

Water and Electrolyte Metabolism of Korean Buddhist Nuns*

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= 國文抄錄 =

韓國女僧의 水分 및 電解質代謝*

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長期的인 菜食攝取가 人體의 水分 및 電解質代謝에 미치는 影響을 알아보기 위하여 젊은 女僧 45名 (20~34歲)과 對照群으로는 寄宿舍生活하는 女大生 28名(20~22歲)을 研究對象으로 하였다. 熱量攝取는 女僧들이 하루에 1947 kcal였고 女大生은 1815 kcal였다. 熱量構成 比率은 女僧들이 炭水化合物 : 蛋白質 : 脂肪 = 85 : 11 : 5였고 學生은 70 : 15 : 15였으며 이는 女僧들의 炭水化合物 偏重 및 脂肪攝取 不足을 보여준다. 身體計測 結果 女僧들이 女大生보다 身長은 낮은 反面, 體重 및 脂肪層두께는 높았다. 1日 尿量은 女僧들이 1,697±68 ml/day 로서 女大生の 1,505±67 ml/day 보다 有意하게 높았으며 (P<0.05), 尿滲透質濃度는 女僧이 617±18 mOsm/kg H₂O 로 學生의 688±36 mOsm/kg H₂O 보다 有意하게 (P<0.05) 낮았다. 그러나 두 實驗群사이에 尿中 Na⁺이나 K⁺의 排泄率에는 差異가 없었으며 尿中 尿素排泄率은 女僧群이 5.0±0.2 g/day 로서 女大生の 6.4±0.5g/day 보다 有意하게 (P<0.01) 낮았다. 女僧들의 free water clearance는 -1.82±0.08 ml/day 로서 女大生の -2.16±0.14 ml/day 보다 높았으나 (P<0.05) osmolar clearance는 差異가 없었다. 血清 creatinine濃度나 尿中 creatinine 排泄率은 兩群사이에 差異가 없었고 腎絲毬體 濾過率을 나타내는 creatinine clearance도 差異가 없었다. 1日 尿排泄量은 尿素排泄量 (r=0.42), Na⁺排泄量 (r=0.76)이나 osmolar clearance (r=0.57)와 有意한 相關關係가 있었으나, free water clearance (r=0.06)와는 有意한 相關關係가 없었다.

以上の 結果에서 女僧은 女大生보다 尿濃縮能力이 낮았으며 이는 女僧들의 低蛋白攝取로 因한 尿素, 代謝와 關係있음을 示唆해 주고 있다.

INTRODUCTION

Many studies have demonstrated that the renal concentrating ability is affected by dietary protein intake¹⁻⁵⁾. In the early 1960's, Hong and his associates reported that Koreans had lower urine concentrating ability than Westerners probably due to

low protein diet⁶⁻¹⁰⁾. Furthermore, salt intake of Koreans is known to be more than twice higher than that of Westerners^{11,12)}. Thus the urine excreted by Koreans has greater salt but lower urea concentrations than the Westerners. However, the renal plasma flow or glomerular filtration rate of Koreans was the same as Westerners⁷⁾. Since the Buddhist nuns are vegetarians with a peculiar food habit, their body water and electrolyte metabolism as well as other physiological functions would be different from the ordinary women. However, little study has been conducted on them.

The present study is attempted to analyze dietary intake and metabolism of fluid and electrolytes of young Buddhist nuns.

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MATERIALS AND METHODS

Buddhist nuns at the Unmoonsa Temple in Kyungpook Province and female nursing students staying in the dormitory at Kyungpook Medical School were studied in the Fall, 1981. Among approximately 150 Buddhist nuns in the temple, 45 volunteer subjects aged 20 to 34 years who had been Buddhist nuns over 5 years were studied. The Buddhist nuns are under the strict dietary regulation of no animal products except milk.

