Nutritional Potassium Status of Healthy Adult Males Residing in the Rural Northeast Thailand

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Abstract

Sixteen villages from rural areas of 8 provinces in the northeastern region of Thailand were randomly selected as study sites. Data on potassium (K) contents in 24-hour urine and serum samples of 93 healthy adult volunteer males aged 20-50 years old were completely collected and covered all 3 seasons of the year. The method of direct weighing of food was used to assess K intake in 13 subjects. K loss through sweat during working (9 hours) in the field was measured in 14 subjects by soaking their worn-clothes in distilled water after which K contents were measured by the flame photometry method. The results showed that the means urinary K excretion of 93 subjects were less than that of the cut-off value for normal ($\geq$30 mmol/day) in all seasons of which 76.71%, 90.71% and 81.02% of the urine were categorized as hypokaliuria in the hot, rainy and cold seasons, respectively. In the case of serum K of these subjects, though the mean values were within a normal limit ($\geq$3.5 mmol/l), 36.56%, 34.41% and 29.03% of the serum were classified as hypokalemia in the hot, rainy and cold seasons, respectively. In the assessment of K intake, it was clearly demonstrated that the values in all 3 seasons were much lower than that of the estimated safe and adequate daily dietary intake (ESADI) of K for the westerners (1975-5625 mg/day), i.e., the means of intake in the hot, rainy and cold seasons were only 807$\pm$172, 877$\pm$257 and 902$\pm$227 mg/day, respectively. Furthermore, K loss through sweat in the cold and the hot seasons were as high as a third (7.4$\pm$2.4 mmol/day) and a half (11.5$\pm$1.6 mmol/day), respectively, of the urinary excretion. Though the total body K contents were not evaluated in this study, our results suggest rural people in the northeast region of Thailand may be in a state of K deficiency. The severity is probably worsened in the hot season as seen from the tendency of decrease in serum K levels among 650 renal stone formers and 260 blood donors in this season.

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Potassium (K) is the principal intracellular cation of all cells and is most abundant in skeletal muscle[1,2]. By co-functioning with other ions, K plays a number of important roles in our bodies, for instance, controls of neuromuscular function, acid-base balance, ostomotic pressure as well as water retention of the cells[1]. Since K is classified as a macroelement and found commonly in a variety of food sources, its deficiency in human nutrition seems unlikely. However, signs of K deficiency among the northeastern Thai population may probably emerge from our previous studies on blood and urine biochemistry of renal stone formers residing in rural villages, where we found that they had low levels of K in both serum and urine[3,4]. Similar results were also reported by another group of investigators[5]. These abnormalities were also detected in normal subjects living in the same rural areas. The findings suggest the northeastern Thai population might be in a state of K deficiency.

The notheastern region is comprised of 18 provinces with an area of one-third of the whole country and is inhabited by a population of the lowest socioeconomic status. They are facing quite a number of public health problems. Besides nutritional deficiency and a high rate of liver fluke infection[6], four metabolic diseases are found unique to the region, i.e., renal tubular acidosis[7], sudden unexplained death syndrome[8], renal stone disease[9] and malnutrition-related diabetes[10]. These metabolic diseases were thought to be partly caused by K deficiency[11,12]. Due to the important roles of K as such and the tendency of being deficient in K of the people in this region, we therefore were interested in assessing their K status. We also studied the loss of K through sweat in a group of normal subjects while working in the field. Furthermore, to visualize more about K status, we also showed data on serum K of renal stone formers who had been admitted to and received treatment from Khon Kaen provincial hospital and also the data on serum K of blood donors at Ubon Ratchathani provincial hospital.

MATERIAL AND METHOD

Subjects

Eight out of 18 provinces in the northeast region were selected so that all its sub-areas were geographically equally included in the studied protocol. Two rural villages situated close to each other were randomly selected from each province and 10 healthy male volunteers were recruited from each of these villages. The subjects were20-50 years old, had no history of any illness or medications at the time of study and had normal urine examination with Labstix (for urinalysis). Altogether, there were 16 villages as site areas and 160 subjects participated in our studied protocol.

