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Some Effects of High and Low Sodium Intake on a Vegetarian Diet in Rats[1,2]

I. Longevity, Food Consumption, Weight Gain, Organ Weight, Serum and Bone Sodium and Potassium, Sodium and Potassium Balance and Hematology

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ABSTRACT

Ninety weaned albino rats divided into three different dietary groups according to the amount of salt in their diet. Each diet consisted of a basic diet of vegetable origin to which was added a specific amount of NaCl. Diet I contained 0.51 mEq Na(0.03% NaCl), diet II 9.96mEq Na(0.58%NaCl), and diet III 24.60 mEq Na(1.45% NaCl) per 100 grams of diet. Each diet contained 14 mEq of potassium per 100 grams of diet.

All rats grew satisfactorily, regardless the type of diet, until the age of 60 weeks. Both male and female rats were on the highest volume of water consumption in the first 10 weeks and in all groups the female rats consumed more water than males. No significant difference in the level of serum and osseous electrolytes was found. In animals receving the higher sodium diet the ratio of heart to kidney weight per kilogram of body weight was 6-8% higher than in the other groups. The frequency of occurence of a chromophobe adenoma seems to be influenced both by the rat strain and by the stress such as is found where a low sodium diet is given.

In this study, animals on the highest sodium diet (24.60 mEq Na: 1.45% NaCl) had a longer life span than the two other lower sodium diet groups.

INTRODUCTION

Sodium chloride is an essential element in human and rat nutrition.(Black, 1952; McCane, 1936; Osborne et al., 1918) Its main function is the preservation of physical and chemical homeostasis. (Gamble, 1954) The level of sodium and potassium found in naturally occuring foods influences the dietary intake of sodium chloride. For example, herbivorous animals travel long distances to salt licks, thereby manifesting a salt craving which is not found in carnivorous animals. Bunge(1905) suggested that the abundance of potassium in vegetable foods produces the salt required by herbivora. Although the protein content of the diet does not in itself seem to affect the glomerular filtration rate to any marked degree, the filtration rate is depressed when the diet is low in salt. The Kempner's rice and fruit diet(low protein, low fat, and low salt)administered to hypertensive subjects caused an average decrease in glomerular filtration rate at 25 per cent while the renal plasma flow decreased 20 per cent. However, when the rice diet was supplemented by salt the filtration rate rose toward the value observed on normal diet. (Bodil Schmidt-Nielsen, 1958; Kempner, 1948)

Geographic studies of the intake levels of sodium

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chloride show marked variations. In the United States the usual intake level is 4 grams per day with some intake levels of 10 and 20 grams per day being reported. In contrast, in Japan, instead of 4 grams per day the average intake is 17 to 24 grams per day with levels varying from 12 to 38 grams of salt per day.

Several studies have been made on the effect of low and high sodium diets in patients with cardiac and renal disease. Meneely et al.(1953, 1957) observed that a high sodium diet produced chronic effects in male albino rats. Kirksey et al.(1962) reported their findings on the effect of low and high sodium diets in the pregnant rats.

The quantitative nutritional requirement of sodium chloride in rats on a strictly vegetarian diet, and the physiological effect of salt in animals on this diet has not previously been reported. For people who habitually consume an excessive amount of salt while on a vegetable diet studies need to be made to determine the exact nutritional requirement of salt.

The present study investigates the effect of low and high sodium levels on a basic vegetarian diet which has been modified to conform to usual Korean food habits, and reports changes found in longevity, food consumption, weight gain, maximum body weight, organ weight, serum and wet bone sodium and potassium levels, sodium and potassium balance, and ematology.

MATERIALS AND METHODS

1. Animal dietary studies

Ninety weaned albino rats having approximately the same weight were used in two experiments. Sixty rats, in the first experiment, were divided into three dietary groups each containing ten males and ten females. At the age of ten weeks seven day study of water and sodium balance was made on each rat including urinalysis of its sodium, potassium and chloride excretion. These studies were repeated at ten week intervals until the rats reached the age of 80 weeks. All animals were kept until the time of their natural death to determine longevity as well as growth, food consumption, osseous electrolytes content, and tissue pathology. Thirty rats, in the second experiment, were divided into three dietary groups each containing five males and five females. At the age of 68 weeks these animals were studied for comparative changes in their serum sodium and potassium, osseous electrolytes, and organ weights.

Each of the three groups received the same basal diet but varied in the content of sodium chloride which was added to the diet. Diet I contained 0.51 mEq Na(0.03% NaCl); Diet II contained 9.96 mEq Na(0.58% NaCl) and Diet III added 24.60 mEq Na (1.45% NaCl) per 100 grams of diet. All diets contained 14 mEq of potassium per 100 grams of diet. Table 1 gives the composition of the basic diet.