Participants provided detailed medical and social histories. Weight, height and skin-fold thicknesses at the back of the left arm and supra-iliac area were measured. A detailed 24-hour dietary recall interview was conducted for 2 days to get the quantitative data on daily consumption of the specific nutrients, total caloric intake and meal pattern. The contents of carbohydrate, protein and lipid, and their caloric values in the diet were calculated on the basis of food composition tables in the "Recommended Daily Allowances of Koreans" compiled by the Korean branch of FAO¹³⁾. The 24-hour urine samples were collected in the presence of boric acid, and 20ml aliquot of the sample were frozen until analysis after measuring the urine volume. Urinary concentrations of Na⁺ and K⁺, and

osmolality were measured with flame photometer (Beckman), and osmometer (Precision) by the method of freezing point depression, respectively. Creatinine and urea were determined by the Jaffee reaction¹⁴⁾ and by the enzymatic method¹⁵⁾, respectively.

Urinary excretion rates (Ex) of electrolytes or creatinine, osmolar clearance (Cosm) and free water clearance (C_{H2O}) were calculated according to the following equations.

$$Ex = \dot{V} \cdot U_x \quad (\dot{V}: \text{Urine volume/day})$$

$$(\quad U_x: \text{Urine concentration of } x)$$

$$Cosm = \frac{\dot{V} \cdot U_{osm}}{P_{osm}} \quad (P_{osm}: \text{plasma osmolality})$$

$$C_{H_2O} = \dot{V} - Cosm$$

RESULTS

Physical characteristics and nutrient intake are shown in Table 1 and 2, respectively. The Buddhist nun showed significantly higher values of body weight, skin-fold thickness at the supra-iliac region and body surface area except height than the female students. Total caloric and carbohydrate intakes of the Buddhist nuns were higher than those of the students. However, the amount of protein and fat intake of the Buddhist nun was significantly lower than those of the students. Rice was the main source of protein, carbohydrate and caloric intakes for the Buddhist nuns.

Table 1. Physical characteristics of young Buddhist nuns (BN:20-34 yrs) and students (20-22 yrs)

	n	Height	Weight	Skinfold Thickness		Body surface
		cm	kg	Back arm	Supra-iliac	area m ²
BN	45	154±0.7**	53.4±0.9**	1.51±0.04	1.28±0.01**	1.5±0.03**
Students	28	158±0.8	48.5±0.6	1.53±0.06	0.92±0.06	1.2±0.11

Mean±S.E. **P<0.01, Buddhist nuns vs. students.

Table 2. Average daily nutrient intake of young Buddhist nuns (BN:20-34 yrs) and students (20-22 yrs)

	n	Energy	Carbohydrate	Protein	Fat	Carbohydrate	Protein	Fat
		Kcal/day	g/day	g/day	g/day	%Cal	%Cal	%Cal
BN	45	1947±95	427±25.6**	53.7±3.1**	10.6±1.2**	85.1±3.7**	11.0±1.8**	4.9±0.8**
Students	28	1815±173	329±28.4	71.2±3.2	29.8±4.0	69.6±3.1	15.6±2.4	14.8±1.2

Mean±S.E. **P<0.01, Buddhist nuns vs. students.

Table 3. Urine flow (\dot{V}), urine osmolality (Uosm), and osmolar (Cosm), free water (C_{H_2O}), and creatinine (Ccr) clearances of young Buddhist nuns and female students

	Buddhist Nun				Student	
	Age:	20~24	25~29	30~34yr	Total	20~22yr
\dot{V} , ml/day		1751±97*	1658±95	1651±154	1697±68*	1505±67
Uosm, mOsm/kg H ₂ O		637±36	613±21	572±18**	616±18*	688±36
Cosm, L/day		3.64±0.20	3.48±0.19	3.26±0.28	3.50±0.12	3.65±0.17
C_{H_2O} , L/day		-1.92±0.15	-1.81±0.11*	-1.61±0.14**	-1.82±0.08*	-2.16±0.14
Ccr, ml/min (n)		85.2±3.79 (19)	84.5±4.21 (19)	78.5±13.09 (7)	84.1±2.89 (45)	92.3±4.52 (20)

Values are Mean±S.E. *P<0.05, **P<0.01, Buddhist nuns vs. students.