Studied periods

The studied protocol was divided into 3 periods according to the seasons of the year. The first period of the hot season was from March to May. The second and the third periods were of the rainy and the cold seasons respectively from August to October and from December to February. The circulation of data collection from the first to the last villages was the same in each period.

Blood and urine collection

Two 24-hour urine samples were collected from each subject with thymol as a preservative. After the measurement of volume, each urine sample was determined for creatinine contents by Jaffe's reaction[13]. Any urine with creatinine excretion of less than 20 mg per kg body weight was considered to be an incomplete collection and discarded. At least one complete 24-hour urine sample had to be obtained for each subject, otherwise, further urine collections would be made. About 10 ml of urine samples were brought back to the laboratory for K analysis using a flame photometer. Five ml of fasting clotted blood were collected and analyzed for serum K by autoanalyzer. Any urine with the K contents of less than 30 mmol was considered to be hypokaliuria and a serum with the K content of less than 3.5 mmol/l was hypokalemia[3].

Serum K of blood donors

Five ml of fasting clotted blood were collected from each rural villager who came for blood donation at Ubol provincial hospital and analyzed for the K contents, Only the first 5 subjects in each week were included in the final analysis. Data were gathered for a period of 1 year (52 weeks) by one of our co-investigators.

Serum K of renal stone formers

Data on serum K of renal stone formers from the patient record unit of Khon Kaen provincial hospital were gathered by one of our co-investigators. Only patients who formed small stones not bigger than 2 cm in diameter and received treatment by the shock wave lithotripsy were included in our analysis. Altogether there were 650 patients who met our including criteria during a 3-year period of 1992-1995.

Measurement of K in sweat

K loss through sweat of 14 males while working as cassava plant cultivators for 9 hours in the field was measured. The measurements were made twice, during growing in the hot and during its cultivation in the cold seasons. A pair of trousers, underwear, a long-sleeved shirt and a piece of handkerchief were provided for each volunteer. Before providing, these clothes were detergent-cleaned, soaked overnight in 5 l of distilled water and finally air-dried. The subiects were instructed to take a bath before wearing the clothes in the morning and to take them off in the evening after work. Sweat loss in the face was wiped off with the handkerchiefs. All clothes were brought back in plastic bags to the laboratory and soaked overnight in 5 l of distilled water. Before removing the next morning, the clothes were hand-rubbed for a few minutes and about 20 ml of soaked-water were taken for analysis of the K contents by a flame plotometer. Prior to analysis, the soaked water was evaporated at 60-70°C on a hot plate until the volume was reduced to about one-third.

Measurement of dietary K intake

The method of direct food-weighing was used to assess dietary K intake. All meals including drinking water were weighed both before and after consumption from which the actual amount of meals and water intake could be calculated. Two subjects from each of 16 villages were studied for 2-consecutive days in each season. On the third day, all ingredients of each meal were purchased and cooked by the same persons. The samples of these meals were then brought back to the laboratory and analyzed for the K contents by the method described by Oiso and Yamaguchi[14].

RESULTS

Demographic data

Out of 160 subjects recruited at the beginning of this study, only 93 had completed data collection covering all 3 seasons of the year. Distribution of these subjects in each studied area are shown in Table 1. They had an age average of 39.52±6.67 years old and a body weight average of 59.25±7.21 kg.

Urinary volume and K excretion

Fig. 1 shows the means of 24-hour urinary volume of subjects in each province according to the seasons of the year. The mean values of all provinces in the hot season was smallest (984± 406 ml), in the rainy season was highest (1720± 616 ml) and in the cold season was in between (1339±11 ml). The means of urinary K excretion of subjects in each province according to the seasons are shown in Fig. 2 where the means of all provinces in the hot, rainy and cold seasons were 23.01±9.88, 18.75±8.69 and 23.25±9.77 mmol, respectively. All these values were below a cut-off point for normal (30 mmol). When a

Table 1. Demographic data of the study subjects.