Table 1. Composition of the basic diet

Polished rice	74%
Soybean flour	12%
Vegetable oil	6%
Brewer's yeast	5%
Cod liver oil	2%
Bone meal *	1%
Vitamin supplement-E and B12	

* Bone meal salt was mixed with the following constituents:

Bone	460 gm
$MgCO_3$	23 gm
KCl	131 gm

All rats were provided with tap water and the assigned diet ad libitum, were weighed and carefully examined weekly. All were autopsied and the tissues checked for pathologic changes.

2. Chemical analytic studies

Glass tubes containing a few drops of toluene were used for collection of the urine for sodium, potassium and chloride output studies. The Volhard-Arnold method was used for the quantitative analysis of the chloride present.

In the second experiment, under light anesthsia with ether, blood from the femoral artery was collected for analysis of the serum sodium and potassium.

For the sodium and potassium analysis of the bone, all the femurs were ashed at 525°C for 48 hours following which the ash was dissolved in 2 N-HCl which was diluted with distilled demineralized water. Osseous calcium analysis was done by the method of the Association of Official Agricultural Chemists(1960) which uses potassium permanganate

Table 2. Total food intake and weight gain to the 40th weeks

Dietary treatment	sex	Weaning-10 weeks		10-20 weeks		20-30 weeks		30-40 weeks	
		Food intake	Weight gain	Food intake	Weight gain	Food intake	Weight gain	Food intake	weight gain
Na mEq/100gm		gm	gm	gm	gm	gm	gm	gm	gm
0.51	M	1072	102	1330	84	1168	59	1229	31
9.96	M	1172	113	1418	89	1296	65	1348	36
24.60	M	1117	118	1491	89	1462	68	1504	31
0.51	F	1004	91	1166	30	996	29	1059	18
9.96	F	1054	91	1253	34	1045	32	1051	32
24.60	F	1081	71	1225	38	1097	38	1139	20

as the oxidizing agent.

The Patwin Flame Photometer was used to measure actual levels of sodium and potassium in the urine, serum, and bone.

RESULTS AND DISCUSSION

1. Food consumption and weight gain

Figure 1 presents the average growth rate for the three groups of animals as age increased. Subsequent time increments were progressively increased by periods of 180 days, from 210 to 420 days. Male rats on the lowest sodium level of diet showed a steady increase in weight and gradually increased to the highest weight in the growth curve. Rats on the highest sodium level of diet started to gradually decline in weight at 350 days of age. Female rats on the lowest sodium level of diet showed a slightly higher weight increase throughout the entire experiment. Animals on the highest sodium diet had a greater amount of food consumption than those on the lower sodium dietary levels.

Generally all rats grew satisfactorily, regardless of the type of diet, until the age of 60 weeks. Campbell(1956) found no significant difference in growth of rats receiving up to 9.09% NaCl in their diets. Meneely et al.(1953) reported that rats fed on either a high(2.8~9.8%) or low (0.01%) sodium chloride level gained more slowly than did rats receiving the control diet ration which was 0.15% sodium chloride.

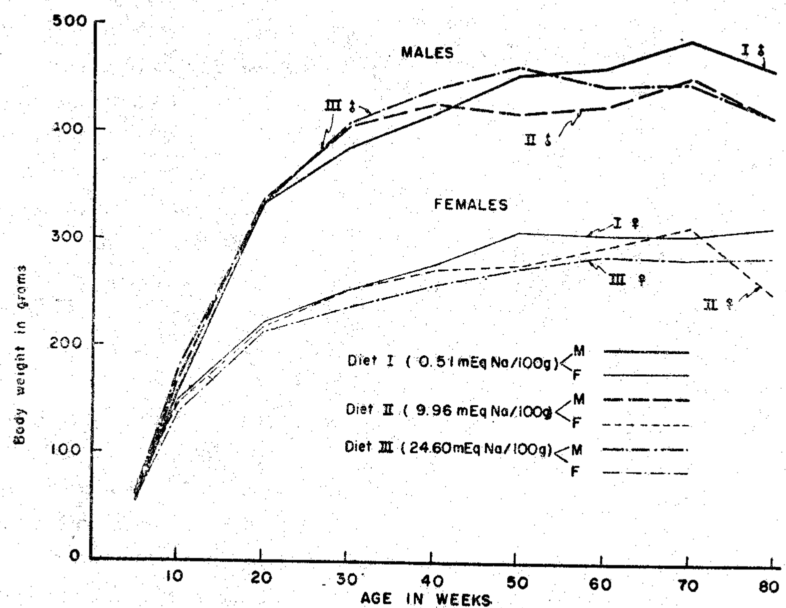

Fig. 1. Weight curve of animals at various ages.

