The Stability of Iodine in Human Sweat

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Abstract The relation between the sweat iodine loss and the urinary iodine excretion was studied on 13 physically active male athletes. There were no statistical differences between the sweat iodine concentrations before and after high iodine food intake, no difference between those before and after 1-h strenuous exercise, or no difference between those of the goitrous and the non-goitrous. These results indicate that the sweat iodine concentration is quite steady and the total iodine loss per day seems to be directly related to the volume of the sweat lost in each subject. The concentration variation of sweat iodine among individuals is small. The mean concentration of 13 athletes during 8 consecutive days was about $37 \pm 6.6 \mu\text{g/l}$. By comparing the iodine concentration of urine and sweat, the iodine concentration of sweat seems to be more stable than that of urine. The results indicated that the urinary iodine excretion plays a regularity role for iodine balance in the body and that iodine appeared to be an essential constituent of sweat.

Key words: stable iodine excretion, human sweat.

Administered iodine is rapidly excreted mainly in urine and in small quantities in saliva, milk (SACK *et al.*, 1977), sweat (CONSOLAZIO *et al.*, 1966; SUZUKI and TAMURA, 1985), bile and feces (VOUGHT *et al.*, 1963). Urinary excretion of iodine fluctuates from day to day according to the plasma iodine concentration and iodine in food intake (FOLLIS *et al.*, 1962). This phenomenon is due to the fact that the renal iodine clearance rate is constant (STANBURY and HETZEL, 1980). Heat loss of the human body is enhanced by perspiration at high ambient temperature or during heavy exercise. A series of observations on sweat iodine and urinary iodine were made to compare the nature of sweat iodine with that of urinary iodine.

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SUBJECTS AND METHODS

All 13 male volunteers were students of a high school in Taipei, Taiwan, with an age range of 16–18 years and with no history related to any goiter problem, ascertained by inquiry. The group consisted of well-trained soccer team players who had been trained intensely for 6 months prior to this study. Their routine training session was 2:30–5:30 P.M. 5 times/week, exclusive of Saturday and Sunday. The soccer players were fully informed of the objectives, procedures, and requirements for this study.

The players took a self-selected identical daily diet during each day of the study period. No high-iodine food was supplemented in the first 4 days, but 3 g of processed seaweed containing about 200 μg of iodine was supplemented daily (about 6:00 P.M.) starting from Saturday in the subsequent 6 days after every training session. Sweat and urine samples were collected during the first 4 days and the last 4 days.

The urine and sweat samples were collected (about 3:00 P.M.) after the players underwent 30 min of pre-exercise training. Then after a 1 h training game, sweat samples were collected again.

Sweat collections were performed in a small room near the athletic ground. Windows and doors were closed to keep the room temperature in the range of 32–37°C, air movement below 0.1 m/s, and relative humidity 30–50% during the experimental period.

The subjects' back and chest were thoroughly washed with deionized water and dried with the sterilized iodine-free towels before the collections of sweat samples. The newly appeared sweat was collected with a special plastic collector with a dimension of 15 cm (length) $\times$ 9 cm (width) $\times$ 2 cm (height). In order to collect the sweat from the chest and back very quickly, we used neither filter paper (PILARDEAU *et al.*, 1988) nor macroduct (WEBSTER and BARLOW, 1981). Sweat (5–10 ml) was collected from each subject within 5 min by softly placing this collector in contact with the skin of the chest and back, letting the sweat drip into the collector. This procedure was repeated until enough sweat was obtained. The sweat could be obtained easily in the above-mentioned room immediately after exercise. The collected sweat sample was then transferred to a 20 ml plastic tube, and 1 drop of toluene was added as preservative.

The Folin-Wu method (BONSNES and TAUSKY, 1945) was adopted to determine the urine creatinine. The total iodine in sweat and that in urine were determined by the modified Benotti method (BENOTTI and BENOTTI, 1963). Urinary iodine was shown as μg iodine per g creatinine ($\mu\text{g I/g Cr}$).

Body weight loss was determined by calculating the difference in nude body weight taken before and after the training game. No fluid replacement was provided during each experimental session. The accuracy of platform balance was ± 20 g.

The goiter was measured with the method developed by PEREZ *et al.* (1960), which was recommended by WHO; the method is based on a "grading" of the size

of goiter into four categories. The results were designated as follows: cases with no goiter (grade 0); cases with palpable goiter with the head in normal position and readily visible with the head thrown back (grade I); cases with a visible goiter (grade II); and cases with a very large goiter (grade III). The examination was conducted with the subject's head in the normal position and then with the neck extended, while the subject and examiner remained standing, with the front of the subject's neck well exposed to the light. The examiner then palpated the thyroid area with his right forefinger.

Experimental data were analyzed by the method of "*F* test for mean difference" or "*F* test for homoscedasticity."