No.	Provinces	No. of subjects	Age, years ($\bar{X}$±SD)	Body weight, kg ($\bar{X}$±SD)	Location
1	Chaiyaphum	10	38.44±8.23	59.97±8.94	Lower northeastern region
2	Si Sa Ket	16	38.77±8.73	58.44±8.23	Lower northeastern region
3	Nakhon Ratchasima	11	39.95±7.55	57.42±8.13	Lower northeastern region
4	Ubon Ratchathani	15	41.11±6.49	59.42±7.18	Lower northeastern region
5	Khon Kaen	9	40.08±6.21	58.73±7.90	Upper northeastern region
6	Kalasin	8	38.52±8.24	60.05±7.94	Upper northeastern region
7	Loei	15	40.78±8.52	61.00±9.68	Upper northeastern region
8	Udon Thani	9	37.27±4.44	59.72±5.21	Upper northeastern region
	Total	93	39.52±6.67	59.52±7.21	

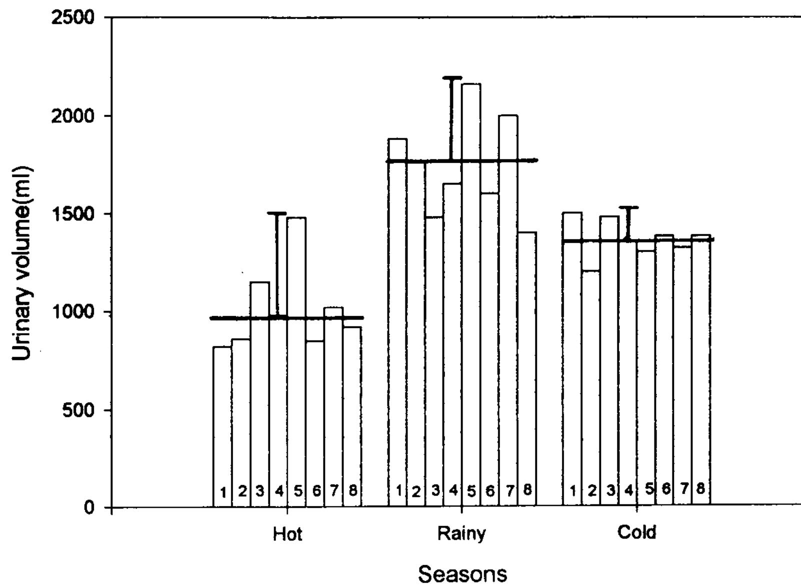

Fig. 1. Means of 24-hour urinary volume of subjects in each province according to the hot, rainy and cold seasons of the year. Figure under each column represents province number (see Table 1). The bold horizontal and vertical lines indicate the magnitude of means and SDs of all 8 provinces for each season.

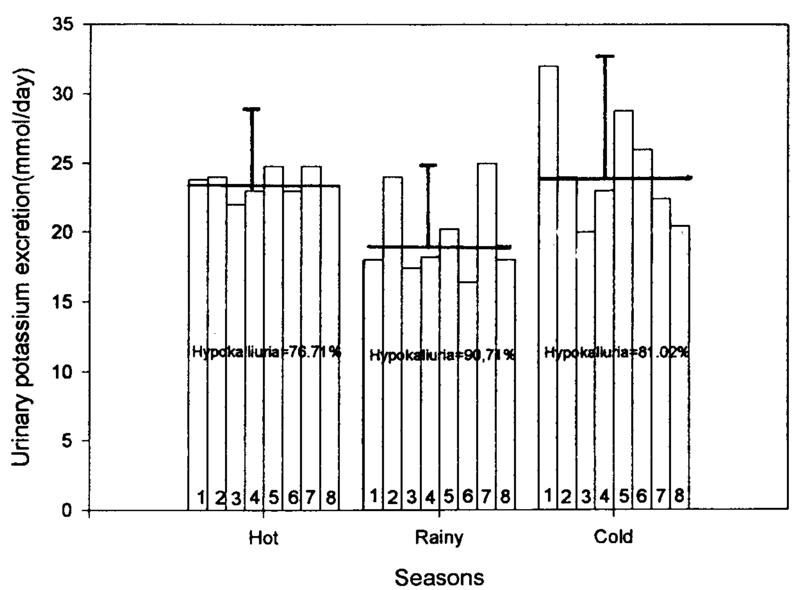

Fig. 2. Means of 24-hour urinary K excretion of subjects in each province according to the hot, rainy and cold seasons of the year. The value in the rainy season was significantly lower than those of the other two seasons ($p<0.001$). Figure under each column repersents province number (see Table 1). The bold horizontal and vertical lines indicate the magnitude of means and SDs of all 8 provinces for each season.