Table 4. Renal solute excretions and serum concentration of creatinine (Scr) for young Buddhist nuns and female students

	Buddhist Nun				Student	
	Age:	20~24	25~29	30~34yr	Total	20~22 yr
Uosm \dot{V} , mOsm/day		1048±55	1002±19	939±18	991±21	1022±48
$U_{Na} \dot{V}$, mEq/day		304.8±22.6	293.1±19.3	278.9±36.2	292.0±11.8	281.9±22.6
$U_K \dot{V}$, mEq/day		53.9±4.2	52.1±4.0	46.8±8.6	51.2±2.3	51.6±3.9
U_K / U_{Na}		0.18±0.01	0.18±0.01	0.16±0.01*	0.18±0.01	0.23±0.03
$U_{ur} \dot{V}$, mg/day		5051±262**	4940±296**	4286±607**	4972±193**	6389±510
$U_{ur} \dot{V}$, mOsm/day		87.4±4.4**	82.2±4.9**	71.4±10.1**	82.7±3.2**	106.4±8.5
$U_{cr} \dot{V}$, mg/day		1032.2±29.1	1048.3±39.3	956.8±66.9	1028.9±22.8	1118.9±89.4
Scr, mg/dl (n)		0.86±0.026 (19)	0.88±0.025 (19)	0.86±0.057 (7)	0.872±0.017 (45)	0.862±0.025 (20)

Values are Mean±S.E.

*P<0.05, **P<0.01, Buddhist nuns vs. students.

$U_x \dot{V}$: urinary excretion of solutes (ur:urea, cr:creatinine).

Table 5. Correlation coefficients between urine output (\dot{V}) and Na excretory rate ($U_{Na} \dot{V}$), osmolar and free water clearances (Cosm, C_{H_2O}), or urea excretory rate ($U_{ur} \dot{V}$) in Buddhist nuns (BN: 20~34yrs) and students (20~22 yrs)

		$U_{Na} \dot{V}$	Cosm	C_{H_2O}	$U_{ur} \dot{V}$
\dot{V}	BN	0.76**	0.57**	0.06	0.42**
	Students	0.41**	0.49**	0.03	0.56**

**P<0.01

Table 3 and Fig. 1 show the urine flow and renal clearances. The Buddhist nuns excreted significantly higher daily urine output (1,697±68 ml/day) but lower urine osmolality (616±18 mOsm/kgH₂O) than the students(1,505±67 ml/day, 688±36 mOsm/kg H₂O). Different age groups of the Buddhist nuns

showed no difference in urinary variables. Osmolar clearance was not different between the two groups. However, free water clearance of the Buddhist nun was significantly higher than that of the students (-1.82±0.08, -2.16±0.14 ml/day, respectively p<0.05). Table 4 and Fig. 2. show renal solute ex-

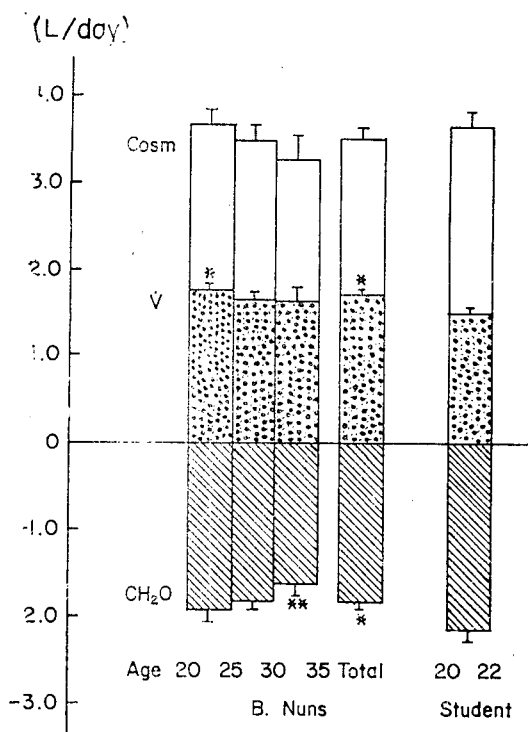


Fig. 1. Urine flow (\dot{V}), osmolar clearance (C_{osm}) and free water clearance (C_{H_2O}) of Buddhist nuns and female students.