RESULTS

Table 1 shows the comparison of the iodine levels in the sweat samples collected from each subject before and after seaweed intake period. The average sweat iodine concentrations of the subjects in the two periods were 37.0 and 36.7 $\mu\text{g/l}$ with the coefficient of variance (%CV) 17.8 and 21.5%, respectively. "*F* test for mean difference" indicated that there was no significant difference of sweat iodine levels between the two periods ($p > 0.05$).

The urinary iodine levels of the subjects during no-seaweed- and seaweed-intake periods are shown in Table 2. The average urinary iodine level was 57.1 $\mu\text{g I/g Cr}$ with no seaweed intake and 108.5 $\mu\text{g I/g Cr}$ with seaweed intake, and the average

Table 1. Sweat iodine level in the soccer team players.

Subject	No seaweed intake (4 days) ($\mu\text{g I/l}$)	Seaweed intake (4 days)* ($\mu\text{g I/l}$)
M	39.8 (11.5)	43.1 (12.6)
N	42.1 (8.5)	51.9 (25.0)
O	28.7 (26.4)	29.4 (9.0)
P	28.6 (15.6)	26.9 (26.8)
Q	38.1 (2.7)	30.1 (17.8)
R	41.4 (3.7)	40.0 (6.8)
S	37.2 (28.5)	30.0 (2.6)
T	24.9 (22.0)	27.7 (8.9)
U	44.1 (11.1)	43.9 (12.5)
V	41.2 (8.6)	39.4 (19.0)
W	35.7 (22.5)	37.0 (29.4)
X	32.4 (13.7)	32.5 (19.1)
Y	46.5 (4.1)	45.4 (7.2)
Average	37.0 (17.8)	36.7 (21.5)

Values shown as mean (% coefficient of variance). * $p > 0.05$ from corresponding no seaweed intake.

Table 2. Urinary iodine level in the soccer team players.

Subject	No seaweed intake (4 days) ($\mu\text{g I/g Cr}$)	Seaweed intake (4 days)* ($\mu\text{g I/g Cr}$)
M	39.6 (56.0)	123.9 (28.0)
N	101.9 (42.5)	213.4 (14.4)
O	49.5 (44.3)	112.8 (20.9)
P	66.3 (23.8)	133.5 (21.4)
Q	57.7 (21.6)	56.3 (15.4)
R	59.9 (57.1)	130.6 (36.2)
S	110.4 (23.0)	113.0 (42.9)
T	8.7 (23.2)	67.4 (14.2)
U	51.7 (32.0)	77.4 (70.5)
V	43.0 (68.1)	50.9 (26.4)
W	21.4 (30.4)	87.8 (9.3)
X	70.9 (40.0)	135.4 (15.0)
Y	61.3 (19.0)	107.8 (18.7)
Average	57.1 (48.9)	108.5 (39.7)

Values shown as mean (% coefficient of variance). * $p < 0.01$ from corresponding no seaweed intake.

of %CV was 48.9 and 39.7%, respectively. There was significant difference between the urinary iodine levels of the subjects in these two periods ($p < 0.05$). It shows that the urinary iodine level significantly increased after seaweed intake.

Because the units of iodine concentrations in the samples of urine and sweat were different, data (Tables 1 and 2) were transformed to the same scale to compare the variance of iodine concentrations in sweat and urine. From the results of F test for homoscedasticity of iodine concentration between urine and sweat, the difference of distribution was statistically significant ($p < 0.05$ and $p < 0.01$) in the periods before and after seaweed intake for the 13 subjects.

Changes of sweat and urinary iodine levels in no-seaweed- and seaweed-intake periods are illustrated for six subjects selected randomly (Fig. 1). The same pattern was seen in the remaining subjects studied. The urinary iodine level fluctuated in the eight observed days, with the coefficient of variance of urinary iodine ranging from 9.3 to 70.5% for all 13 subjects. On the contrary, the sweat iodine concentration remained steady from day to day in all the subjects, with the coefficient of variance ranging from 2.6 to 29.4%.

The mean sweat iodine concentrations of soccer players before and after a 1-h training game were 33.91 ± 1.55 (mean $\pm$ S.E.) and $32.80 \pm 1.62 \mu\text{g/l}$ (mean $\pm$ S.E.), ($p > 0.05$), respectively (Fig. 2). The mean body weight loss of the soccer players during the 1-h game period was about $1.54 \pm 0.57 \text{ kg}$ (mean $\pm$ S.E.). The mean sweat loss was estimated to be 1.54 l (specific gravity of sweat = 1.002). Excluding the goal keeper (with weight loss of $0.25 \pm 0.04 \text{ kg}$), the sweat loss ranged from 1.16 to 2.55 l.

Fig. 1. The variation of iodine levels in the sweat and urine samples in 6 subjects during seaweed-intake (first 4 days) and no-seaweed-intake period (last 4 days). Urine (Cr.) = μg iodine/g creatinine.