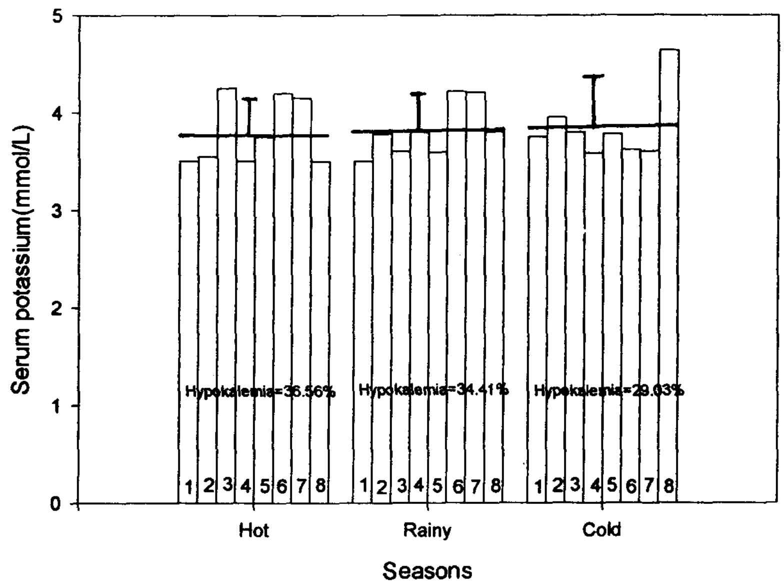

Fig. 3. **Means of serum K of subjects in each province according to the hot, rainy and cold seasons of the year. Figure under each column repersents province number (see Table 1). The bold horizontal and vertical lines indicate the magnitude of means and SDs of all 8 provinces for each season.**

comparison between the seasons were made, the mean urinary K in the rainy season was significantly lower than those of the other two seasons ($p<0.001$). Furthermore, when K contents in individual urine were taken into account, the prevalence of hypokaliuria was as high as 76.71%, 90.71% and 81.02% in the hot, rainy and cold seasons, respectively.

Serum K

Serum K of subjects in 8 provinces

The means of serum K of subjects from each province according to the seasons are shown in Fig. 3. The means of serum K of all provinces in the hot, rainy and cold seasons were 3.78 ± 0.28, 3.82 ± 0.26 and 3.83 ± 0.34 mmol/l, respectively. Although the means of serum K in all 3 seasons were within a normal range, if individual serum was taken into account it was found that 36.56%, 34.41% and 29.03% of these serums were classified as hypokalemia in the hot, rainy and cold seasons, respectively.

Serum K of blood donors and renal stone formers

Data on serum K of 260 blood donors (Fig. 4) were grouped and meaned at a period of 2 weeks and plotted against the time of blood collection throughout the year. Fig. 5 shows the distribution of serum K collected from 650 renal stone formers in a period of 3 years, they were grouped and meaned at a period of 1 month. Although the serum K values in each period were not from the same persons, at least both graphs show that serum K had a tendency of being lower during the hot season, e.g., in March and April.

K loss in sweat

The measurements of K loss through sweat of 14 volunteers while working for 9 hours in cassava plant cultivation are shown in Table 2. The mean values of sweat K in the hot season was 11.5 ± 1.6 mmol (448.5 ± 61.6 mg) and in the cold season was 7.4 ± 2.4 mmol (289.1 ± 91.1 mg). These mean values of sweat K were about a half

