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The Effect of High-Salted Mineral Water on Blood Pressure and Sodium Excretion

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High-salted mineral water (Daehan Deep Water, Korea) that is pumped up from below the sedimentary rock layer of Dadaepo, Busan, Korea has a composition similar with that of deep sea water. Under the well-being boom, the mineral water is processed for various uses including washing or oral administration. However, high concentrations of various minerals in the mineral water are suspected to affect on the physiology of human body, especially on blood pressure (BP). Here, we examined the effect of Hot Mineral®, dried powder of the mineral water, on the change of BP. Sprague-Dawley rats were grouped and orally administered 2.5% Hot Mineral® (group M), 2.5% NaCl (group S) or normal water (group C). Excreted urine was collected in metabolic cage for 24 hours. The systolic blood pressure (SBP) of the group S was remarkably increased (P<0.005) compared with that of the group M and the group C, which showed little changes of the SBP during 2 weeks. While average daily sodium intake were 0.32 mg in the group C, 6.64 mg in the group M and 4.07 mg in the group S, average daily sodium excretion were 11.37 mg, 53.70 mg and 7.75 mg, respectively. These results indicate that the sodium excretion in the group M was much higher than the other two groups. In this study, we suppose that the plenty amount of minerals such as calcium, potassium and magnesium in Hot Mineral® have an effect not to increase the SBP and to prompt sodium excretion out of the body. Therefore, these results suggest that oral administration of appropriate amount of Hot Mineral® for limited period does not induce increased SBP.

Key Words: Mineral water, Blood pressure, Sodium excretion

INTRODUCTION

Deep sea water (DSW) is present at depths between 500~1,000 m and circulates around the world (Broecker, et al., 1985). Composition of the DSW mainly includes calcium, magnesium, sodium and potassium, of which the concentrations are not so different depending on geographical positions where it pumped up. It had been reported that oral administration of the DSW is effective on the prevention of atherosclerosis (Miyamura, et al., 2004), hyperlipidemia (Yoshioka, et al., 2003) and atopic eczema/dermatitis syndromes (Kimata, et al., 2002) with little or no harmful affect on hematological and serological parameters (Tsuchiya, et al., 2004). Commercial applications of the DSW to fermentation (Tsuchiya, et al., 2004), bakery (Kim, et al., 2003) and salting preservation (Lee, et al., 2003a; Lee, et al., 2003b) are also under investigation.

One of the most important considerations on oral administration of the DSW is the effect on blood pressure (BP). Sodium, one of main component of the DSW, increases systolic blood pressure (SBP) (Kwok, et al., 2003) and

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shows, as the result, quantitatively proportion to hypertension, stroke, myocardial infarction, congestive heart failure and end-stage renal disease (Hajjar and Kotchen, 2003). On the other hands, magnesium, calcium and potassium, other main components of the DSW, are proportional to decreased BP. Decreased calcium intake or increased urinary sodium/potassium ratio is proportional to increased SBP (Kwok, et al., 2003). By the high ratio of magnesium, calcium and potassium to sodium, the DSW results little or no influences on BP (Tsuchiya, et al., 2004).

High-salted mineral water (HSMW) that is pumped up at 1,050 m in depth from below the sedimentary rock layer of Dadaepo, Busan, Korea has a composition similar with that of the DSW. Differently from other underground fresh water, HSMW contains high concentrations of minerals such as magnesium, calcium, sodium, potassium, so that it had been evaluated as sea water-like deep water (Bae, 2003). We believe that HSMW also has physiological effects similar with that of the DSW because of various kinds of minerals in the HSMW. However, for the oral administration of the HSMW, the effect on increase in BP has to be investigated.

In this study, Sprague-Dawley (SD) rats were *ad libitum* fed on the HSMW and the short term changes of the systolic blood pressure (SBP) and salt metabolism were measured. Possible effects of the salts in the HSMW other than sodium on the downregulation of the SBP in the SD rats were discussed.

MATERIALS AND METHODS

1. Animals

Six week-old male Sprague-Dawley (SD) rats (body weight between 280~310 g) were purchased from Folas International (Korea) and reared in animal facility under the regulations for animal care of Wonju College of Medicine, Yonsei University. Temperature and humidity was controlled between 22~24℃ and 30~40%, respectively. Twelve hours light and dark cycle was maintained through this study.