cretions. Both groups excreted similar daily amount of Na^+ , K^+ and total osmolar contents in the urine and showed similar urine K^+ to Na^+ ratio. Daily urinary urea excretion was significantly higher in the Buddhist nuns than in the students (6.4 ± 0.5 and 5.0 ± 0.2 g/day, respectively, $p < 0.01$). The two groups showed similar values of serum concentration of creatinine, daily urinary excretion of creatinine and creatinine clearance which is an index of glomerular filtration rate. There were significant correlation (Table 5) between urine flow and Na^+ excretion ($r = 0.76$), osmolar clearance ($r = 0.57$, Fig. 3) and urea excretion ($r = 0.42$).

DISCUSSION

The Buddhist nuns excreted significantly higher volume of urine with lower osmolality than the female students to excrete same amounts of Na^+ or total osmolar contents (Table 3). In early 1960's

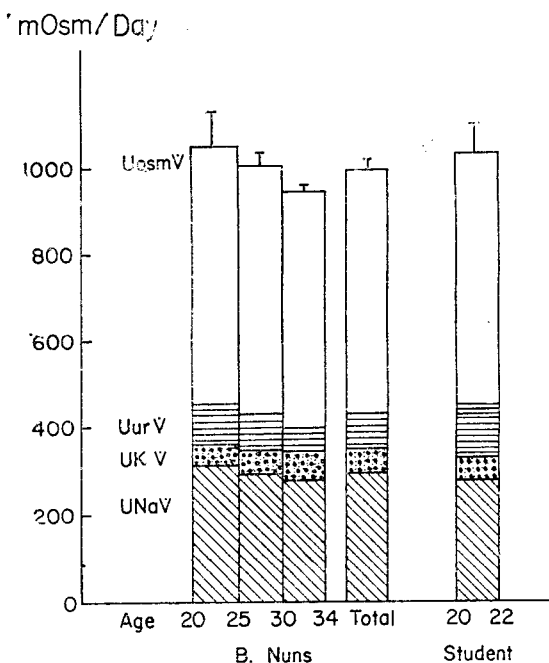


Fig. 2. Patterns of urinary solute excretion in Buddhist nuns and female students. $U_{osm}V$: Total osmolar excretion, $U_{ur}V$: Urea excretion, $UNaV$: Sodium excretion, UKV : Potassium excretion.

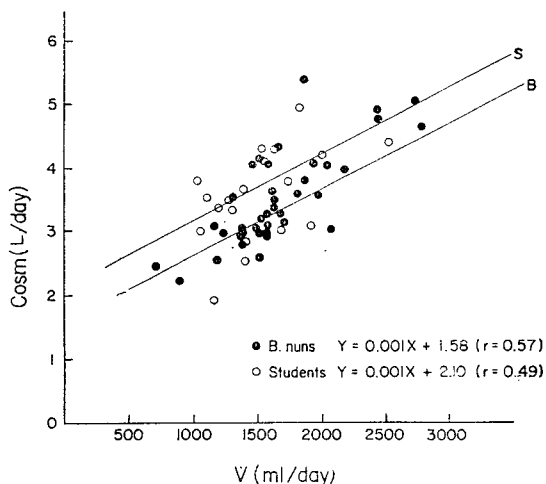


Fig. 3. Correlation between urine flow rate (\dot{V}) and osmolar clearance (C_{osm}) in Buddhist nuns and female students.

it was reported that Koreans had lower renal concentrating ability than the occidentals most likely due to low protein intake⁶⁻¹⁰). It has long

been recognized that urea, the end product of protein metabolism, is essential to the achievement of maximum urinary osmolality for many mammalian species since 1930's^{1~5)}. When high protein diet⁸⁾ or urea⁶⁾ was given to men or protein deficient animals, respectively, urinary osmolality and urea concentration was elevated without much changes in electrolyte excretions. The present results are in good agreement with above reports. That is, the Buddhist nuns took very low protein diet (Table 2), and excreted significantly low amount of urea and diluted urine compared with the female students obtaining sufficient protein intake. Although the urine flow rate of the Buddhist nuns were high, the daily excretion of Na^+ was the same with that of the female students. This result is also in agreement with Kim et al.⁷⁾ that urinary salt excretion was not affected by either the protein intake or the urinary concentrating ability.