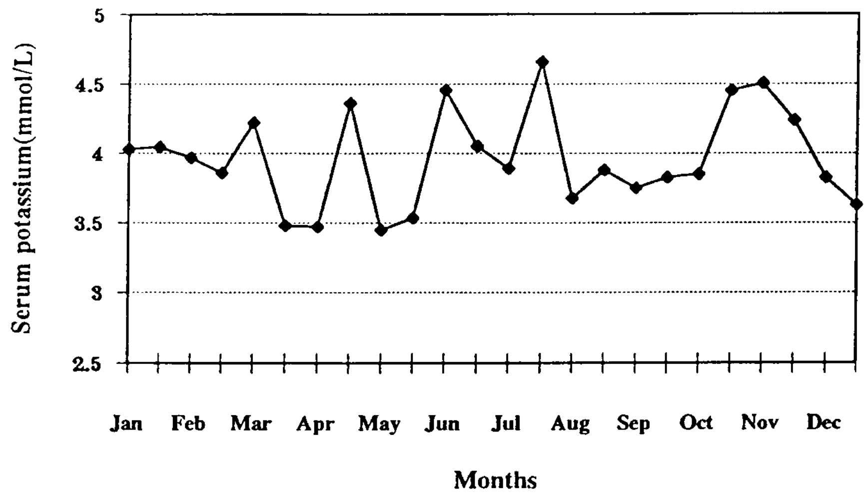

Fig. 4. Means of serum K of 260 blood donors who donated their blood at Ubon Ratchathani provincial hospital during a one-year period. Each point of the graph repersent means of serum K from 10 subjects collected in a period of 2 weeks (5 subjects/week).

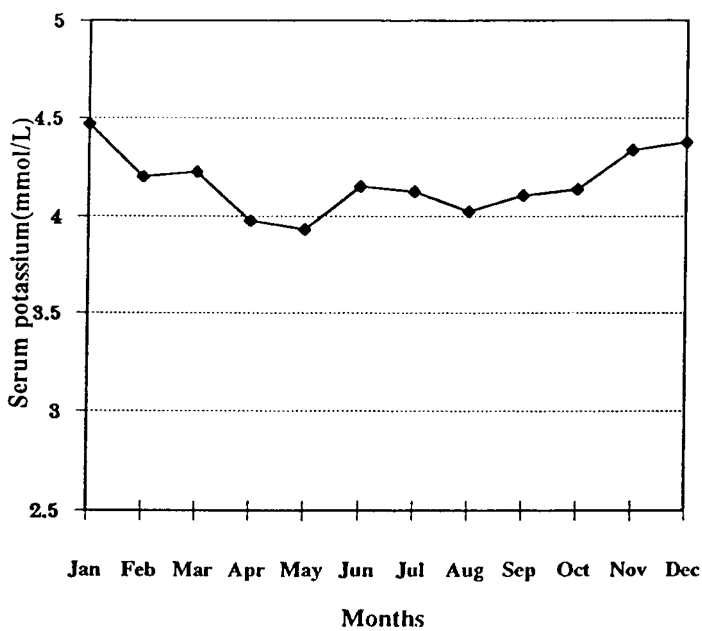

Fig. 5. Means of serum K of 650 renal stone formers who had been admitted to and received treatment from Khon Kaen provincial hospital during a 3 - year period (1992 - 1995). Each point in the graph represents a mean of serum K collected for a whole month period.

Table 2. K loss through sweat of 14 cassava plant cultivators while working for 9 hours in the field.

Subject No.	K in sweat			
	Hot season		Cold season	
	mmol/day	mg/day	mmol/day	mg/day
1	11.7	457.2	6.2	242.4
2	8.8	344.1	6.0	234.6
3	12.0	469.2	4.3	168.1
4	11.6	453.6	2.9	113.4
5	14.3	559.1	8.1	316.7
6	12.4	484.8	8.7	340.2
7	8.7	340.2	9.2	359.7
8	10.7	418.4	9.8	383.2
9	10.0	391.0	6.1	238.5
10	10.6	414.5	8.2	320.6
11	12.4	484.8	12.2	477.0
12	13.8	539.6	6.3	246.3
13	11.2	437.9	9.3	363.6
14	12.4	484.8	6.2	242.4
$\overline{X}$	11.5±1.6	448.5±61.6	7.4±2.4	289.1±91.1

Table 3. Dietary K intake in the hot, rainy and cold seasons of 13 subjects from 8 provinces.