2. Beverage supplementation

SD rats were randomly divided to three groups ($n = 8$ each), and *ad libitum* permitted to normal water (group C), 2.5% NaCl (group S) or 2.5% HSMW (Hot Mineral®, Daehan Deep Water, Korea; group M) for two weeks. Mineral compositions of the beverages were as described in Tables 1, which were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). The changes of volumes of each beverage were measured everyday 24 hours, which was defined as daily beverage consumption (DBC).

Table 1. Compositions of supplied beverages (unit: mg/l)

Component	Group C[a)]	Group M[b)]	Group S[c)]
Na	10.13	198.7	164.1
Mg	2.10	392	0.930
K	1.45	30.5	2.72
Ca	13.7	547	4.80
Mn	0.001	1.31	0.019
Fe	0.123	0.885	0.016
Cu	0.059	0.073	0.003
Zn	0.178	0.038	0.006

[a)] Group C: SD rats fed on normal water
[b)] Group M: SD rats fed on 2.5% HSMW
[c)] Group S: SD rats fed on 2.5% sodium chloride

3. Measurement of daily urine excretion (DUE)

On day 14 of beverage supply, the rats were independently housed in metabolic cages and excreted urines were collected for 24 hours. The volumes of urines were defined as DUE. Concentrations of minerals in the urines were analyzed by ICP-MS.

4. Measurement of systolic blood pressure (SBP)

SBP of rats was measured as described previously (Fraser, et al., 2001). SBP was recorded every week by the tail-cuff method (Narco Biosystems, USA). At least four consecutive cycles (inflation/deflation) were performed on each rat and the mean of the last four recordings, among which there was no more than 10 mmHg difference, was accepted as the SBP.

5. Statistics

The significances in difference between two groups were calculated by PRISM® version 2.0 (GraphPad, USA).

RESULTS

1. Daily beverage consumption (DBC) and daily urine excretion (DUE)

Until day 3 of the experiment, mean DBCs in the groups

Table 2. Daily beverage consume and daily urine excretion of SD rats

	Group C	Group M		Group S	
	Amount (ml)	Amount (ml)	Ratio to group C	Amount (ml)	Ratio to group C
Beverage	31.7±3.6	32.5±5.3	1.03	24.8±5.3	0.780
Urine[1)]	23.5±3.9*	25.1±3.0**	1.07	14.3±3.9	0.609

[1)] significantly different from that of the group S (*P<0.05; **P<0.01)

Table 3. Daily sodium intake and daily mineral excretion of SD rats

Minerals	Group C	Group M		Group S	
	Amount (mg)	Amount (mg)	Ratio to group C	Amount (mg)	Ratio to group C
Beverage					
Na	0.321±0.037	6.45±1.06	20.1	4.07±0.87	12.7
Urine					
Na	10.56±2.60	53.84±8.96***[a)]	5.10	7.72±2.04	0.731
Mg***[b)]	5.05±0.92	13.58±2.49	2.69	0.112±0.031	0.0222
K	65.80±9.03	74.06±14.36	1.13	32.48±7.20**[c)]	0.4936
Ca**[d)]	1.07±0.20	33.9±6.1	31.7	0.513±0.176	0.479

[a)] significantly different from those in groups C and S (P<0.005)
[b)] significantly different between each groups (P<0.005)
[c)] significantly different from those in groups C and M (P<0.01)
[d)] significantly different between each groups (P<0.01 except P<0.005 between groups C and M)

M and S were 7.78±0.63 and 12.1±9.1 ml, respectively, lower than that of the group C, 30.1±10.2 ml. However, after day 3, DBCs in the groups S and M were gradually increased and reached to that of group C. On day 14, mean DBCs of the groups C and M were 31.7±3.6 and 32.5±5.3, respectively, which were higher than that of the group S, 24.8±5.3 (Table 2). However, all three values were not statistically different. On the other hand, on day 14, DUEs in group C (P<0.05) and group M (P<0.01) were significantly different from that of group S. There was no difference between DUEs in groups C and M. The ratios of DBC and DUE of the group M to those of the group C were 1.03 and 1.07, while those of the group S were 0.780 and 0.609, respectively.

