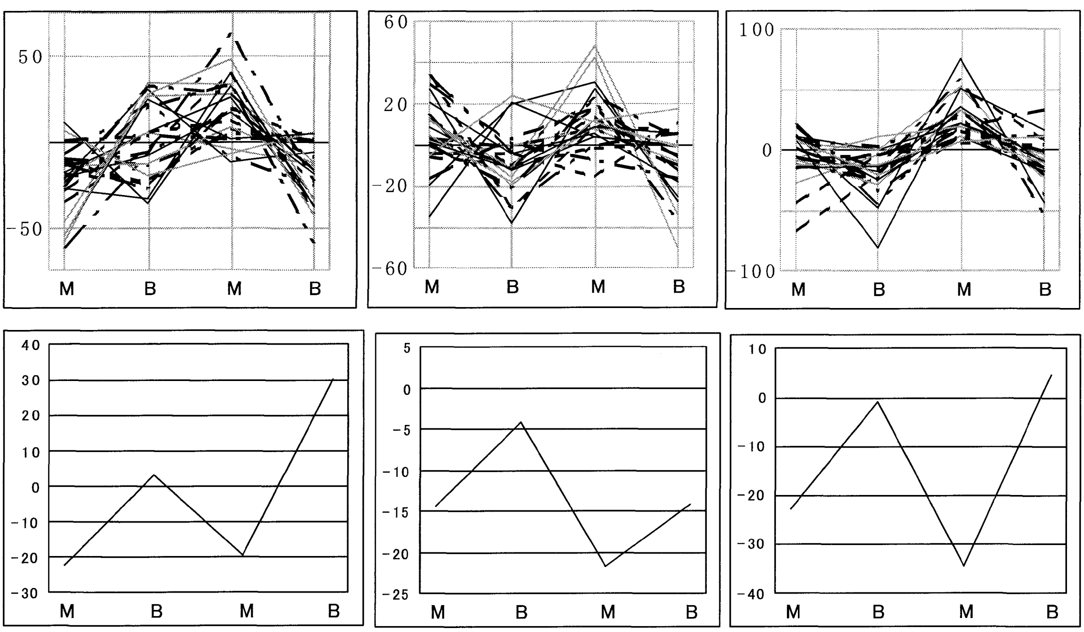


Fig.5 Cumulative graphs of differences between ryodoraku current (upper) and graphs of differences between ORP (lower) before and after each meal or bath.

M : meal, B: bathing. ORP = oxidation reduction potential. See the footnote for Table 2 for further details.

tions on 28 occasions and in the same direction in 8. (Fig.5)

In all three groups, changes in dermal humidity and body impedance appeared to be random; they were not related to changes in ryodoraku current. (Fig.6)

Ⅳ DISCUSSION

After two hours of bathing, ORP of urine reflected that of the bath water. This suggested that certain redox agents in bath water were absorbed transdermally and excreted in the urine for a short time. This in turn suggests that the epidermal cells were permeable to redox agents in the bath water and that ORP of the bath water rapidly affected ORP of the interstitial fluid. The redox agents in the various solutions used were hydrogen sulfide ions in sulfur spring water, bicarbonate ions in bicarbonate salt spring water and hypochlorite ions in tap water. These ions are reportedly easily absorbed through the skin[7].

Urinary ORP showed a significant negative correlation with urinary uric acid: creatinine ratio, suggesting that ORP of interstitial fluids influenced uric acid excretion, which is mediated by voltage-dependent uric acid transporters[8,9]. It was therefore considered that ORP of the interstitial fluid might affect the membrane potential of renal tubular cells.

Changes in ryodoraku currents after bathing were independent of skin humidity and body impedance. Ryodoraku currents were therefore considered not to be directly affected by sweat gland activity and to be epidermal rather than subdermal phenomena.

The epidermis usually has electrical resistance to low voltage direct current; this is caused by polarization of cell membranes[10]. When the cation channels of the cell membrane open due to any type of stimulation, depolarization of the cell membrane results and direct electrical current is able to flow into the epidermis from the voltage load. Since the ryodoraku current changed after bathing, it was assumed that the ORP of interstitial fluids affected the electrical potential of the epidermal cell membranes.