Province (no. of subjects)	K intake, mg/day		
	Hot	Rainy	Cold
Chaiyaphum (3)	1143	832	924
Si Sa Ket (1)	677	1320	955
Nakhon Ratchasima (1)	778	640	1405
Ubon Ratchathani (2)	845	600	720
Khon Kaen (1)	625	1105	650
Kalasin (2)	950	1005	855
Loei (2)	780	625	821
Udon Thani (1)	665	895	890
$\overline{X}$ ± SD	807±172	877±257	902±227

and a third of urinary K excretion in the corresponding seasons.

Dietary K intake

Among 32 subjects from 8 provinces who initially participated in the food intake study, only 13 had completed data of food consumption for all 3 seasons and the results are shown in Table 3. The means daily dietaty K intake for these subjects were 807±172, 877±257 and 907±227 mg in the hot, rainy and cold seasons, respectively. These values were not of significant difference but all were very low when compared to the estimated safe adequate daily dietary K intake (ESADI) for westerners (1975-5625mg/day)[15].

DISCUSSON

It is well recognized that the regulations of K excretion by the kidneys is very efficient. If total body K is deficient, urinary excretion of K will decrease due to increased renal reabsorption[16]. In this study we have shown that normal subjects in all areas studied and throughout the year had low urinary K excretion. The results supported the previous findings[3-5] and therefore points to the possibility of deficiency in K among the northeastern Thai population. Essentially, there are three possible causes of K deficiency, i.e., insufficient dietary intake, abnormal gastrointestinal loss and abnormal renal loss[17]. Since there was no history of diarrhoea or taking diuretic drugs for these subjects during data collection, the cause of low urinary K excretion or K deficiency therefore should be due to the low intake. This is clearly confirmed by the data on the assessment of dietary K intake where the values were very much lower than that of the ESADI for K of the westerners. It is possible that foods consumed by the people in this region may have low K contents or may be their eating habit, as well as the socioeconomic problem, limited their access to foods containing high K. These aspects should be studied further in more detail to help in identification of the real causes of low urinary excretion of K among the northeastern Thai people. With regard to this matter, another point should also taken into consideration is the study of their K balance. Since they all were healthy normal subjects, their body K should be expected to be in a state of good balance. In other words, their low urinary excretion may reflect only the low dietary intake, not a true body K deficiency[17]. Excessive sweating for the people working in the field particularly, for those living in tropical countries is another main route of K loss. Although the concentration of K in sweat is only 4-8 mmol/l[18] but for ones who have extra high activity, for instance, young military men undergoing intensive training in hot weather can lose K up to 30 mmol/day or about half of their 24-hour urinary excretion[19]. Our data on sweat K loss of 14 subjects while working as cassava plant cultivators in the field showed a similar high loss of K through sweat. Thus, by a combination with the data of extraordinarily low dietary intake, these people are really in a high risk of being deficient in K.

Although a very small fraction of body K (1-2%) circulates in serum and does not always reflect the true K status of the body, it is widely used as an indicator due to the simplicity and the convenience in taking blood samples[20]. In this study we found that about a third of blood samples were classified as hypokalemia and the prevalence of the cases seemed to be higher in the hot, though not significantly different from the other two seasons. The tendency of having lower serum K in the hot season was probably reflected from the two separated data of blood donor and stone former groups and agreed well with the data on sweat K loss. The serum K data, therefore, further supported the possiblity of K deficiency among studied subjects. In conclusion, our findings suggest that people of the rural northeast region of Thailand are prone to K deficiency. Since about two-thirds of body K are in skeletal muscle, to assure the true body K status, direct measurment of muscle K contents should be made in a future study.