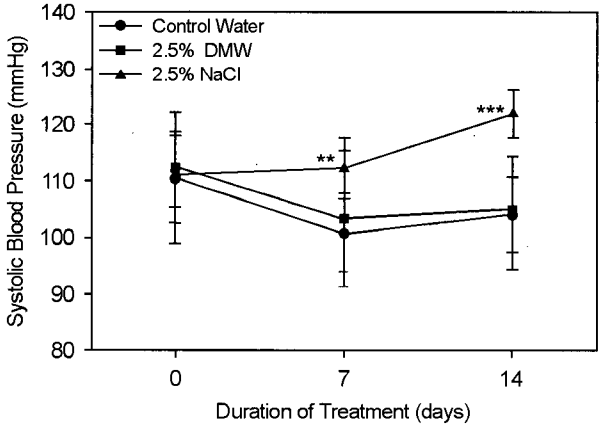

Fig. 1. Change of blood pressure of SD rats fed on normal water (circle), 2.5% KMW (rectangle) or 2.5% NaCl (triangle). Data was expressed as mean ± SD. **P<0.01; ***P<0.001.

2. Daily sodium intake and daily mineral excretion of SD rats

All mineral intake and excretion were calculated from concentrations of the minerals and volumes of the beverages and urine. Sodium intake in the groups M and S were 6.45±1.06 and 4.07±0.87 mg, which were 20.1 and 12.7 times higher than that of the groups C, 0.321±0.037 mg (P<0.005). However, daily sodium excretion (DSE) of the groups M was 53.84±8.96 mg, 5.10 times compared with that of the group S (P<0.005), while DSE of the group S was 7.72±2.04 mg, 0.731 times compared with that of the group S (statistically not significant). Profiles of the excretion of magnesium, potassium and calcium in groups M and S were clearly divided by those of the group C. Excretion of the minerals in the group M were higher compared with those of the group C, while those in the group S were lower compared with those of the group C. Especially, excretion of calcium in the group M was 61.8 times higher

compared with that of the group S. The significances of the differences were described in the Table 3.

3. Change of SBP

On day 0, SBP in the groups C, M and S were 110.6± 11.8, 111.8±6.4 and 110.6±8.1 mmHg, respectively (Fig. 1). On day 7, although SBP of the group S was 112.3±5.5, similar with that on day 0, the value was significantly higher than those of the groups C and M, 100.9±7.0 and 103.4±12.1 mmHg, respectively ($P<0.01$). On day 14, SBP of the group S was 122±4.5 mmHg and significantly different from those of the groups C and M, 104.1±6.6 and 104.4±10.0 mmHg ($P<0.005$). Although the mean SBP of the group C and M on days 7 and 14 were lower than that of on day 0, the differences were not statistically different.

DISCUSSION

In this study, we have proved that oral administration of the HSMW containing high concentrations of minerals to SD rats for 2 weeks does not significantly increase the SBP, meanwhile oral administration of 2.5% NaCl for same period significantly increase. This result implies that the minerals other than sodium in the HSMW have roles on the suppression of sodium-induced SBP increase. To prove this, we measured the amounts of minerals in the HSMW and urine related to the regulation of BP, and discussed the relation on the control of BP.

The HSMW used in this study was dried powder, which was dissolved in distilled water and supplied to SD rats in the group M. ICP-MS analysis of 2.5% HSMW showed that the concentrations of magnesium, calcium and potassium were relatively high compared with sea water, in which about 80% of cationic minerals are composed of sodium.

Volumes of investigations on the relation of mineral intake to hypertension had been reported. Dietary calcium is most outstanding mineral in the correlation to decreased BP across both sexes, all age groups, geographical area and ethnic and racial groups (McCarron and Reusser, 1999). Sufficient calcium supplementation suppresses BP caused by increased sodium intake. One of this reason is that calcium stabilizes the cell membranes and suppress the blood vessel contraction causing hypertension (Wuorela, et al., 1992). Lee *et al* (Lee and Hwang, 1993) had reported that high sodium intake without calcium supplementation possibly increases the BP, which is related to the mechanism of parathormones. Hormonal balances and BP are improved by the supplementation of high amount of calcium to the individuals who intake high amount of sodium (Park and Yoon, 2001).

In this study, SD rats in the group M that were supplemented with high amount of sodium as well as calcium, magnesium and potassium excreted 5.10 times higher amount of sodium compared with that in the group C, while the rats in the group S excreted lower amount. Furthermore, the amounts of calcium, magnesium and potassium in urine in the group M were also increased, while decreased in the group S. We suppose that co-ingestion of magnesium, potassium and calcium in HSMW clearly promoted the excretion of sodium in the SD rats. Most important mineral in sodium excretion was calcium. The amount of calcium in urine in the group M was especially 66.1 times higher than that of the group S. The amount of sodium excreted in the urine was larger than that in ingested HSMW. This imbalance is explained by that many kinds of minerals including calcium and potassium act for the excretion of sodium ingested from the HSMW or supplied chew.