Table 3. Serum and wet bone electrolyte concentration at 68 weeks

Dietary treatment Na mEq/100 gm	Sex	Plasma		Wet bone	
		Na mEq/liter	K mEq/liter	Na mEq/liter	K mEq/liter
0.51	M	138	4.3	92.1	17.6
9.96	M	145	4.9	91.7	15.1
24.60	M	145	4.9	90.3	14.7
0.51	F	143	3.6	89.6	12.2
9.96	F	143	4.2	88.4	12.8
24.60	F	143	4.7	106.7	13.2

Table 4. Bone electrolyte concentration at various ages(mean ±S.E.)

Dietary treatment Na mEq/100gm	Sex	Mean age at death days	Mean wet bone Wt. gm	Wet bone		
				Na mEq/kg	K mEq/kg	Ca mg/kg
0.51	M	486±91.5	1.26±0.08	98.7±3.5	11.4±1.7	231±11.5
9.66	M	486±89.4	1.22±0.09	98.5±3.6	14.5±1.1	289± 9.2
24.60	M	665±44.4	1.17±0.08	109.4±5.7	13.4±1.3	238±13.6
0.51	F	562±11.1	0.77±0.11	113.7±3.9	15.0±1.8	309±32.0
9·96	F	579±72.3	0.87±0.18	113.9±6.3	18.4±2.0	307±48.2
24.60	F	620±60.8	0.82±0.14	114.9±8.3	15.9±1.4	297±17.9

Table 5. Balance studies; part I for male

Weeks	Diet	NaCl % in Diet	Sex	Body Wt. (gm)	Food intake /day. (gm)	Food intake (gm) /body Wt.	Water intake /day(ml)	H_2O /body Wt. (ml)	Urine output /day(ml)	Urine /body Wt. (ml)	NaCl % in urine	Cl % in urine
10	I	0.03	M	165	20.3	0.123	18.5	0.110	5.2	0.032	0.48	0.288
	II	0.58	M	177	22.1	0.125	21.2	0.120	5.8	0.033	1.27	0.762
	III	1.45	M	197	20.7	0.105	24.1	0.120	9.0	0.046	2.01	1.206
20	I	0.03	M	324	17.5	0.054	20.5	0.063	5.0	0.015	0.39	0.235
	II	0.58	M	337	17.6	0.052	22.8	0.067	7.6	0.022	1.39	0.834
	III	1.45	M	333	18.3	0.055	25.9	0.077	9.0	0.027	2.63	1.578
30	I	0.03	M	386	17.7	0.046	20.4	0.052	6.3	0.016	0.48	0.282
	II	0.58	M	405	17.9	0.044	19.1	0.047	7.3	0.018	1.29	0.781
	III	1.45	M	407	20.9	0.051	25.2	0.061	10.3	0.025	2.48	1.489
40	I	0.03	M	418	13.2	0.032	21.3	0.051	6.8	0.017	0.42	0.252
	II	0.58	M	426	14.8	0.035	19.2	0.045	4.8	0.011	1.44	0.864
	III	1.45	M	440	14.9	0.035	24.6	0.056	10.1	0.023	1.89	1.134
50	I	0.03	M	453	14.8	0.033	25.9	0.057	13.3	0.029	0.35	0.210
	II	0.58	M	419	14.7	0.035	13.6	0.042	5.4	0.013	1.47	0.880
	III	1.45	M	461	21.1	0.045	28.8	0.062	16.6	0.036	1.75	1.050
60	I	0.03	M	455	20.8	0.045	19.5	0.044	6.9	0.015	0.41	0.246
	II	0.58	M	424	21.3	0.050	20.5	0.048	8.9	0.022	1.28	0.768
	III	1.45	M	443	23.3	0.052	26.3	0.059	15.6	0.035	1.97	1.182
70	I	0.03	M	492	18.5	0.037	25.4	0.051	7.8	0.018	0.55	0.331
	II	0.58	M	445	15.3	0.034	20.6	0.046	5.9	0.013	1.27	0.768
	III	1.45	M	466	18.4	0.039	24.9	0.053	16.7	0.033	1.87	1.152
80	I	0.03	M	485	25.3	0.052	25.7	0.052	11.8	0.024	0.46	0.276
	II	0.58	M	410	25.8	0.062	18.9	0.046	9.8	0.023	1.16	0.696
	III	1.45	M	433	29.2	0.067	35.2	0.081	14.4	0.033	1.89	41.13