Average daily salt intake of Koreans is known to be approximately 20 g (342 mEq of Na^+) which is more than twice of the Westerners^{11,12)}. Daily amount of Na^+ excreted by the Buddhist nuns and students (292 ± 12 , and 282 ± 23 mEq/day, respectively) were similar to that excreted by young Korean men reported by Sung¹²⁾ (277 ± 30 mEq/day) which suggests that Na^+ intakes in both studies were similar. However, K^+ output and the urinary K^+/Na^+ ratio in the present study were higher than the results of Sung. The urinary K^+/Na^+ ratio has been used as an index of aldosterone activity^{12~14)}. Laragh et al.^{17,18)} demonstrated that aldosterone secretion in Americans was inversely proportional to urinary Na^+ output and was proportional to the urinary K^+/Na^+ ratio, but this relationship no longer exist when the urinary Na^+ output exceeds 200 mEq/day. Same phenomenon was demonstrated in Koreans but Koreans excrete significantly higher Na^+ and lower urinary aldosterone than Americans^{11,12)}. Since the Na^+ output in the present study was much higher than 200 mEq/day, urinary K^+/Na^+ probably is not an accurate index of aldosterone activity. Both

groups showed significant correlation between urine output and Na^+ excretion ($r=0.76$), and osmolar clearance ($r=0.57$). Since the amount of Na^+ excreted into urine is proportional to Na^+ intake, the result suggests that higher salt intake produces more natriuresis accompanied by elevated osmolar clearance.

The Buddhist nuns showed higher urine flow and less negative values of free water clearance but no difference in osmolar clearance than the female students. This indicates that the Buddhist nuns excreted larger volume of urine than the students by increasing the free water clearance, but not by increasing osmolar clearance. The value of free water clearance is determined by the amount of water reabsorbed from the collecting tubule which in turn is determined by the amount of antidiuretic hormone (ADH) present^{23,21)} and medullary osmotic gradient¹⁹⁾. When present, ADH permits osmotic equilibrium to occur between fluid in the collecting tubule and the hyperosmotic medullary interstitium, almost half of which is made up of urea, and produces concentrated urine. Thus, diluted urine is formed either in the absence of ADH or low osmolality due to urea depletion in the renal medullary interstitium. Actually low protein diet impairs the urine concentrating ability, and high protein diet or urea administration to a protein deficient animal restores the impaired urinary osmolality^{1~5)}. In the present study, both urinary concentration of urea and osmolality of the Buddhist nuns were significantly lower than those of the students. This result indicates that the reduced renal concentrating ability of the Buddhist nuns is at least in part a result of their low protein intake. The possible involvement of ADH in low concentrating ability of the Buddhist nuns has to be investigated.

SUMMARY

The relationship between water and electrolyte metabolism, and dietary intake were studied in 45 healthy Buddhist nuns who were vegetarians aged

20-34, and 28 nursing students aged 20-22 who stayed at the dormitory of Kyungpook Medical School in the Fall, 1981. The Buddhist nuns obtained significantly higher carbohydrate and total caloric intakes but significantly lower protein and lipid intakes than the female students. The Buddhist nuns excreted significantly higher urine output ($1,697 \pm 68$ ml/day, $p < 0.05$) and lower osmolality (616 ± 18 mOsm/kg H_2O , $p < 0.05$) than the students ($1,505 \pm 67$ ml/day and 688 ± 36 mOsm/kg H_2O). However, both groups excreted similar amounts of urinary Na^+ , K^+ and total osmolar contents. Free water clearance of the Buddhist nuns was higher ($p < 0.05$) than that of the students but the osmolar clearance was about the same in the two groups. Daily urine output showed good correlation with Na output ($r = 0.76$) and osmolar clearance but not with free water clearance. Both groups showed similar values of plasma concentration of creatinine, daily excretion of creatinine and clearance. Urinary excretion of urea for Buddhist nuns was 6.4 g/day, and was significantly higher than that of the students (5.1g/day).

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