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ภาวะโภชนาการของแร่ธาตุโพแทสเซียมในผู้ชายชาวชนบทภาคตะวันออกเฉียงเหนือของประเทศไทย

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ในการวิจัยครั้งนี้ได้ทำการคัดเลือกหมู่บ้านชนบทจำนวน 16 หมู่บ้าน โดยการสุ่มจาก 8 จังหวัดของภาคตะวัน-ออกเฉียงเหนือ เพื่อเป็นแหล่งศึกษา จากนั้นได้คัดเลือกอาสาสมัครเข้าร่วมโครงการ จำนวน 93 คน ซึ่งเป็นชายอายุ 20-50 ปี มีสุขภาพร่างกายทั่วๆ ไปแข็งแรงดี ทำการเก็บตัวอย่างปัสสาวะ 24 ชั่วโมง 2 วันติดต่อกันและตัวอย่างเลือด 1 ครั้งในแต่ละฤดู (ร้อน, ฝน และหนาว) ตลอดระยะเวลา 1 ปี จากนั้นทำการวิเคราะห์หาปริมาณโพแทสเซียม (K) ได้ทำการประเมินปริมาณ K ที่ได้รับในอาหาร 1 วัน ของทั้ง 3 ฤดู โดยการชั่งอาหารโดยตรง ทั้งก่อนและหลังรับประทาน นอกจากนี้ยังได้ทำการวัดปริมาณ K ที่ขับออกมาในเหงื่อของอาสาสมัคร 14 คน ขณะทำงานในไร่มันสัมปะหลังทั้งวัน (9 ชั่วโมง) ในฤดูร้อนและฤดูหนาว โดยการแช่เสื้อผ้าที่ใส่ทำงานแล้ว ในน้ำกลั่นก่อนนำไปวิเคราะห์หาปริมาณ K โดยวิธี flame photometry ผลการศึกษาพบว่าค่าเฉลี่ยของการขับถ่าย K ในปัสสาวะของประชากรทั้งหมด มีค่าต่ำกว่าเกณฑ์ปกติ (ค่าปกติ $\geq$30 mmol/วัน) ในทุกฤดูตลอดทั้งปี โดยพบว่าร้อยละ 76.71, 90.71 และ 81.02 ของตัวอย่างปัสสาวะ 24 ชั่วโมง ในฤดูร้อน ฤดูฝน และฤดูหนาว ตามลำดับ จัดเป็นปัสสาวะที่มีปริมาณ K ต่ำผิดปกติ (hypokaliuria) ส่วนในกรณีของตัวอย่างเลือด พบว่าแม้ค่าเฉลี่ยของปริมาณ K ในทุกฤดูกาลจะอยู่ในเกณฑ์ปกติ ($\geq$3.5 mmol/ลิตร) แต่ก็พบว่าร้อยละ 36.56, 34.41 และ 29.03 ของซีรั่มในฤดูร้อน ฝน และหนาว ตามลำดับ จัดเป็นซีรั่มที่มีปริมาณ K ต่ำผิดปกติ (hypokalemia) สำหรับการประเมินค่า K ในอาหารที่ได้รับประจำวันนั้น พบว่าในฤดูร้อน ฤดูฝน และฤดูหนาว ได้รับเพียง 807$\pm$172, 877$\pm$257 และ 902$\pm$227 มิลลิกรัมต่อวันตามลำดับ ซึ่งเป็นค่าที่ต่ำมากเมื่อเปรียบเทียบกับค่าที่เป็นข้อกำหนดความเพียงพอต่อการได้รับประจำวัน (ESADI) ของชาวตะวันตกคือ 1975-5625 มิลลิกรัมต่อวัน ส่วนการสูญเสีย K จากเหงื่อก็พบว่ามีค่าสูงมากขณะทำงานกลางแจ้งคือในฤดูหนาวประมาณหนึ่งในสาม (7.4$\pm$2.4 mmol/วัน) และในฤดูร้อนประมาณครึ่งหนึ่ง (11.5$\pm$1.6 mmol/วัน) ของปริมาณ K ที่ขับออกมาในปัสสาวะ แม้จะไม่ได้ทำการประเมินปริมาณ K ทั้งหมดที่มีในร่างกายโดยตรง แต่จากข้อมูลของการศึกษาในครั้งนี้ชี้ให้เห็นว่าประชากรในภูมิภาคนี้น่าจะกำลังอยู่ในสภาวะการขาด K และการขาดน่าจะรุนแรงที่สุดในฤดูร้อน ดังจะเห็นได้จากปริมาณ K ในซีรั่มของผู้ป่วยโรคนิ่วไต 650 คน และของผู้มาบริจาคเลือด 260 คน มีแนวโน้มต่ำสุดในฤดูนี้

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