Table 6. Balance studies; part I for female

Weeks	Diet	NaCl % in Diet	Sex	Body Wt. gm	Food intake /day (gm)	Food intake(gm) /body wt.	Water intake /day(ml)	H_2O /body wt. (ml)	Urine output day (ml)	Urine /body wt. (ml)	NaCl % in urine	Cl % in urine
10	I	0.03	F	154	18.7	0.121	19.8	0.120	5.6	0.036	0.37	0.222
	II	0.58	F	152	19.4	0.127	22.8	0.150	8 5	0.063	0.91	0.546
	III	1.45	F	144	20.0	0.138	21.1	0.140	9.8	0.068	1.75	1.050
20	I	0.03	F	217	13.4	0.061	14.7	0.063	4.4	0.022	0.39	0.235
	II	0.58	F	219	14.4	0.094	15.4	0.070	4.8	0.026	1.10	0.660
	III	1.45	F	209	12.0	0.057	21.1	0.100	8.3	0.039	1.84	1.104
30	I	0.03	F	245	16.4	0.066	16.5	0.067	3.6	0.014	0.57	0.343
	II	0.58	F	252	15.1	0.060	15.7	0.072	7.2	0.018	0.95	0.572
	III	1.45	F	237	13.8	0.058	16.8	0.071	8.5	0.035	1.88	1.134
40	I	0.03	F	277	15.3	0.055	15.6	0.056	4.2	0.015	0.39	0.234
	II	0.58	F	271	15.9	0.058	17.8	0.062	5.1	0.018	1.17	0.708
	III	1.45	F	257	14.8	0.058	16.3	0.063	7.8	0.030	1.92	1.152
50	I	0.03	F	308	14.4	0.095	15.5	0.050	6.5	0.021	0.42	0.252
	II	0.58	F	286	16.0	0.056	18.2	0.063	6.3	0.022	1.22	0.732
	III	1.45	F	273	17.9	0.066	20.1	0.073	7.9	0.028	1.60	0.960
60	I	0.03	F	305	16.3	0.053	14.6	0.047	7.9	0.026	0.37	0.222
	II	0.58	F	294	15.7	0.053	16.9	0.057	8.7	0.030	1.05	0.630
	III	1.45	F	276	18.1	0.065	25.9	0.090	14.7	0.053	1.72	1.032
70	I	0.03	F	295	17.5	0.059	16.2	0.054	6.6	0.022	0.54	0.324
	II	0.58	F	321	13.7	0.043	16.0	0.049	5.6	0.017	1.48	0.876
	III	1.45	F	295	14.4	0.048	26.4	0.089	13.0	0.044	1.67	1.002
80	I	0.03	F	348	19.4	0.070	28.4	0.081	10.9	0.031	0.32	0.192
	II	0.58	F	249	22.2	0.089	26.1	0.104	13.1	0.052	1.04	0.624
	III	1.45	F	279	24.7	0.088	35.0	0.125	20.8	0.074	1.65	0.990

Fig. 2. Mean water consumption per gram of body weight of rats.

Table 7. Balance studies; part II

Age weeks	Dietary treatment mEq	Sex	Na intake mEq/day	K intake mEq/day	Urine Na mEq/day	Urine K mEq/day	Balance		Urinary excretion		
							Na	K	Na/K	Na % ingested	K % ingested
30	0.51	M	1.834	2.016	0.947	1.292	+0.887	+0.724	0.73	52.1	63.7
	9.96	M	3.500	2.016	2.755	1.491	+0.745	+0.525	1.85	78.7	72.8
	24.60	M	5.566	2.088	4.535	1.951	+1.060	+0.137	2.32	81.3	92.3
40	0.51	F	2.227	2.448	0.957	1.058	+1.270	+1.439	0.90	41.6	42.7
	9.96	F	3.250	1.672	2.057	1.189	+1.193	+0.683	1.73	63.8	63.4
	24.60	F	4.608	1.728	2.788	1.153	+0.818	+0.576	2.42	81.1	56.3
50	0.51	M	1.637	1.800	1.223	1.371	+0.415	+0.439	0.89	73.3	74.0
	9.96	M	3.660	1.824	2.187	0.357	+1.717	+1.467	6.12	59.7	20.0
	24.60	M	7.808	2.961	6.095	2.345	+1.713	+0.916	2.59	78.2	79.6
	0.51	F	1.944	1.920	1.209	1.114	+0.669	+0.835	1.08	65.3	60.4
	99.6	F	3.750	2.156	2.071	0.962	+1.679	+1.198	2.15	51.7	50.5
	24.60	F	6.272	2.352	3.128	1.310	+3.140	+1.066	2.38	49.5	54.7
60	0.51	M	2.751	3.040	1.305	1.752	+1.406	+1.285	0.74	43.8	59.1
	9.96	M	5.250	3.024	2.782	1.089	+1.968	+1.661	2.36	52.9	43.9
	24.60	M	8.909	3.341	5.894	1.762	+3.024	+1.579	3.34	67.4	50.8
	0.51	F	2.129	2.340	1.344	1.877	+0.785	+0.463	0.71	64.0	79.1
	9.96	F	3.830	2.208	2.518	1.346	+1.312	+0.878	1.87	64.7	67.4
	24.60	F	6.976	2.616	4.549	1.497	+2.409	+1.119	3.04	64.6	54.8
70	0.51	M	2.410	2.649	1.309	1.642	+1.138	+0.946	0.79	51.8	40.6
	9.96	M	3.810	2.196	1.877	0.969	+1.759	+1.142	1.83	39.7	31.8
	24.60	M	7.060	2.667	5.830	1.731	+1.203	+0.907	3.38	80.8	66.3
	0.51	F	2.358	2.888	1.092	1.152	+1.297	+1.373	0.94	42.6	49.9
	9.96	F	3.420	1.801	1.661	0.966	+1.764	+1.186	1.71	46.8	48.0
	24.60	F	5.504	2.064	4.077	1.622	+1.411	+0.465	2.51	73.3	77.9
80	0.51	M	2.838	3.120	1.643	2.252	+1.195	+0.534	0.73	56.8	74.2
	9.96	M	5.580	3.216	3.386	2.209	+2.297	+1.041	1.48	58.9	68.3
	24.60	M	8.256	3.096	5.329	1.579	+2.926	+1.266	3.43	55.9	56.2
	0.51	F	2.489	2.736	1.210	2.129	+1.275	+0.574	0.57	48.3	78.5
	9.96	F	4.190	2.391	2.216	1.528	+1.934	+0.862	1.45	49.6	61.2
	24.60	F	7.372	2.764	4.362	1.751	+3.010	+0.994	2.48	54.0	57.1