The epidermis usually exhibits a pH gradient from the acidic superficial layer to neutral deeper layer[11] and this gradient is maintained by Na+/H+ antiporters which are regulated by extracellular pH[12]. The pH of bathing water should therefore have very little direct effect on ryodoraku current through the epidermis.

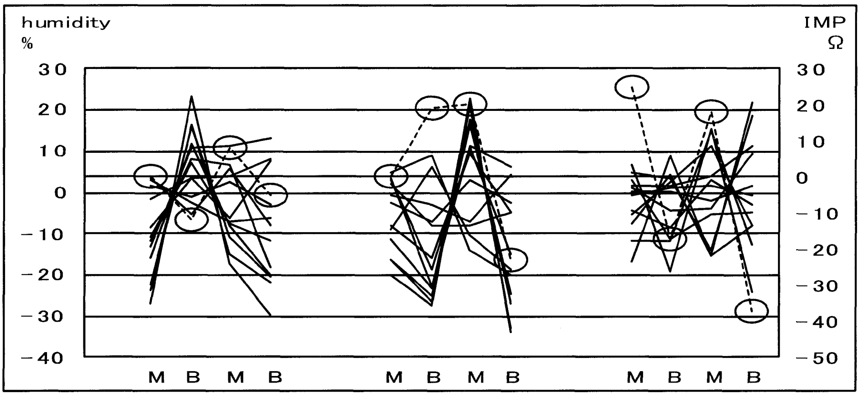
The formula for calculating ORP (Nernst equation) is as follows:

$$E=-RT/nF \cdot \ln(K) + (n-a)/n \cdot RT/F \cdot \ln([H+]) + RT/nF \cdot \ln([So]/[Sr]) \cdot \cdot \cdot (1)$$

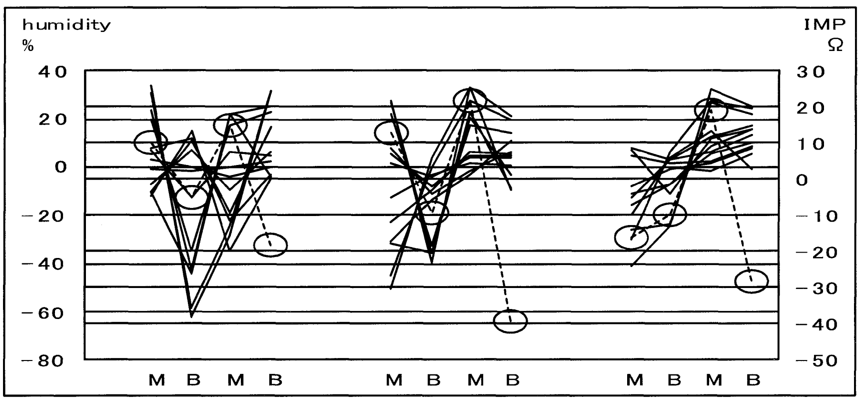
(R is the universal gas constant, T the temperature in Kelvin, a the chemical activity on the reduced and oxidized side, respectively, F the Faraday constant, K equilibrium constant, n the number of electrons transferred in the half-reaction, [So] the concentration of oxidizing agent, and [Sr] the concentration of reducing agent.)

If a redox agent opens even a few channels in the cell membrane, according to equation (1), it can add newly generated potential to the existing membrane potential. It was reported that administration of a large amount of ascorbic acid causes a decrease in serum uric acid[13], while a small amount of ascorbic acid does not[14]. Moreover, the ascorbic acid transporter has been detected in the human ovary[15]. Taken together, these results suggest that because ascorbic acid has a low ORP, it could

(a) Sulfur spring group.



(b) Bicarbonate salt spring group.



(C) Tap water group.