In this study, we showed that supplementation of HSMW containing various kinds of high minerals for two weeks did not significantly increase SBP in SD rats. Authors believe that this result is caused by the effects of calcium, potassium and magnesium on the suppression of increased SBP and excretion of sodium. This study suggests that appropriate administration of HSMW does not significantly affect on the change of BP and that physiological mechanisms related to mineral metabolism should be elucidated in future.

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REFERENCES

Bae SJ, Report: Physiological effect of Daehan deep mineral water, 2003, pp.2-5, Marine-Bio Center, Silla Univeristy, Busan, Korea.

Broecker WS, Peteet DM, Rind D. Does the ocean-atmosphere system have more than one stable mode of operation? Nature 1985. 315: 21-26.

Fraser TB, Turner SW, Mangos GJ, Ludbrook J, Whitworth JA. Comparison of telemetric and tail-cuff blood pressure monitoring in adrenocorticotrophic hormone-treated rats. Clin Exp Pharmacol Physiol. 2001. 28: 831-835.

Hajjar I, Kotchen T. Regional variations of blood pressure in the United States are associated with regional variations in dietary intakes: the NHANES-III data. J Nutr. 2003. 133: 211 -214.

Kim M-L, Jeong J-S, Lee M-H, Lee G-D. Effects of deep seawater and salt on the quality characteristics of breads. Kor J Food Preservation 2003. 10: 326-332.

Kimata H, Tai H, Nakagawa K, Yokoyama Y, Nakajima H, Ikegami Y. Improvement of skin symptoms and mineral imbalance by drinking deep sea water in patients with atopic eczema/dermatitis syndrome (AEDS). Acta Medica (Hradec Kralove). 2002. 45: 83-84.

Kwok TC, Chan TY, Woo J. Relationship of urinary sodium/ potassium excretion and calcium intake to blood pressure and prevalence of hypertension among older Chinese vegetarians. Eur J Clin Nutr. 2003. 57: 299-304.

Lee G-D, Kim S-K, Kim J-O, Kim M-L. Comparison of quality characteristics od salted muskmelon with deep seawater salt, sun-dried and purified slats. J Kor Soc Food Sci Nutr. 2003a. 32: 840-846.

Lee G-D, Kim S-K, Lee H-A, Lee M-H, Kim M-L. Changes of qualit characteristics of radishes salted with deep seawater salt. Kor J Food Preservation 2003b. 10: 182-186.

Lee J-W, Hwang Y-S. Effects of dietary calcium levels on blood pressure and clacium metabolism in normotensive female young adults with the hypertension family history. Kor J Nutr. 1993. 26: 728-742.

McCarron DA, Reusser ME. Finding consensus in the dietary calcium-blood pressure debate. J Am Coll Nutr. 1999. 18: 398S-405S.

Miyamura M, Yoshioka S, Hamada A, Takuma D, Yokota J, Kusunose M, Kyotani S, Kawakita H, Odani K, Tsutsui Y, Nishioka Y. Difference between deep seawater and surface seawater in the preventive effect of atherosclerosis. Biol Pharm Bull. 2004. 27: 1784-1787.

Park J-A, Yoon J-S. The effect of habitual calcium and sodium intakes on blood pressure regulating hormone in free-livng hypertensive women. Han Gook Yung Yang Hak Hoei Ji. 2001. 34: 409-416.

Tsuchiya Y, Watanabe A, Fujisawa N, Kaneko T, Ishizu T, Fujimoto T, Nakamura K, Yamamoto M. Effects of desalted deep seawater on hematologic and blood chemical values in mice. Tohoku J Exp Med. 2004. 203: 175-182.

Wuorela H, Porsti I, Arvola P, Makynen H, Vapaatalo H. Three levels of dietary calcium-effects on blood pressure and electrolyte balance in spontaneously hypertensive rats. Naunyn Schmiedebergs Arch Pharmacol. 1992. 346: 542-549.

Yoshioka S, Hamada A, Cui T, Yokota J, Yamamoto S, Kusunose M, Miyamura M, Kyotani S, Kaneda R, Tsutsui Y, Odani K, Odani I, Nishioka Y. Pharmacological activity of deep-sea water: examination of hyperlipemia prevention and medical treatment effect. Biol Pharm Bull. 2003. 26: 1552-1559.