Table 2 summarizes the relationship between total food intake and the amount of weight gain up to the age of 40 weeks.

During the first 30 weeks the male rat was directly related to the diet group and to the quantity of food intake. Animals on the high sodium diets gained more than those on the lower sodium diets.

2. Serum and wet bone sodium and potassium

The concentration of sodium and potassium in the serum and wet bone of the rats after 476 days on the experimental diets are shown in table 3.

In the male rat the lowest serum concentrations, and in the female the lowest potassium concentrations were found in rats receiving the lowest sodium content in the diet. According to Kirksey et al.(1962) the most significant plasma changes($p=0.05$) occurred in pregnant rats on the low sodium diet. In male rats the bone sodium was not altered by low Na in serum, but in the same rats, bone potassium content remained slightly higher than that found in the other groups. With increasing age the concentration of electrolytes, as expressed per kg,

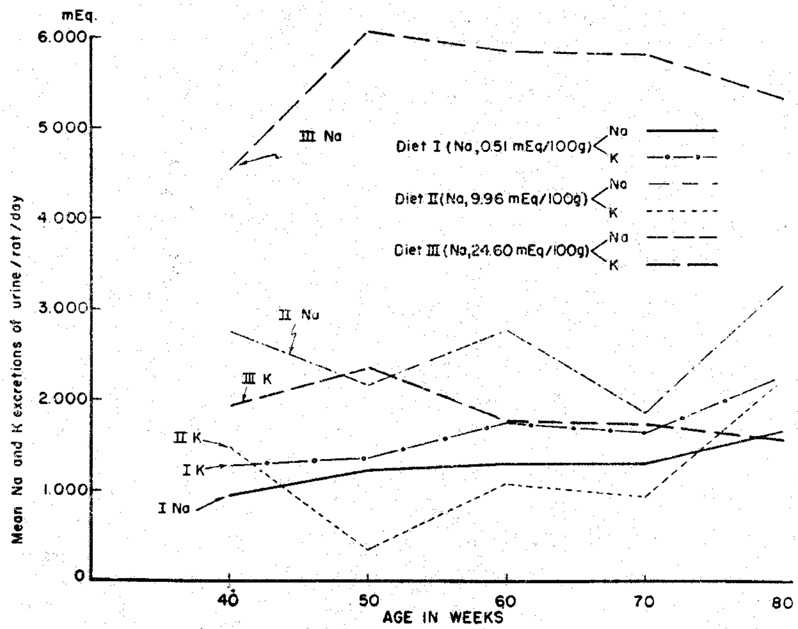

Fig. 3. Mean sodium and potassium excretions in urine for male rats.