Therefore, no significant change in the sweat iodine concentration was found after 1.54 kg loss of sweat.

Six of the 13 soccer players were found to have goiter grade I, and five had urinary iodine level lower than $50 \mu\text{gI/g}$ creatinine in the no-seaweed-intake period. The mean sweat iodine levels of the goitrous and the non-goitrous in the soccer team group were 38.9 ± 7.8 (mean $\pm$ S.E.) and $35.4 \pm 5.5 \mu\text{g/l}$, respectively; the mean urinary iodine levels were 47.4 ± 32.9 (mean $\pm$ S.E.) and $65.4 \pm 22.0 \mu\text{g I/g Cr}$

Fig. 2. Correlation of sweat iodine concentration between pre- and post 1-h training game. Paired *t*-test, $p > 0.05$ from corresponding pre- and post 1-h training game value.

Table 3. The goiter prevalence and the iodine level in sweat and urinary samples.

Group	Goiter	No.	Conc. of sweat iodine (µg I/l)	Conc. of urine iodine (µg I/g Cr)
Soccer team (<i>n</i> = 13)	(+)	6	38.9 (7.8)*	47.4 (32.9)*
	(-)	7	35.4 (5.5)	65.4 (22.0)

Values shown as mean (S.E.M.) of iodine level in the 4 days no-seaweed-intake period.
 * Not statistically different from the non-goitrous; $p > 0.05$.

(mean $\pm$ S.E.), respectively (Table 3). These results indicated that the sweat and urinary iodine levels of these two groups were not significantly different ($p > 0.05$).

DISCUSSION

With the Perez method, 6 out of the 13 players (46%) were diagnosed to be

goitrous. If judged with the Follis's method (FOLLIS, 1964), the group had a remarkably high prevalence of iodine deficiency. This shows the consistency of the results obtained from both methods. Similar to that reported by VOUGHT *et al.* (1963), the urinary iodine excretion fluctuated significantly and increased remarkably after iodine intake. These findings show that the urinary iodine excretion functions as a safety valve in the regulatory mechanism.

There was no significant difference between the sweat iodine levels of the subjects 1) before and after supplemental seaweed intake, 2) pre- and post-exercise, 3) the goitrous and the non-goitrous. It is apparent that the sweat iodine concentration was more steady than urinary iodine concentration, although urinary iodine levels of the goitrous and non-goitrous were not significantly different in this study group. Furthermore, the sweat iodine level had no association with the quantity of iodine intake or urinary iodine excretion for the subjects. These results indicate that there is little variation in sweat iodine concentration. The steadiness of sweat iodine concentration during intensive exercise activity seems to show the necessity of iodine as a constituent of sweat or as an important role of iodine in sweat formation.

Newly excreted sweat (5–10 ml) was collected only in 5 min. The amount of evaporating sweat could have been neglected. Since we did not examine sweat iodine level when iodine-free food had been taken, the steadiness of this condition has not yet been confirmed in this study.

The turnover rate of iodine in urine and sweat after a single dose of supplemented seaweed containing 200 μg of iodine was made in this study (data not shown); the result showed that sweat iodine level remained steady at any time after seaweed intake in a day; thus, sampling time of sweat should not be a great concern. Urinary iodine level increased to a peak level (750 $\mu\text{g I/g Cr}$) 5 h after seaweed intake, decreased rapidly to a lower level (among 200–350 $\mu\text{g I/g Cr}$) 7 h after seaweed intake, and remained at this lower level for the rest of the sampling period.

This lower level of urinary iodine of the soccer players in the seaweed-intake period was still significantly higher than that of the period with no seaweed intake. Therefore, we believe that the urinary iodine level in the seaweed-intake period is higher than that of the period with no seaweed intake for the whole period of the testing.

KEATING and ALBERT (1948) stated that when radioactive iodine was administered by mouth to subjects, the rate of absorption was of the order of 5%/min. At this rate, the absorption would be 90% complete in 45 min, and 99% complete in 90 min; the fate of iodine during the first hour or two after administration is obviously not too important.

SUZUKI and TAMURA (1985) reported that serum iodine level is related to the supplementary iodine intake, but had no relation to the sweat iodine level. The rate of excretion of iodine by the kidney (E) is determined by the plasma iodine level (I) and renal plasma clearance of iodine (C), with the equation $(E) = (I) \times (C) \times 1.44$;

but the iodine is collected by the thyroid gland (by the regulation of thyroid-stimulating hormone) and excreted by the kidneys. Therefore, the iodine pool of plasma is very complicated and it has not been proven to be a measurement of any clinical usefulness.

Our finding might have some value for understanding goiter and for substantial improvement in preventing the occurrence of simple goiter in people who have enough iodine intake but profuse perspiration. It might be of further value in determining the relationship between calorogenic function of thyroxine and heat prostration, because some symptoms of heat prostration are similar to the symptoms of hypothyroidism (WYNGAARDEN and SMITH, 1988).

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