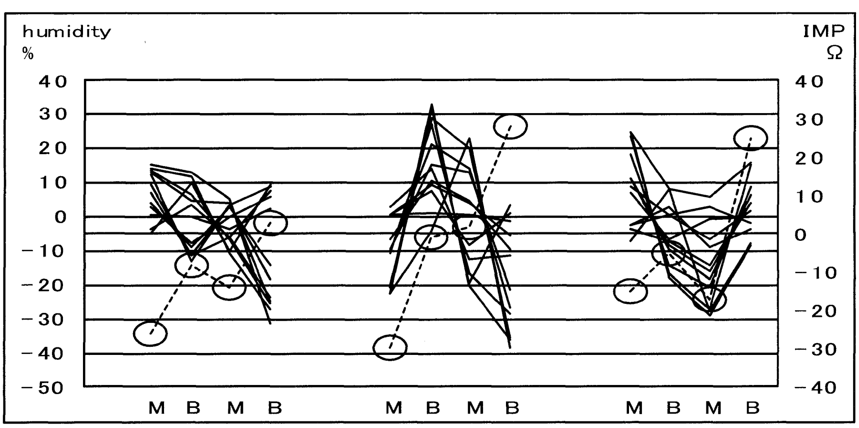


Fig.6 Cumulative graph of differences between skin moisture level before and after each meal or bath (solid lines) and differences between body impedance before and after each meal or bath (broken lines and circles).

M : meal, B: bathing. See the footnote for Table 2 for further details.

change the membrane potential of renal tubular cells according to the amount administered, causing uricosuria and subsequently hypouricemia.

In the present study, it appears that, because they caused changes in urinary ORP after bathing, redox agents in the bath water permeated the cell membranes. It is therefore likely that such agents could alter the membrane potential of renal tubular cells and cause fluctuation of uric acid excretion. Ryodoraku currents were also influenced by the ORP of interstitial fluid and are thought to relate to the membrane potential of epidermal cells. These findings suggest that the ORP of interstitial fluid appears to affect membrane potential in various tissues.

Urinary ORP and pH were negatively correlated. Moreover, it has been reported that ion current through voltage dependent Ca channels is similarly affected by an increase of membrane potential and by an elevation of extracellular pH[16]. We have previously found (findings not published) that at 2 hours after administration of 3 g of ascorbic acid, urinary pH decreased and urinary ORP increased if initial pH was over pH 6.0, while urinary pH increased and urinary ORP decreased if initial pH was below pH 6.0. These findings suggest that the relationship between ORP and pH that is described in equation (1) is actually observed in vivo. We therefore postulate that pH in the human body is not only chemically maintained by many mechanisms, but that it is also electrically buffered by ORP.

V CONCLUSIONS

Because ORP of bathing water altered uric acid excretion and ryodoraku current after bathing, and because urinary ORP was negatively and significantly correlated with urinary pH, ORP of bathing water appears to electrically influence the human body.

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Summary

Background: Spring water exhibits “aging”, characterized by increased oxidation reduction potential (ORP) and diminished therapeutic efficacy. However, the influence of spring water ORP on the body during bathing is unknown. Gout has been treated by spa bathing and by acupuncture, as well as pharmacologically. We accordingly examined the relationship between ORP and uric acid excretion, and that between ORP and ryodoraku current, which is closely related to acupuncture.

Design: Three groups of three volunteers each bathed in a different solution; sulphur-containing spring water, bicarbonate-containing spring water, or tap water. Serial changes in uric acid excretion and ryodoraku were measured.

Results: Urinary uric acid: creatinine ratio and ryodoraku current increased after sulphur spring water bathing and diminished after tap water bathing. Urinary ORP was negatively correlated with urinary uric acid: creatinine ratio and urinary pH. Ryodoraku current and urine ORP changed in opposite directions.

Conclusion: Bathing water ORP affected urinary ORP, urinary uric acid excretion, and ryodoraku current. Urinary ORP was assumed to reflect interstitial fluid ORP, suggesting that uric acid excretion and ryodoraku current were affected by interstitial fluid ORP. These findings appeared to indicate that ORP influenced cell membrane potential because voltage-dependent transporters or channels exist in the kidney and epidermis. Moreover, as urinary ORP was negatively correlated with urinary pH, ORP seemed to electrically buffer pH. As these findings can be explained by the Nernst equation by which ORP is derived, ORP of spring water might electrically influence the organism during bathing.

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