Table 8. Hematology

Weeks	Dietary treatment Na mEq/100gm	Sex	Hb gm/dl	RBC /Cmm x104	WBC /Cmm	Differential counts %				
						Lymphocytes	Neutrophils	Eosinophils	Monocytes	Basophils
10	0.51	M	—	718	15160	73.2	24.0	1.6	1.0	0.2
	9.96	M	—	699	12480	75.4	20.4	3.8	0.6	—
	24.60	M	—	728	15675	73.6	23.5	3.1	1.0	0.3
	0.51	F	—	710	16625	78.1	17.6	3.6	0.5	—
	9.96	F	—	719	14340	78.6	18.0	2.8	0.6	—
	24.60	F	—	713	16400	80.4	17.0	2.2	0.4	—
30	0.51	M	14.5	793	17650	65.0	29.3	4.5	1.3	—
	9.96	M	14.3	720	19263	68.5	29.3	1.5	0.8	—
	24.60	M	15.1	787	15790	66.6	29.2	2.8	1.2	0.2
	0.51	F	14.9	702	12500	70.0	27.3	1.7	1.0	—
	9.96	F	14.8	759	14700	67.3	28.8	3.5	0.5	—
	24.60	F	14.3	714	13700	71.4	23.8	3.2	1.6	—
50	0.51	M	12.0	668	8500	46.6	47.3	5.3	0.3	—
	9.96	M	14.0	710	14800	27.0	71.0	2.0	—	—
	24.60	M	13.1	755	14490	43.0	54.0	2.8	0.2	—
	0.51	F	12.3	670	11425	48.5	49.0	1.5	1.0	—
	9.96	F	14.5	668	11383	42.5	54.7	2.7	0.3	—
	24.60	F	13.1	821	13200	44.5	54.2	0.8	0.5	—
70	0.51	M	13.0	862	13367	53.3	43.6	3.0	—	—
	9.96	M	12.8	787	15000	41.0	54.3	4.5	0.5	—
	24.60	M	12.4	829	20987	32.7	61.5	4.5	1.3	—
	0.51	F	13.3	827	16187	44.0	52.3	1.8	1.8	0.3
	9.96	F	13.3	887	10700	57.3	37.7	2.7	2.0	0.3
	24.60	F	12.5	739	13891	39.7	52.8	6.3	1.0	—

Table 9. Organ weights of rats at 68 weeks old of animal age

Dietary treatment Na. mEq/100gm	Sex	No. of rats	Body weight (gm)	Heart weight /kg(gm)	Kidney weight /kg(gm)	Adrenal weight /kg(gm)	Pituitary weight /kg(gm)
0.51	M		453	3.29±0.03	6.35±0.14	0.26±0.05	0.15±0.02
9 96	M		475	3.15±0.18	6.92±0.28	0.25±0.06	0.11±0.06
24.60	M		367	3.81±0.16	7.17±0.54	0.32±0.08	0.11±0.00
0.51	F		273	3.84±0.25	7.72±1.08	0.62±0.07	0.18±0.03
9.96	F		266	3.91±0.47	7.11±0.52	0.49±0.04	0.18±0.03
24.60	F		258	3.91±0.43	7.05±1.01	0.54±0.06	0.27±0.05

of whole wet bone, increased(Table 4).

In 1961 Casey and Zimmermenn reported in marrow free bone the sodium is in a very stable form which does not show significant changes following sodium loading, sodium deprivation or acute acidosis,

3. Balance studies

Figure 2 shows the mean volume of water consumption per gram of body weight per day during the time of balance studies. Both male and female rats attained the highest volume of water consumption in the first 10 weeks, but thereafter the female rats on the highest sodium intake diet showed a gradual decrease in water consumed up to the age 40 weeks. Then the water intake increased with age contrary to Meneely et al. (1958) Figure 2 shows that the water consumption of male rats not directly related to the dietary level of NaCl. Perhaps it is more closely related to the total amount of food consumed. However, the female rats, as illustrated in Figure 2 showed a direct relationship between the intake of water and of salt during most of the study period.

Tables 5 and 6 summarize water consumption and show that the females drank more water than the males during the entire study period.

Tables 5, 6 and 7 summarize the NaCl balance studies. Throughout the various ages the percentages concentration of sodium chloride, and of urine chloride remained comparatively constant and increased in proportion with the increase in dietary sodium chloride.

According to figure 3 and 4 in the older rats the mean sodium excretion in the urine per rat per day was directly increased by increased dietary intake. Sodium excretion in the lowest intake level

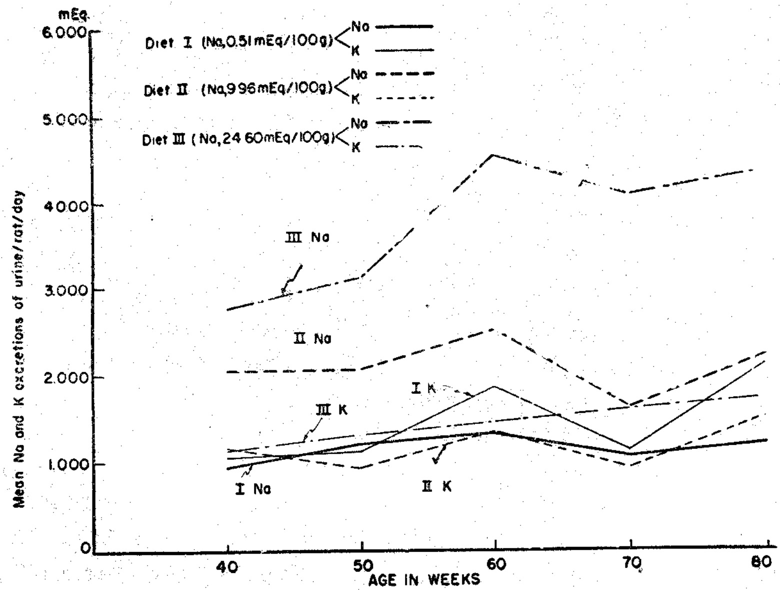

Fig. 4. Mean sodium and potassium excretion in urine for female rats.

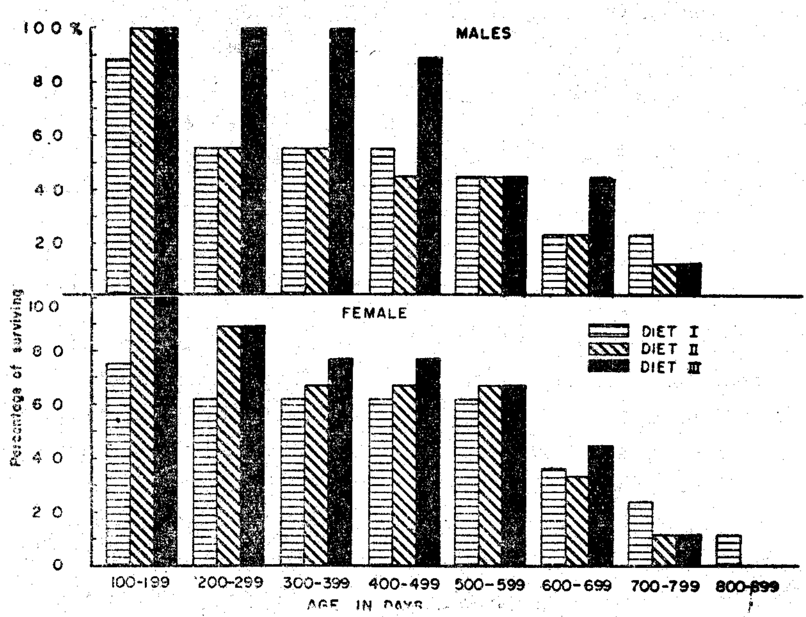

Fig. 5. Mortality and survival rates of rats receiving various levels of sodium chloride.

was fairly constant in its gradual increase with age.

Female rats in all three groups showed the highest sodium excretion at 60 weeks of age.

4. Hematology

Hematological studies done at 10, 30, 50 and 70 weeks showed a normal ranges of erythrocytes and leucocytes per unit volume of blood. (table 8) One case of leucoma was found. In old age there was a marked increase in the number of neutrophils along with a decrease in the percentage of lymphocytes. In the young animal 22% lymphocytes and 74% neutrophils were found.

6. Longevity

With three exceptions all of the 90 rats remained in good health during the first 20 weeks. The mortality rate in all groups gradually increased from 50 weeks until 130 weeks when all of the rats were dead.

Animals on the highest sodium diet (24.60 mEq Na or 1.45% NaCl) had a longer life span than the two lower intake groups. Meneely et al. (1953) observed that rats on a 2.8 or 5.6% sodium chloride diet survived less than those on the control diet of 0.15% NaCl. Although the percentage content of NaCl in this study is not as high as that reported by Meneely, the longevity data in this experiment appears to favor the group with the higher sodium intake.

In this study the basic diet is a vegetarian one modified according to Korean food habits. The basal diet is composed of low protein and fat but not high potassium, with a large portion of rice. It appears that the sodium requirement for a vegetarian diet is higher than that found in the usual western diet which is higher in animal products

Statistical analysis of the data obtained showed no significant difference in the three groups as far as animal longevity was concerned. These has been considerable evidence in the literature (Benjamin, 1960) that nutrition in the rat is one of the forces which regulates longevity and the time of onset of disease.

Kondo noted that in the villages of Japan in which the diet contains little animal products, but considerable soybeans, there was a higher percentage of aged people. However, in the fishing villages, where vegetable foods are scarce, the percentage of aged was low. Also where sea food, particularly seaweeds are eaten in abundance, there is an extremly low incidence of cerebral hemorrhage.

Hong et al(1961) demonstrated that the osmotic

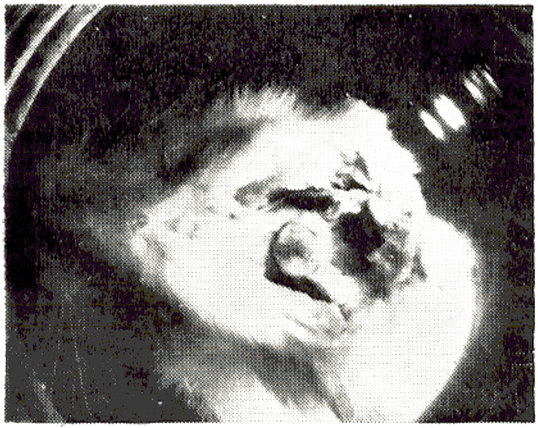

Fig. 6. Chromophobe adenoma lesion in hypophysis of rat.

composition of the urine excreted by Korea is somewhat unique in that NaCl accounts for nearly 2/3 of the total urine osmolality, suggesting that the salt intake is less in the Korean than in the occidental.

Further investigation is required the dietary effects of sodium relating with protein, fat, and potassium intake.

7. Chromophobe adenoma lesion

In 1956 to 1958 when the author first made a similar study while a graduate assistant in the laboratories ef Dr. McCay of Cornell University, it was observed that, in the group of rats given the lowest amount of sodium chloride (0.06%), 80% of the males and 30% of the females developed a chromophobe adenoma in the pituitary gland. In the present experiment no pituitary tumor was found in any of the three groups of rats. Saxton and Graham (1941, 1944) found that the Yale strain of rats developed chromophobe adenoma like lesion more frequently than those of other strains. 52% of the males and 12.81% of the females developed the lesion between 400 to 600 days. In the 1956 study the Yale strain of rats was used. The present experiment used the CF Wister strain. Therefore the frequency of occurence of a chromophobe adenoma seems to influenced both by the rats' strain and by stress such as is found where a low sodium is given.

SUMMARY

1. The three groups of rats showed no statistically significant growth difference.

2. At the lowest level of salt in the diet the male rats showed the lowest serum sodium and the female rats the lowest serum potassium concentrations for the three groups.

3. Although at an increased age the higher sodium diet rats showed a slightly higher content of wet bone sodium, it was felt that the three groups did not show any significant differences in the level of osseous electrolytes.

4. The highest water consumption for both the male and female rats occured during the first 10 weeks of life. Female rats on the highest sodium intake had a gradual decrease in water consumption up to the age of 40 weeks when the consumption amount again increased with age. Females in all groups consumed more water than males.

5) In the male rats the mean weight of the kidneys and adrenals increased directly with increases in the quantity of salt in the diet (However, the ratio of kidney weight per kilogram of body weight was 6-8% higher in the rats getting the highest sodium diet). The incidence of occurence of pituitary tumor of the chromophobe adenoma type in pituitary is related to rat strain, and to stress such as found in rats on the low sodium diet.

6. In this study rats on the high sodium intake lived slightly longer. It appears that the vegetarian diet with high amounts of cereals requires a greater amount of sodium than does the typical western basic diet which is high in animal products which contain more sodium and protein.

REFERENCES

Benjamin, N. B.: *J. Nutrition 73:23, 1960.*

Black, D. A. K.: *Blackwell Scientific Publications, Oxford, 1952.*

Bodil Schmidt-Nielsen: *Physiological Reviews 38:139, 1958.*

Bunge, G.: *Text-book of physiological and pathological chemistry, 2d. English ed. Philadelphia, P. Blackiston's Son & Co. 1905.*

Campbell, H. L.: *J. Am. Physiol. 147:340, 1946.*

Casey, J. H. and Zimmermenn B: *Am. Surg. 152:927, 1927.*

Gamble, J. L.: *Lane medical lectures companionship of water and electrolytes in the organization of body fluids. Stanford Univ. Press, Stanford, Calif. 1954*

Hong, Y. P., Park, C. S. and Hong, S. K.: *Yonseie Med, J. 2:27, 1961.*

Kempner, W.: *Am. J, Med. 4:545, 1948.*

Kirksey A., Pike, R. L. and Callahan, J. A.: *J, Nutrition 77:55, 1962.*

Kondo, S.: *The XIV, Japan Med. Congress, Part I.*

McCane, R. A.: *Proc. Roy. Soc. (London) ser. B. 119:245, 1936.*

Meneely, G. R., Tucker, R. G,. Darby, W. J. and Auerbach, S. H.: *Ann, Internal Med. 39:991, 1953.*

Methods of Analysis: *A. O. A. C., Washington D. C. 1960.*

Nichols, G. Jr. and Nichols, N.: *Metabolism 5:438, 1956*

Osborne, T. B. and Mendel, L. B.: *J. Biol. Chem., 34:131, 1918.*

Saxton, J. A.: *Cancer Reseach 1:277, 1941.*

Saxton, J. A. Jr. and Graham J. B.: *Cancer Research 4:168, 1944.*

Tucker, R. C. Youmans, J. B., Ball, C. O., Darby, W. J., Early, W. R., Kory, R. C. and Meneely, G. R.: *J. Gerontology 12:182, 1957.*